Final Report - House Bill 2427

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EXECUTIVE SUMMARY

In 2013, House Bill 2427 provided funding to assess the potential for co-existence between canola and other Brassicaceae seed crops in the Willamette Valley. The data collected provide valid, science-based insight into volunteer, disease, and insect pest differences among Brassicaceae seed crops in the years studied. However, it is important not to extrapolate these data to predict that there would never be an issue or to state positively that unlimited Brassicaceae crop production within the Willamette Valley would not result in production problems. Changes in crop varieties, pest management, cultural practices, or the introduction of new pests and diseases could affect production of Brassicaceae seed crops over time as could dramatic shifts in acreage of any other Brassicaceae crops such as cover crops or fresh market vegetables.

The results of this research provide no reasons, agronomic or biological, that canola production should be prohibited in the Willamette Valley when there are no restrictions on the production of other Brassicaceae crops. Although there were some differences among crops monitored, there were no pest issues unique to canola compared to the other Brassicaceae crops. If canola fields were pinned within the Willamette Valley Specialty Seed Association system to maintain isolation distances with sexually compatible crops then cross-pollination could be avoided.

One of the issues with the designation of specialty seed Brassicaceae crops is that there is no distinction between the crops being grown for the production of seed for forages or the cover crop markets and the vegetable seed market. The forage and cover crop markets may not have as stringent of requirements for genetic purity or pest tolerances (disease and insects) as the vegetable seed markets. Some specialty seed markets require inspection to meet phytosanitary requirements. It is not true that all specialty seed is inspected or tested for pest problems. It is incumbent on the entire agricultural industry to maintain good stewardship practices to protect the status of the Willamette Valley as a premier seed production region.

Findings:

Genetics, isolation and pinning

- Canola should be treated the same as other Brassicaceae crops in relation to establishing isolation distances.
- Isolation is required between canola and other *B. napus* crops to maintain seed purity.
- Isolation is required between canola and *B. rapa* crops to maintain seed purity.
- No isolation is needed between canola and *B. oleracea* crops to maintain seed purity.
- No isolation is needed between canola and radish to maintain seed purity.
- Isolation distances are generally set by consensus within the industry within a state or country and are not the same from place to place.
- In Oregon, pinning Brassicaceae crops with the exception of canola is voluntary.
- In Washington, pinning *Brassica* crops is required by state law.
- In New Zealand and Idaho, pinning is voluntary.
- In Europe, mapping is required and fields are inspected to ensure isolation.
- There are different pinning systems including private, public, and combinations of the two.

- Canola production districts vary by state and country.
- Oregon and Idaho have Protected Districts where canola is prohibited.
- Washington does not prohibit canola production but does require that it be pinned.
- France, New Zealand, and the UK do not prohibit the production of canola or restrict its production to certain areas.

Potential acres for canola production

- *Brassica* seed production in the Willamette Valley ranged from 2,020 to 3,375 estimated acres from 2012 through 2017 excluding canola acreage for 2014 through 2017.
- The number of *Brassica* fields ranged from 156 to 225 in the years 2012 through 2017.
- A map of areas of *Brassica* specialty seed crop densities, which might have led to the recommendation of canola exclusion zones, could not be created without *Brassica* GPS coordinates and species identification or industry validation.
- Based on the number of acres that are planted to wheat and grass seed, an expansion of canola acres is reasonable and feasible.

Monitoring

- Canola volunteer persistence was not different for turnip, daikon radish, or forage rape.
- Volunteer control was effective using available herbicides.
- Volunteer plants associated with monitored fields have not spread along roadsides or to adjacent areas.
- No insect pest was unique to winter canola, nor more prevalent than related fall-seeded crops.
- In general, spring-seeded Brassicaceae crops (daikon radish and spring canola) had greater insect activity than fall-seeded Brassicaceae (winter canola, turnip, and forage rape).
- Canola did not exhibit an overall greater incidence or severity of diseases relative to turnip or forage rape seed crops in western Oregon.
- Daikon radish seed crops had fewer diseases and lower disease levels compared to *Brassica* crops examined during this research.
- Brassicaceae weeds with black leg and light leaf spot were found along Interstate-5 within 20 miles of Washington and California and along roadsides in the Willamette Valley. These weed populations likely lead to wider spread of the diseases.

Recommendations:

Option A-1. Limit acreage of canola grown for oil to a level that would allow expansion of the industry while continuing to provide consideration for the established *Brassica* specialty seed industry.

This is a conservative approach that requires a designation of a specific number of acres for canola production beyond the 500 acres now permitted annually under HB 3382. Based on the number of acres that are planted to wheat and grass seed, an expansion of canola acreage within those acres would be reasonable and feasible. (See section on Potential Acres Available for Canola Production)

To date, all of the canola seed that is being produced in the Willamette Valley is delivered to Willamette Biomass Producers (WBP) to be crushed. Because the facility is certified to produce organic products, it does not accept genetically modified (GM) seed. The facility could produce food quality oil if canola production was at 5,000 acres (Craig Parker, CEO and President, personal communication). The canola oil produced could be labeled and marketed under the Non-GMO Project Verified.

Willamette Valley canola growers could consider putting in place a *Grower Opportunity Zone*, similar to those in place in California and Idaho for the production of either GM or non-GM alfalfa (www.alfalfa.org/pdf/GOZseed.pdf). The zones were established by growers to produce either GM seed or non-GM seed in a designated area. In California, the growers defined the zone and a >80% approval was needed to establish it as either a GM or non-GM zone. The Willamette Valley Oilseed Producers Association (WVOPA) would need to decide if they wanted to pursue this process. The canola growers would need to vote to form the GM-free zone.

2. Establish a pinning system that is transparent and open to Brassicaceae seed crop and canola producers with equal rights for all.

Options Considered to Accommodate Co-existence Between Brassicaceae Specialty Seed Crops and Canola

Ideally, all Brassicaceae seed crops and canola fields in the Willamette Valley would be pinned in order to ensure that seed purity is maintained. The authority for required pinning would most likely come through legislation or the Oregon Department of Agriculture. A better option is to find a path forward where pinning is voluntary rather than regulatory. Regardless of the option chosen, there should be an advisory group that represents both the specialty seed industry and the oilseed industry to continually update rules and address issues in the pinning system or other concerns as they arise.

Isolation distances required between canola and other Brassicaceae seed crops should be based on genetics of the crops and the potential for cross-pollination, rather than an arbitrary distance. The same rules that govern the isolation of other Brassicaceae seed crops should be applied to canola. (See section on *Brassica* genetics)

A. Options for co-existence of canola and other Brassicaceae crops in the Willamette Valley

Option A-1. Limit acreage of canola grown for oil to a level that would allow expansion of the industry while continuing to provide consideration for the established Brassicaceae specialty seed industry.

This is a conservative approach that requires a designation of a specific number of acres for canola production beyond the 500 acres now permitted annually under HB 3382. Based on the number of acres that are planted to wheat and grass seed, an expansion of canola acreage within those acres would be reasonable and feasible. (See section on Potential Acres Available for Canola Production)

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Option A-2. Use existing Willamette Valley Specialty Seed Association (WVSSA) pinning data to construct accurate maps of Brassicaceae seed crop production acres and field locations, including cover crop seed and vegetable seed crops based on chromosome number. The maps could be used for spatial density analysis to determine areas of Brassicaceae specialty seed crop concentration and could potentially lead to the designation of a canola exclusion zone if warranted.

Option A-2 requires that the WVSSA provide the pinning data to a third party and assist in validation of the maps and cooperate in the process. Before this option is considered, the data would need to be provided up front and maps constructed so that the results could be evaluated by the Oregon Department of Agriculture for use in its final recommendation.

Option A-3. Do not limit canola acreage in the Willamette Valley as long it is pinned under the same rules as the Brassicaceae specialty seed crops.

Option A-3 provides no extra protection of the specialty seed industry for their stated concerns about international market repercussions from canola production in the Willamette Valley. Nor does it provide any precaution for the potential increase in pests and diseases that could accompany uncontrolled expansion of Brassicaceae crops. However, this option puts canola on the same footing as the Brassicaceae crops such as radish, forage rape, and turnip, which are now being grown on larger acreages to produce seed for the cover crop market**.**

Note: An option to ban or exclude canola from the Willamette Valley was not considered because it does not lead to an outcome of co-existence between canola and specialty Brassicaceae seed crops.

Recommendation: Option A-1 is the recommended option because it allows for limited expansion of canola production. In addition, the canola growers are encouraged to explore the option of the *Grower Opportunity Zone*.

B. Options for pinning systems.

Option B-1. Use the WVSSA system currently used for pinning specialty seed crops. Changes in pinning rights would be necessary to expand membership so that growers not contracting with a WVSSA company member would have access to pinning and equal rights to the pinning system. If pinning is regulatory rather than voluntary, this system likely would not be feasible.

Option B-2. Contract with the California Crop Improvement Association to provide pinning for Oregon growers. This system is currently used by producers in Idaho as well as California. This option would be cheaper than creating a new pinning system. The most expensive maps created to date cost about $5,500 to generate (Katy Solden, California Crop Improvement Association, personal communication). Once the isolation maps are established, there is a $10.00 fee for each field pinned. Rules established by specialty seed and canola growers for pinning in Oregon would need to be implemented for the maps.

Option B-3. Create a new pinning system that would be a joint public and private partnership. The public entity could either be the Oregon Department of Agriculture or Oregon State University Seed Certification working with a company not affiliated with either WVSSA or WVOPA to oversee the pinning system. Contracting with the California Crop Improvement Association could be one option.

Option B-4. Turn the pinning system over to either of the public entities listed in Option B-3 and leave the decision up to the entity on how to proceed.

Options B-1 and B-2 would be the most cost effective. Option B-1 brings the depth of understanding for the Oregon specialty seed industry while Options B-2 or B-3 would provide greater options for a reset to overcome the contentious atmosphere that has plagued the discussion of co-existence between canola and the specialty seed industry.

A one year transition period might be required to accommodate the priority pins that members now hold so that production would not be unduly disrupted. After the transition period, canola growers would be able to obtain priority rights. Or, it is possible that priority rights would no longer be part of the system. Growers in Washington State start over each year using a lottery system to determine who pins first.

Recommendation: None of the specific options is recommended over another, only that a pinning system is put in place that is transparent and provides equal access and treatment for all growers.

Background

The production of canola in the Willamette Valley has been a contentious issue for many years. During those years, research was conducted, hearings were held and advisory committees formed to try find a resolution that would allow co-existence between canola and Brassicaceae specialty seed production.

Research was conducted by Oregon State University (OSU) from 2006-2010. Major findings of those studies were:

- Insect pest levels in canola fields were low.
- White mold was found in all of the canola fields at low to high levels.
- Significant canola seed was lost due to seed pod shatter during harvest.
- Volunteer canola plants were controlled in subsequent crops.

However, no compromises for co-existence were found that could be agreed upon by all parties. This controversy surrounding the production of canola in the Willamette Valley led to the passage of two house bills, HB 2427 and HB 3382 (Attachments 1 and 2). In those bills, specific issues related to the production of canola were raised. In response to the concerns, Oregon State University was directed to establish research (Attachment 3) in cooperation with growers and the Oregon Department of Agriculture. House Bill 2427 provided funding to conduct the research studies. House Bill 3382 provided no funding.

Specific to HB 2427 passed in 2013:

1) Provide an assessment that shall include, but not be limited to, a review of available published materials and historical data on canola and *Brassica* specialty seed production.
2) The college shall use field monitoring and other research to develop information and recommendations regarding whether, and under what conditions, canola growing in the Willamette Valley Protected District is compatible with the growing of other crops. The information must include a comparison of the compatibility of canola with the growing of other crops to the compatibility of other *Brassica* seed with the growing of other crops.
3) Must include a map of the Willamette Valley Protected District showing the places within the district where plants of the genus *Brassica* could be grown while maintaining typical isolation distances from vegetables, vegetable seeds and other crops.
4) Provide a report by November 1, 2017, with recommendations on coexistence of production in the Willamette Valley.

Specific to HB 3382 passed in 2015:

1) That a review of published materials and historical data on canola and *Brassica* specialty seed production from northern France, England and New Zealand be included.
2) A review of how western Washington, western Idaho and central and eastern Oregon manage canola for seed production.

For the purposes of this report, canola and rapeseed which can be either *Brassica napus* or *B. rapa* are used to denote the same crop. Canola grown in the Willamette Valley is *B. napus.* Officially, rapeseed is the correct common name; however, in the literature the crop is referred to by both names and the House Bills specify canola not rapeseed. Canola refers to edible rapeseed oil. Rapeseed will be used when the references refer to the crop by that name especially if in state laws as described in the sections on isolation distances and pinning and control districts or if it is not clear that the references mean edible oil. *Brassica* refers to all of the related species in that genus. Radish belongs to a different genus (*Raphanus*) so it is designated separately when required. Brassicaceae is the plant family name that includes *Brassica*, *Raphanus*, and *Sinapis*, as well as other genera.

Introduction

The Willamette Valley has mild, wet winters and warm, dry summers which allow for the production of high-quality seed with little to no artificial drying (Brewer 2005). Soils in the Willamette Valley vary from well drained alluvial deposits to poorly drained or steep hillslopes (Oregon State Land-Use Planning Committee 1941). Bottom and terraced soils accounted for 828,000 acres of the valley floor in 1941, and support diverse crops often with developed irrigation. In 2012, there were 707,286 acres with irrigation available in the Willamette Valley (USDA 2014). In order to ensure reliable production, vegetable seed crops are often grown on land that has irrigation available. Around 988,000 acres of cultivated ground in the valley were classified as hillslopes (Oregon State Land-Use Planning Committee 1941). These areas are characterized by steep slopes, poor drainage, lack of irrigation, and production is limited to grass, pasture, cereal crops, and tree production. Generally, it is on these acres without irrigation where commodity rotational crops are grown.

Because of its unique climate, the Willamette Valley and similar regions in Washington state produce over 50% of the U.S. supply of *Brassica* vegetable seeds (Schreiber and Ritchie 1995). Brassicaceae specialty seed production is not limited to vegetable seed species but also includes crops such as radish, turnip, and forage rape grown to produce seed for the cover crop market.

Oregon is also the world's major producer of cool-season forage and turf grass seed. Between 350,000 to 400,000 acres of grass seed are produced annually with estimated farm gate sales to be $228,464,000 (Anderson 2017). Grass seed producers have expressed the need to find a broadleaf rotational crop which would disrupt pest, weed, and disease cycles, slow the development of herbicide resistance, diversify cultural practices, and provide economic returns while utilizing their current production equipment (Hadley 2015). Commodity crops offer the grower the option of when to sell and at what price (Sharf 2015). In addition, growers receive payment within 30 days of delivery which is economically important for some enterprises. Canola is a commodity crop.

However, interest in the production of canola as a rotation crop within cereal and grass seed rotations raised concerns about the potential for seed contamination of specialty seed crops due to volunteers arising from long-term seed bank persistence, increased pest pressure, and gene flow that would lead to hybridization which would reduce seed purity (Loberg 2013).

Specialty seed production in the Willamette Valley

Vegetable and specialty seeds have been produced in Oregon in some capacity since the early decades of the twentieth century (Schudel 1952). *Brassica* seed crops have been grown in the Willamette Valley for at least eight decades (Hyslop and Schoth 1937). Vegetable seed production increased when World War II interrupted the trade of seeds from Europe and necessitated a large increase in domestic production. A vegetable production survey reported 6,700 acres of vegetable seed production with a farm gate value of $2,500,000 (Oregon Vegetable Seed Industry 1943). Oregon's potential to produce high quality seed was recognized and production peaked in 1944 at nearly 10,000 acres (Schudel 1952). The end of conflicts allowed foreign trade to resume and Oregon's seed acreage decreased. In the decades to follow seedsmen and growers steadily expanded and increased production. In 1980, a collection of seedsmen and companies formed the Willamette Valley Specialty Seed Association (WVSSA) (Loberg 2013).

Oregon produced 14,125 acres of vegetable seed with a farm gate value of $27,429,748 in 2012 (National Agricultural Statistics Service 2014). In 2012, 5,115 acres of vegetable seed was produced in central Oregon (Butler and Simmons 2012) and 822 acres of seed in Malheur county (FSA 2017) leaving around 8,000 acres of vegetable species, not just *Brassica* species, in the Willamette Valley. The WVSSA estimated a farm gate value of nearly $50 million for 2012 (Loberg 2013) but there were no data provided to support the figure. The two estimates include different crop species, for example sugar beet seed is not included in the NASS data. Therefore, it is difficult to reconcile the differences in the figures reported by National Agricultural Statistics Service (NASS) and WVSSA. Maps provided by WVSSA show that pinned *Brassica* specialty seed field numbers decreased from 225 in 2012 to 156 in 2017 with a range of 156 to 225 fields for that time period (WVSSA Maps Attachments 4-9). However, there is no doubt that the specialty seed industry is a significant sector of the agricultural community in the Willamette Valley and that the Willamette Valley is recognized worldwide for its high-quality seed. International markets are critical for the sale of Oregon's seed and it is important that those markets be preserved.

Rapeseed and canola production in the Willamette Valley

Rapeseed has been grown in the Willamette Valley for over three-quarters of a century. It was considered a valuable pasture and companion crop as well as a good seed producer (Hyslop and Schoth 1937). The rapeseed (*B. napus*) variety 'Dwarf Essex' was high-yielding and produced very desirable pasture stands which could be grazed and overwintered to produce seed the following season, or to be grazed and then tilled under as a soil amendment. Between the years of 1936 and 1943, rapeseed was harvested on around 200 acres annually (Thomas et al. 1944).

The first winter rapeseed variety and agronomic trials were conducted between 1966 and 1968 at OSU and a breeding program was initiated in 1969 (Calhoun et al. 1975). The main goal was to develop a high-erucic acid, low glucosinolate, cold-tolerant variety for production in western Oregon. This goal was partially realized with the release of 'Indore' which met the desired chemical profile and yielded equally as well as Dwarf Essex, but was slightly less cold tolerant (Calhoun et al. 1983). Commercial success was never realized as Coast Trading Company Inc., which held the exclusive rights to distribution, closed due to financial difficulties (Karow 1986). In 1979, a funding request was submitted to the Pacific Northwest Regional Commission for research into the development of oilseeds as alternative crops for the Pacific Northwest (Auld 1979). This joint research effort between Oregon State University, University of Idaho, and Washington State

University researchers provided the broad base needed to test varieties and agronomic traits across the region before its funding was discontinued in 1981 (Karow 1986). Limited varietal and agronomic trials continued at Oregon State University into the mid 1980's.

Currently, 500 acres of canola are allowed to be grown each year in the Willamette Valley Protected District under permits issued by the Oregon Department of Agriculture (HB 3382 2015). Because of the restriction on acres, it is not possible to estimate the economic contribution that canola could make if acres were not limited. Requests for acreage in 2017 and 2018 exceeded the allowed acres by 419 and 524 acres, respectively. The fields that were planted and the fields requested but not planted to canola are shown in Figure 1. The map provides an indication of the areas where growers showed interest in producing canola but should not be viewed as the only areas where growers might choose to plant if acreage was not limited.

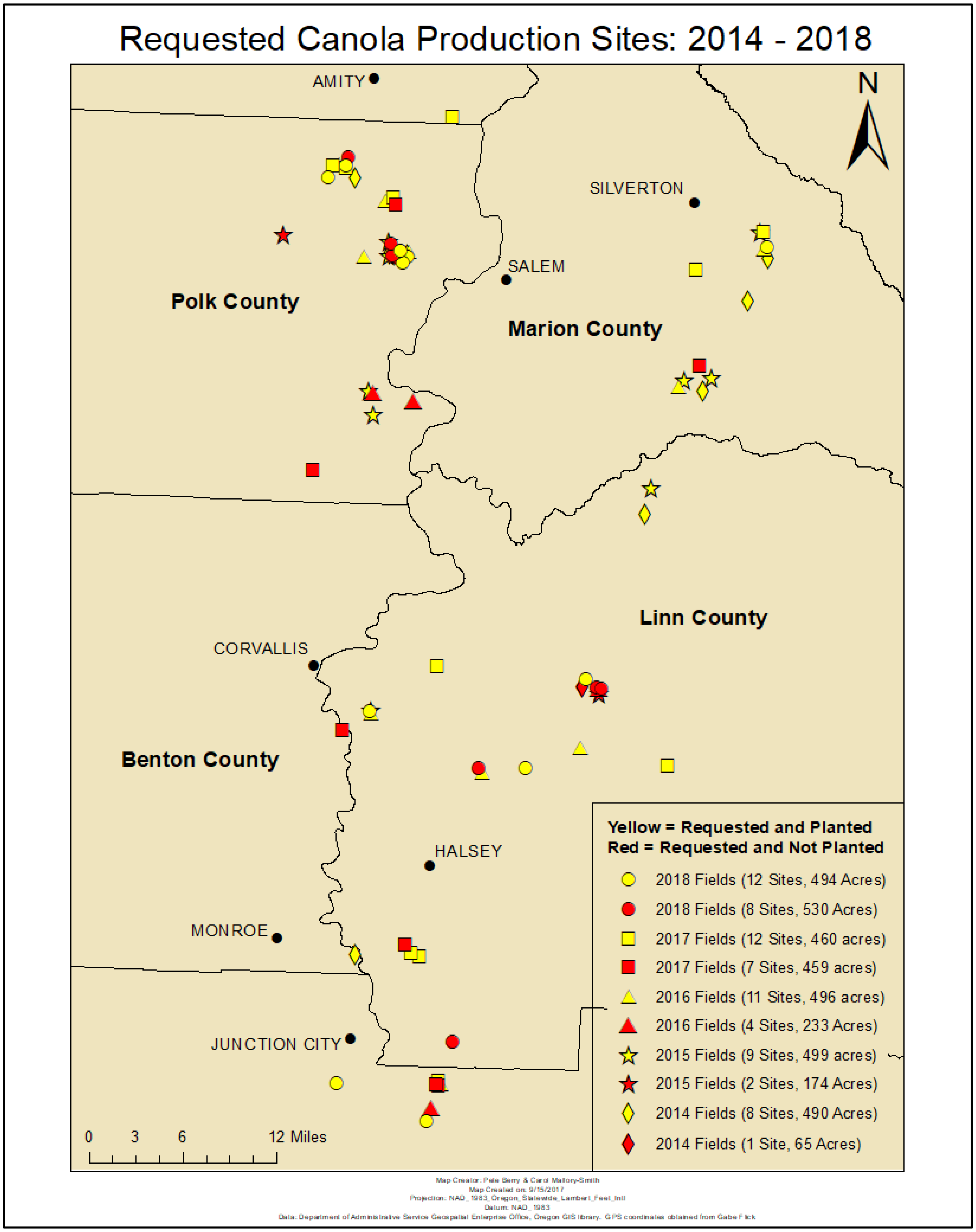


Figure 1. Map of canola production sites and requested sites from 2014 to 2018.

Issues of Co-existence for Production of Canola and Other Brassicaceae Crops in the Willamette Valley

Co-existence allows for different kinds of production or crops at the same time in the same area, it is not about exclusion. Co-existence requires compromises. It is important that all parties involved recognize how decisions made by one sector can impact another sector. Co-existence does not mean that risks, if any, are equally distributed among the sectors.

There is a precedent for co-existence within Willamette Valley specialty seed production. Genetically modified (GM) sugar beet, chard, and table beet seed are all produced within the Willamette Valley in the same season. These crops are sexually compatible, in fact they are all variants of the same species, *Beta vulgaris*. The crops are pinned in the WVSSA system in order to maintain isolation distances for seed purity.

In the case of canola produced for oil production versus Brassicaceae seed crops being grown for seed, the impact of a large increase in the acreage of Brassicaceae crops may not be evenly distributed because the final market requirements for the seed are different. Canola grown for oil production does not require the level of seed purity or quality that some seed markets require. Certain markets require that Brassicaceae seed pass phytosanitary inspections or seed tests. Therefore, co-existence will require stewardship and cooperation of all Brassicaceae crop growers to maintain the ability of the specialty seed producers to meet market and export needs.

The stewardship that has allowed the Willamette Valley to be a premier seed production region for decades is required for the co-existence of canola with the specialty seed industry. It should be noted that most, if not all, of the canola growers who have grown canola since 2013 also grow specialty seed crops. Therefore, it is not as if this is a new concept or beyond their abilities.

Producers of all Brassicaceae crops should adhere to management principals which include but are not limited to:

- All producers should plant clean, treated, seed which is certified to be black leg-free.
- Canola growers should only plant varieties listed as black leg resistant and rotate resistance genes.
- All producers should control diseases and insect pests during the production season.
- All producers should maintain rotation cycles between the planting of Brassicaceae crops that reduce the buildup of diseases or insect pests. Rotations of 3 to 4 years between crops should be maintained and Brassicaceae crops should never be planted back to back.
- All seed should be transported in closed containers or trucks.
- Volunteers should be controlled within production fields and field margins as soon as is feasible.
- Producers should not allow any volunteer Brassicaceae plants to flower.

Pinning all Brassicaceae crops would provide the isolation required to ensure that cross pollination does not occur. However, isolation is only required between sexually compatible species so the distances need to be based on science. If GM canola were grown, isolation distances could be increased as is done between GM sugar beets and related species.

Black leg epidemics have been reported in other regions. In Europe, Australia, and Canada the epidemics were related to planting of black leg susceptible varieties (Cowling 2007, Gugel and Petrie 1992). If available, black leg resistant *Brassica* varieties should be grown. All Oregon Brassicaceae growers must plant certified black leg-free seed according to ODA 603-052-0862. Although not required, all Brassicaceae seed planted in Oregon should be fungicide or hot water treated. Fungicide applications should be made as needed during the crop year. Black leg infected residues should be tilled to bury them to reduce inoculum being released (Hall 1992).

Black leg is not the only disease that growers need to be concerned about; rotation is critical for Brassicaceae crops to reduce inoculum of other pathogen problems such as clubroot (Peng et al. 2014, Strehlow et al. 2015) and Sclerotinia stem rot (del Río et al. 2007, Garza et al. 2003, Williams and Stelfox 1980).

In other regions where canola/rapeseed is widely grown, the pollen beetle (*Melgethes aeneus*) has become widely spread (Ekbom 1995, Hokkanen 2000). The control of this pest in radishes has become more difficult over time. Radish seed production in Frances is threatened because of increasing pressure when the pollen beetle moves from fall planted canola to radish (Emmanuelle Laurent, personal communication). Canola flowers earlier than the radishes so the insect moves from canola to radish over the season. In the Willamette Valley, there are other fall seeded *Brassicas* that the pollen beetle also feeds on. Therefore, Brassicaceae seed producers should scout for this insect and control populations before they build up and move to radish crops later in the season. The insect is less damaging to other *Brassicas*.

Feral crop populations and Brassicaceae weed populations should be controlled where feasible in order to reduce plants that may host disease or insect pests and that can maintain or overwinter disease and insect pests. The pollen beetle overwinters on flowering wild plants before it migrates to oilseed rape crops so control of wild hosts is important for managing the pollen beetle (Mauchline et al. 2017). Disease surveys that were conducted for weeds along Interstate-5 show clearly that they can be infected with black leg and light leaf spot and may have a role in disease persistence and spread (See Figure 15). The feral crop populations along roadsides in areas of Brassicaceae production in the Willamette Valley reinforce the need to cover seed during transport.

***Brassica* genetics**

The taxonomy and genetics of the *Brassica* species are complex (Figure 2) (U 1935). Spontaneous hybridization between some of the species led to the formation of new species. For example, spontaneous hybridizations of *B. oleracea* and *B. rapa* produced *B. napus*; *B. rapa* and *B. nigra* produced *B. juncea*; *B. oleracea* and *B. nigra* produced *B. carinata* (Cheng et al. 2017). These events occurred naturally thousands of years ago. For example, the species *B. juncea* and *B. napus* are estimated to be between 35,000 to 55,000 years old.

The *Brassica* genus includes many crop species also known as crucifer crops (Table 1). One of the unique aspects of these species is that crops with very different morphology were derived from the same species (Hancock 2004). In the Willamette Valley, most of the *Brassica* seed crops are *B. rapa*, *B. napus*, *B. oleracea*, or *B. juncea*. Cabbage, kohlrabi, cauliflower, broccoli, Brussels sprouts, and kale are *Brassica oleracea*. In North America, most of the canola grown is *B. napus*; however, canola can be either *B. napus* or *B. rapa*. Chinese cabbage and turnip are *B. rapa* and rutabaga and Siberian kale are *B. napus*. Radish (*Raphanus sativus*) is more distantly related but belongs to the Brassicaceae family and is widely grown as a seed crop in the Willamette Valley.

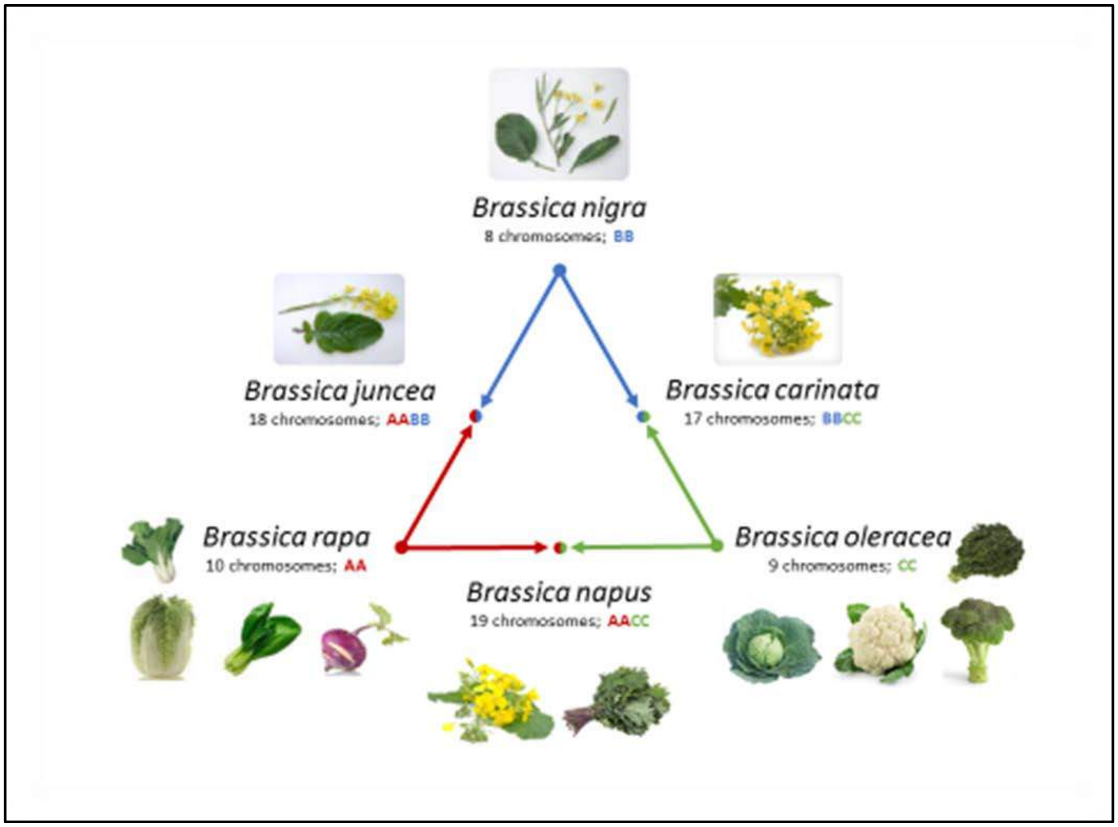


Figure 2. Genetic relationship between Brassica species. (Adapted from U 1935)

Table 1. Brassicaceae crops grown in the Willamette Valley.

Species[1]	Common names	Seed	Fresh market / processing	Oil	Cover crop
Brassica Genus					
9 chromosome					
Brassica oleracea	cabbage – red or white	X	X		
	collards	X	X		
	cauliflower	X	X		
	kale – red or white	X	X		
	kohlrabi	X	X		
	Brussels sprouts	X	X		
	broccoli	X	X		
19 chromosome					
Brassica napus	canola[2]			X	
	forage rape	X			X
	rutabaga	X	X		
	Siberian kale	X	X		
10 chromosome					
Brassica rapa	turnip	X	X		X
	forage rape	X			X
	Chinese cabbage	X	X		
	tot soi	X	X		
	pak choi, bok choi	X	X		
	mizuna	X	X		
18 chromosome					
Brassica juncea	Chinese mustard	X	X		
	Indian mustard	X	X		
	leaf mustard	X	X		
	red mustard	X	X		
	Florida broadleaf	X			
	southern giant curled	X	X		
8 chromosome					
Brassica nigra	black mustard	X	X		
Other genera					
Armoracea rusticana	horseradish	X	X		
Raphanus sativus	radish	X	X	X	X
Sinapis alba	white mustard	X		X	
Eruca sativa	arugula	X	X		
Iberis umbellate	candy tuft	X	X		
Cherianthus allioni	Siberian wallflower	X	X		

[1] within each species there can be numerous subspecies with different morphologies
[2] canola presently grown in the Willamette Valley is *Brassica napus* not *B. rapa*

Compatibility between Brassicaceae species

Findings: (See Table 1 for examples of crops in each group.)

- **Canola should be treated the same as other Brassicaceae crops in relation to establishing isolation distances.**
- **Isolation is required between canola and other *B. napus* crops to maintain seed purity.**
- **Isolation is required between canola and *B. rapa* crops to maintain seed purity.**
- **No isolation is needed between canola and *B. oleracea* crops to maintain seed purity.**
- **No isolation is needed between canola and radish to maintain seed purity.**

Varying levels of interfertility are reported and reports vary a great deal in the percent of hybridization that can occur between and among species. Hybridization rates vary based on many factors including environment, whether species are outcrossing or self-pollinating, size of the pollen source, and distance between the plants. The crop variety or which species used as either the male or female parent also can affect the success of the cross. FitzJohn et al. (2007) analyzed the results of more than 300 studies to provide an extensive review of hybridization in *Brassica* and allied genera. This review and others as cited were used to determine the compatibility between species grown in the Willamette Valley.

Brassica napus is self-fertile and mainly self-pollinated; however, outcrossing rates from 12 to 47% have been reported (Becker et al. 1992). In a study that simulated breeding field trials, an outcrossing rate of 4% was measured between plots that were separated by 2 ft (Cuthbert and E. McVetty 2001). *Brassica rapa* is typically self-incompatible and therefore requires cross-pollination. Crosses occur between *B. rapa* and *B. napus* with reported levels of hybridization varying widely. Hybrids were reported to have reduced fertility and low seed set compared with the parents (Jorgenson and Andersen 1994). Crosses were more successful when *B. napus* was the male parent. Because of the compatibility between these species, canola and *B. rapa* crops will require isolation to maintain seed purity.

Brassica oleracea and *B. napus* hybridization is rare. There is only one report of spontaneous hybridization in the wild (Ford et al. 2006). Producing crosses between *B. napus* and *B. olerace*a is very difficult even when using laboratory-breeding techniques such as embryo rescue (as reviewed in FitzJohn et al. 2007). In one study, more than 65,000 crosses produced only two hybrids. Ovule culture was required to produce seed from crosses between *B. oleracea* var. *alboglabra* (Chinese kale) and *B. napus* (Bennett et al. 2008). Other researchers found reduced crossing when *B. napus* was the male parent, which is important because it reduces the risk of crossing through gene flow from canola fields to *B. oleracea* vegetable crops (FitzJohn et al. 2007). A low success rate of producing *B. oleracea* and *B. rapa* also has been reported. Isolation distance requirements of canola from *B. oleracea* should be the same as required for isolation from *B. rapa*.

Researchers reported both successful and unsuccessful crossing between *B. napus* and *B. juncea* and that crosses between *B. rapa* and *B. juncea* were successful more often (FitzJohn et al. 2007). In a field study in Canada, hybrids among the three species were identified (Bing et al. 1996). Isolation distance requirements of canola from *B. juncea* should be the same as required for isolation from *B. rapa.*

Brassica napus hybridization with radish or wild radish is rare or not reported. Successful crosses have only been the result of embryo rescue or other laboratory techniques (Huang et al. 2002, Paulmann and Röbbelen 1988). The frequency of hybridization between B. *napus* and wild radish (*Raphanus raphanistrum*) was assessed in field studies in Australia. No hybrids were found in 25,000 seeds collected from the wild radish plants and two hybrids were identified from more than 52 million seedlings produced from seeds on the *B. napus* plants (Rieger et al. 2001). Because of the difficulty of the crosses, isolation between canola and radish is not needed which would be the same as is now required in the WVSSA pinning rules.

Compatibility between canola and *Brassica rapa* and *B. oleracea* vegetable cultivars

Data are limited on gene flow, hybridization rates, and success of crosses between *B. napus* and related vegetable crops. Most often, if vegetable crops are mentioned at all, authors state that the vegetable crops are harvested before they flower so gene flow is not a concern. This is true if the crops are being produced for human consumption but not if they are being grown for seed production.

One of the few studies to examine cross-pollination between canola and vegetable *Brassicas* was conducted at Oregon State University (Quinn 2010). In 2007, 2008, and 2009, fields isolated from vegetable seed production were selected for the study. The study was designed as a worst-case scenario for hybridization because the vegetable plants were placed within the canola field and pollen concentration from the canola was greater than would occur if isolation distances for the crops had been followed. *Brassica rapa* var. *chinensis* (Pak-choi), *B. rapa* var. *pekinensis* (Pei tsai), *B. oleracea* var. *botrytis* (broccoli) or *B. oleracea* var *capitata* (cabbage) plants were grown in the greenhouse and moved into the field when the *B. napus* began flowering, and returned to the greenhouse once pollination had occurred. Each species was placed in the field sequentially to prevent cross-pollination of the receptor vegetable plants. Seed from each receptor plant was harvested individually.

Seed was produced on all the receptor species, but seed only germinated when produced on the *B. rapa* maternal parents. Hybrids between *B. napus* and both *B. rapa* varieties were confirmed using DNA analysis. Seed collected from the *B. oleracea* maternal plants were mostly shriveled and a tetrazolium assay of these seed showed that there was no embryo formation.

Greenhouse crossing experiments were conducted using transgenic Roundup Ready™ *B. napus* as the pollen parent and either self-incompatible *B. rapa* or male sterile vegetable seed cultivars of *B. oleracea* as receptor plants. Crosses produced in the greenhouse between *B. rapa* and *B. napus* confirmed the interfertility documented in the field study, but the observed outcrossing rates varied greatly (0.0026% to 15%) depending on the *B. rapa* cultivar. Transgenic DNA in the shrunken, non-germinable seed produced from the *B. rapa* crosses was detected. No viable seed was produced on crosses between canola and the *B. oleracea* cultivars. The results of this study confirm published data on crossing between *B. napus*, *B. rapa* and *B. oleracea* and support the need to isolate canola from *B. rapa* crops but not *B. oleracea* crops.

Isolation Distances and Pinning Systems

Findings

- **Isolation distances are generally set by consensus within the industry within a state or country and are not the same from place to place.**
- **In Oregon, pinning Brassicaceae crops with the exception of canola is voluntary.**
- **In Washington, pinning *Brassica* crops is required by state law.**
- **In New Zealand and Idaho, pinning is voluntary.**
- **In Europe, mapping is required and fields are inspected to ensure isolation.**
- **There are different pinning systems including private, public, and combinations of the two.**

Seed certification

Each of the states producing seed in the Pacific Northwest has a seed certification agency involved in the inspection of crops and the issuance of certificates or tags guaranteeing the purchaser that the seed stock meets certain quality standards. In Oregon, seed certification is performed by Oregon State Seed Certification within Oregon State University Extension and the Department of Crop and Soil Science. The Oregon Department of Agriculture is responsible for phytosanitary inspections and certificates if required for seed export. In Washington, vegetable seeds are certified by the Washington State Department of Agriculture. In Idaho, California, and for some crops (cereals and legumes) in Washington, certification is performed by their respective Crop Improvement Associations, which are third-party non-profit organizations. These organizations maintain standards for different quality classes of seed.

One standard that must be met is the isolation distance from any other field of the same variety or from other species, which are capable of cross-pollination. In Oregon, for example, 1,320 ft is required between cross-pollinating mustards, kales, turnips and radishes to meet foundation seed certification while Washington requires 1 mile between such fields (Oregon Seed Certification Service 2017, WAC 16-302-480 2000). Foundation seed of self-pollinating varieties requires an isolation distance of 660 ft in both states. Certified seed, which has lower standards, requires half the distance, 330 ft. Idaho utilizes a table with different distances based on the species of crop with distances varying from 10 to 1,320 ft (Idaho Crop Improvement Association 2017).

Although all states have seed certification agencies, specialty seed is not typically certified by the agencies. International phytosanitary and purity standards exist, but buyers have their own requirements and seed companies must meet the terms of the contract. Because pollen movement among compatible *Brassica* species could lead to the production of hybrid seeds and off-types in subsequent crops, fields of compatible species are isolated from one another. Industry field representatives, breeders, and others involved in the seed industry have agreed upon isolation distances. Isolation distances are not necessarily based on scientific data but are often arrived at through consensus of the contracting companies and contract requirements. For many *Brassicas*, especially for hybrid seed production, the use of pollinators is necessary. Bees and other pollinators can move among fields and facilitate unwanted gene flow between crops. Several factors come into play including topography, prevailing wind direction, vegetation, placement of beehives, pollen production of plants, and the size of fields. Isolation distances attempt to account for these factors in order to minimize risk of unwanted contamination. Distances vary based on the crop species and on variations within a particular species.

Because *Brassica* species have the potential to cross-pollinate, the specialty seed industry needs a mechanism to address market requirements for genetic purity. Therefore, industry standard isolation distances and a pinning or mapping system are used to maintain isolation distances between sexually compatible species. Nearly all seed producing regions rely on a pinning system to isolate seed crops from one another. Isolation schemes are used in Oregon as well as other areas where *Brassica* seed are produced in order to reduce the risk of cross-pollination.

Radish is in the Brassicaceae family but isolation is not required from *Brassica* crops but there are separate rules for isolating different types of radish. The following is a comparison among different systems for *Brassica* species.

Oregon

Except for canola, there are no legal requirements for isolation among *Brassica* crops in Oregon (HB 2427 2013). The isolation distances are set by the WVSSA based on the sexual compatibility of the species (chromosome number/genome - Triangle of U Figure 2) and whether the seed is being produced through open pollination or via a hybrid system. For *B. oleracea* (9 chromosomes), the distance varies from 1 to 3 miles, depending on crop type and pollination system (WVSSA 2016). Crops in this group include cabbage, kale, kohlrabi, and Brussel sprouts. For *B. rapa* (10 chromosomes), the distance varies from 1 to 3 miles. Crops in this group include turnip, Chinese cabbage, bok choi, and pak choi. Only physical isolation is required between *B. rapa* and *B. oleracea* vegetable species. *Brassica juncea* (18 chromosomes) requires only physical isolation from other *Brassicas*. The isolation for canola (19 chromosomes) from any other specialty seed crops is 3 miles. There is no mention of isolation for other 19 chromosome crops such as rutabaga or Siberian kale from other *Brassica* crops. In 2011, the WVSSA began using an electronic pinning system to replace the system of pinning a physical map in OSU county extension offices. In order to place a pin on the map, a company must be a member of the WVSSA and membership is subject to review by the Board of Directors.

Washington

In the northwestern and the Columbia Basin regions of Washington, *Brassica* seed production isolation is legislated and pinning is required (WAC 16-326 2008). In northwestern Washington, isolation among *Brassica* species distances vary depending on crop. In Washington's Columbia Basin, there is a 3-mile isolation between canola and other oilseed types of rapeseed grown for seed (CBVSFRA 2017). A 2-mile isolation distance is required between all other *Brassica* species.

Physical maps are used for pinning in Washington. Pinning occurs on specific dates depending on the crop type. The program is based on a first-pinned, first-priority basis and the pinning order for each crop type is decided by a lottery system each year. Each company can pin two fields at a time. All seed companies are required to pin and no companies can be excluded. Commercial seed growers must pin even if not contracting with a seed company and are treated the same as if a company.

Idaho

The Idaho-Eastern Oregon Seed Association sets isolation distances for *Brassica* crops in Idaho and Malheur County in Oregon. The isolation distances are either 1 or 2 miles depending on type and color with no isolation required between *Brassicas* and radish (IEOSA 2015).

Since 2015, pinning of Idaho *Brassica* fields has been contracted with and managed by the California Crop Improvement Association pinning system. Only members of the IEOSA may place pins on the map.

France

Isolation for *Brassica* seed certification is broken down into two categories, self-pollinating (*B. napus* and *B. juncea*), and cross-pollinating (*B. rapa, B. nigra, Sinapis alba*). Certification classes are similar to that in the United Kingdom (see below) as are the required isolation distances. Prebasic seed (similar to Foundation seed designation in Oregon) isolation distances for self-pollinating *Brassicas* range from 0.001 to 0.62 miles, basic from 0.001 to 0.25 miles and certified from 0.003 to 0.12 miles (Ministère de l'Agriculture 2008). Cross-pollinating *Brassica* isolation distances range from 0.001 to 0.62 miles for prebasic, 0.25-0.62 miles for basic and 0.25 miles for certified seed.

New Zealand

In New Zealand, isolation distances are 0.62 to 1.24 miles for open pollinated and hybrid production, respectively (AssureQuality and MAF 2009). The distances are the same within either the *B. rapa* or *B. oleracea* groups. There is no isolation requirement between the two *Brassica* groups. Canola and rapeseed are pinned within the *B. rapa* group, the same as the vegetable species, with no increased isolation distance. *Brassica juncea*, *B. nigra*, and *Sinapis alba* are isolated as separate groups but with the same isolation distances based on pollination type. The isolation distances can be reduced between similar types and varieties of vegetable seed production. On a case-by-case basis, the isolation distance can be increased if evidence for the need is provided to the system administrator. Changes to the agreed upon isolation distances must be based on scientific evidence of cross-pollination. At present, membership is voluntary and there is no requirement to pin or identify fields.

New Zealand uses an electronic pinning system that has been in place since 2008 (AssureQuality and MAF 2009). The pinning system was developed through cooperative efforts of the MAF Sustainable Farming Fund and the Foundation for Arable Research. AsureQuality, a company owned by the New Zealand government, runs the system.

United Kingdom

Isolation is required for *Brassica* seed that is inspected for certification. The certification system includes prebasic, basic and certified seed. Prebasic (similar to Foundation seed designation in Oregon) is the first generation produced from breeder seed. The risk of cross-pollination is assessed during field inspections. Isolation distances range from 0.12 to 0.62 miles for the production of prebasic or basic seed and from 0.06 to 0.37 for certified seed depending on the crop (Animal and Plant Health Agency 2016, www.gov.uk/government/uploads/system/uploads/attachment_data/file/571970/crop-inspectors-instructions.pdf).

Rapeseed/Canola Production Districts

Findings:

- **Canola production districts vary by state and country.**
- **Oregon and Idaho have Protected Districts where canola is prohibited.**
- **Washington does not prohibit canola production but does require that it be pinned.**
- **France, New Zealand, and the UK do not prohibit the production of canola or restrict its production to certain areas.**

Note: In most documents, rapeseed is used instead of canola.

Oregon

Oregon has four protected districts: Willamette Valley as defined by the 2013 HB 2427; Central Oregon (Crook, Deschutes and Jefferson counties); Northeast Oregon (all of Baker and Union counties and a portion of Wallowa County); Malheur/Idaho (in Malheur County a 3-mile wide strip of land along a portion of the Idaho border where rapeseed is prohibited). In the Willamette Valley Protected District, rapeseed is prohibited except for the 500 acres per year allowed under HB 3382. These acres are approved by the Oregon Department of Agriculture and are pinned within the WVSSA pinning system. Rapeseed is prohibited in the Central Oregon Protected District except under a research permit. In the Northeast Oregon Protected District, rapeseed is allowed with a 2-mile isolation distance from compatible crops and the fields must be recorded at an OSU extension office at least 10 days prior to planting. In the Malheur/Idaho Protected District, rapeseed crops are prohibited. All areas of the state not in the protected districts are in the General Production Area and rapeseed is allowed.

Washington

Washington has two defined districts that require pinning of all *Brassica* crops but are not specific to rapeseed (WAC 16-326 2008). Canola can be grown in both districts but must be pinned. Winter canola is not allowed in District 2 according to WAC 16-326-040. District 2 is divided into two subdistricts 2A and 2B. Only spring canola grown for seed is allowed in 2A and spring canola grown for either seed or oil is allowed in 2B. Canola production outside of these two districts is not regulated. (apps.leg.wa.gov/WAC/default.aspx?cite=16-326)

Idaho

In Idaho, the production districts cover three species, *B. napus*, *B. rapa* and *B. juncea*, and two oil rapeseed types, edible and industrial. Idaho has two districts (IDAPA 02-06-13 2014). District II includes all land within the boundaries of Ada, Canyon, Gem, Owyhee (north of Murphy) and Payette counties. No rapeseed can be produced in District II. District I is all of Idaho not included in District II. Industrial and edible rapeseed are allowed in District I with restrictions. Industrial rapeseed in District I must have an isolation distance of 1 mile from edible rapeseed. Industrial rapeseed growers must have written approval from farmers whose fields border the field being planted to industrial rapeseed. (adminrules.idaho.gov/rules/current/02/0613.pdf)

France

There are no protected production districts in France (Gombert, personal communication 2017).

New Zealand

There are no rapeseed/canola legislated production districts in New Zealand. But, there is an understanding that canola grown for oil will not be grown in the areas of intensive irrigation where smaller scale hybrid canola seed is produced.

United Kingdom

There are no protected production districts in the United Kingdom.

Potential Acres Available for Canola Production in the Willamette Valley.

Findings:

- *Brassica* seed production in the Willamette Valley ranged from 2,020 to 3,375 estimated acres from 2012 through 2017 excluding canola acreage for 2014 through 2017.
- The number of *Brassica* fields ranged from 156 to 225 in the years 2012 through 2017 with an average of 164 fields excluding canola fields for 2014-2017.
- A map of areas of *Brassica* specialty seed crop concentration which might have led to the recommendation of canola exclusion zones could not be created without *Brassica* GPS coordinates and species identification or industry validation.
- Based on the number of acres that are planted to wheat and grass seed, an expansion of canola acres is reasonable and feasible.

House Bill 2427 stated that a map be produced showing the places within the Willamette Valley Protected District where plants of the genus *Brassica* could be grown while maintaining typical isolation distances from vegetables, vegetable seeds, and other crops. There are no typical isolation distances required or needed for *Brassica* crop production except between sexually compatible species being grown for seed. In the research proposal related to HB 2427 submitted by Oregon State University (Attachment 3), there was a clear statement that in order to produce the map as requested there would have to be cooperation from the specialty seed industry to provide data. This request was reinforced by then Governor Kitzhaber (Attachment 10).

The 2012-2017 Willamette Valley Specialty Seed Association (WVSSA) pinning data comprised of GPS coordinates and crop type are archived at Oregon State University in the PRISM Climate Change Group. The data are owned by WVSSA but multiple requests for these data did not result in them being made available for the research related to HB 2427. There were GPS field locations provided by Barenbrug Seed Company and Mr. Don Wirth, Saddle Butte Ag Inc. However, the number of fields validated by the two cooperating companies did not provide enough field locations to allow mapping of *Brassica* production.

WVSSA did provide static maps which included both radish and *Brassica* crops with a 3-mile buffer around each point on the map (Attachments 4). However on the maps, 3-mile buffer zones used for radish fields were layered over the top of *Brassica* crop buffer zones so it was impossible to determine where the area of Brassica crop production. There was no identification of *Brassica* crop species by chromosome number, so sexually compatible *Brassica* species could not be identified. There is no 3-mile buffer required between radish and *Brassica* specialty seed crops, nor between *B. rapa* and *B. oleracea*, so the maps provided by WVSSA do not represent the isolation distances or area needed (see section on Brassica isolation requirements). The *Brassica* points (red dots) on the images show this very well because in some cases the points overlap. The maps contain limited information for use by this research project.

Because we did not have access to the *Brassica* pinning data (GPS coordinates and species type) to create the map requested in HB 2427, multiple sources were used to determine the number of *Brassica* specialty seed acres grown in the Willamette Valley. It was not possible to define acres only within the protected district so data from Clackamas, Benton, Lane, Linn, Marion, Polk, Washington, and Yamhill counties were included. Farm Service Agency (FSA) crop report data were used to determine the grower reported acreage by crop species, county, and intended use (seed/grain/forage, etc.) (FSA 2017) (Table 2). Crop Scape (CS) also was used to determine acreage of *Brassica* production because so few GPS coordinates were provided. Crop Scape was launched in 2012 as a cropland data layer (CDL) program with the purpose of providing acreage estimates to the Agricultural Statistics Board for a state's major commodities and to produce digital, crop-specific, categorized geo-referenced output products (USDA 2012). Satellite imagery from the Landsat 8 OLI/TIRS sensor, the Disaster Monitoring Constellation DEIMOS-1, and UK2 sensors collected during the current growing season are used with ground surveys to estimate cropland acreage. The FSA validated the satellite data with the United States Department of Agriculture (USDA), National Agricultural Statistics Service (NASS), Research and Development Division, Geospatial Information Branch, and Spatial Analysis Research Section. CS uses a decision tree analysis and relies on known ground truth areas. The known areas are comprised of independently validated data sets generated from the FSA Common Land Unit (CLU) data and the National Land Cover Database (NASS 2017). The CDL layer is a raster (grid based), geo-referenced, crop-specific land cover with a resolution of 98.4 ft (less than a quarter acre).

The B*rassica* crops raster data sets were layered with Landsat 8 images on a date(s) that supported visual interpretation of field boundaries. CS raster data were processed in ArcMap 10.3.1 to determine acreage production and when validation occurred, field locations. Individual pixelated fields were traced and acreage calculated based off standard area calculation methods used in ArcMap.

Brassica specialty seed field sizes can be as small as a quarter acre. A minimum of 2 acre field size was used in estimates because without GPS coordinates or industry validation of field locations, it was not possible to determine between CS error and a *Brassica* seed crop using the smaller scale (¼ acre). Limiting fields to larger than 2 acres produces the lower field numbers using CS than those from the WVSSA static map counts (Table 2). The CS fields included vegetable production and large cover crop acreage. Oregon State University monitored cover crop fields averaged 63 acres. There is no way to distinguish between crops grown for fresh markets and seed crops, along with the combination of large cover crop fields being included, is likely why acreage per year estimations in analyzed CS data are greater than FSA data (Table 2). Acreage in crop production in the Willamette Valley is estimated to be 1.69 million acres. Farm Service Agency estimates *Brassica* seed production to average 1,702 acres over 5 years and analyzed CS data estimated 3,003 acres over the same period of time (Table 2). Comparing the difference in the data resulted in a difference of 0.077% of estimated *Brassica* production acres in the Willamette Valley.

Table 2. Acreage and field numbers used to calculate average field size.

	2012		2013		2014		2015		2016		Average
FSA Acreage	1798		1511		1578		1980		1645		1702
WVSSA Field No*	225		156		165		166		167		
FSA Field Size	………	8.0	………	9.7	………	9.6	………	11.9	………	9.9	9.8
CS Acreage	3317		3039		2627		2763		3271		3003
CS Field No	128		123		122		102		138		
CS Field Size	………	25.9	………	24.7	………	21.5	………	27.1	………	23.7	24.6

*Field number does not include canola fields for 2014, 2015, 2016.

Because we did not have data or the ability to validate the points on the WVSSA's static maps as to field location or *Brassica* species, we calculated potential acres of *Brassica* crops that were grown. Points on the static maps provided by WVSSA were tallied to determine how many *Brassica* fields were planted in each year. The average *Brassica* field sizes calculated from the available data averaged 9.8 and 24.6 acres (Table 2). Data from the Oregon Department of Agriculture (ODA) acreage and the number of fields which were submitted for phytosanitary field inspections from 2009 – 2015 had an average field size of 10.9 acres (Ludy 2017) (see Table 14 for complete data set). Based on the three field size values, 15 acres was chosen as an average field size and multiplied by the number of tallied pin points from WVSSA static maps to estimate *Brassica* acreage per year (Table 3).

Table 3. Predicted Brassica acreage assuming 15 acres per field using WVSSA map sites.

Year	WVSSA *Brassica* Fields	Predicted *Brassica* Acreage	WVSSA Brassica Fields Minus Canola Fields	WVSSA Brassica Acreage Minus Canola Acres
2012	225	3,375	-	-
2013	156	2,340	-	-
2014	173	2,595	165	2,095
2015	175	2,625	166	2,125
2016	178	2,670	167	2,170
2017	168	2,520	156	2,020
Average	179	2,688	164	2,103

Based on multiple data bases and the static maps provided by WVSSA, neither the number of fields nor acreage of *Brassica* specialty seed crops have increased from 2012 to 2017. It should be noted that the number of *Brassica* fields could vary slightly because of the clarity of the static maps and the potential that a point might be hidden under another point. However, the number of acres falls between the estimates of the other two data sources used. The number of acres is not a true reflection of the land area needed to produce *Brassica* crops because isolation is required between some of the crops. Again, without the data to determine which crops require isolation, it was not possible to predict where canola and these crops could coexist.

However for comparison, we were able to construct maps for radish production in the Willamette Valley, even without GPS coordinates from the pinning maps, using analyzed CS data and validation assistance provided by Mr. Terry Ross, Integrated Seed Growers, who helped ground truth the accuracy of the maps. Radish production in 2014, 2015, and 2016 was calculated to be 90 to 99% accurate (Table 4, Figure 3).

The methodology of determining estimated acreage using Crop Scape data for *Brassica* and radish seed crops was reviewed and confirmed appropriate by Dr. Jamon Van Den Hoek, Assistant Professor in the College Earth, Ocean, and Atmospheric Sciences at Oregon State University.

Table 4. Crop Scape radish acreage validation.

Year	Crop	Estimated Acreage	WVSSA Pinned Radish Fields	Estimated Fields	Field Number Accuracy	Fields Locations Validated
2014	Radish	10,422	239	240	99%	85
2015	Radish	5,946	155	139	90%	29
2016	Radish	5,367	151	145	96%	22

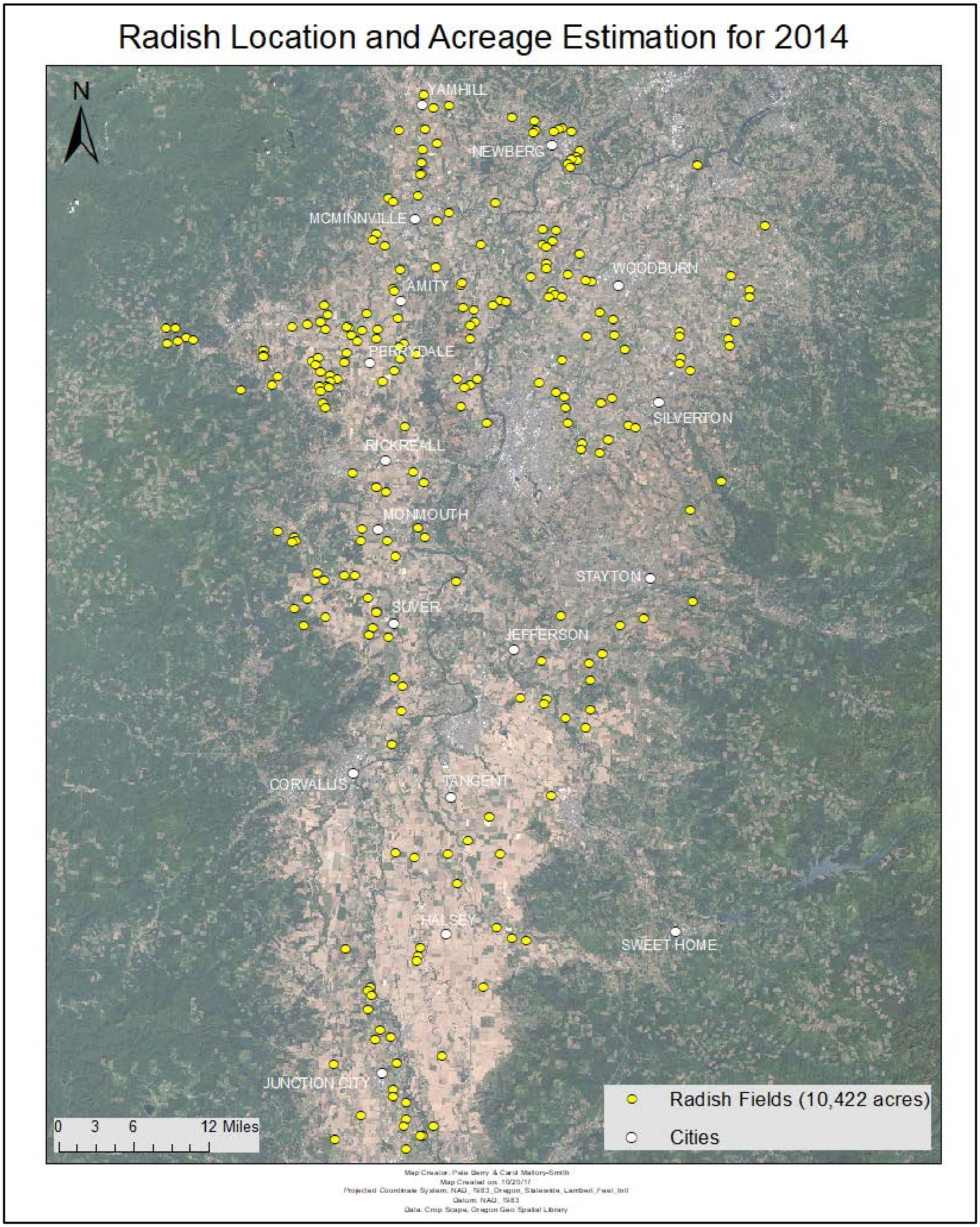


Figure 3. Radish field location and acreage based on Crop Scape estimates and industry validation for production in 2014.

Further analysis was conducted on radish populations utilizing spatial analysis software in ArcMap. Because radish field locations were validated, density mapping was completed for each year to determine regions of the Willamette Valley that have the greatest density of production. Higher populated regions of interest appear by comparing the proximity of points (fields) to adjacent points with each point (field) having a weighted value of acres (Figure 4). The map displays regions within the Willamette Valley that produce the most radish acreage per square mile. A similar map could be created for *Brassica* crops to provide guidance on where canola production might need to be excluded. However, without GPS coordinates, crop type, or industry validation these potential regions of concern could not be determined.

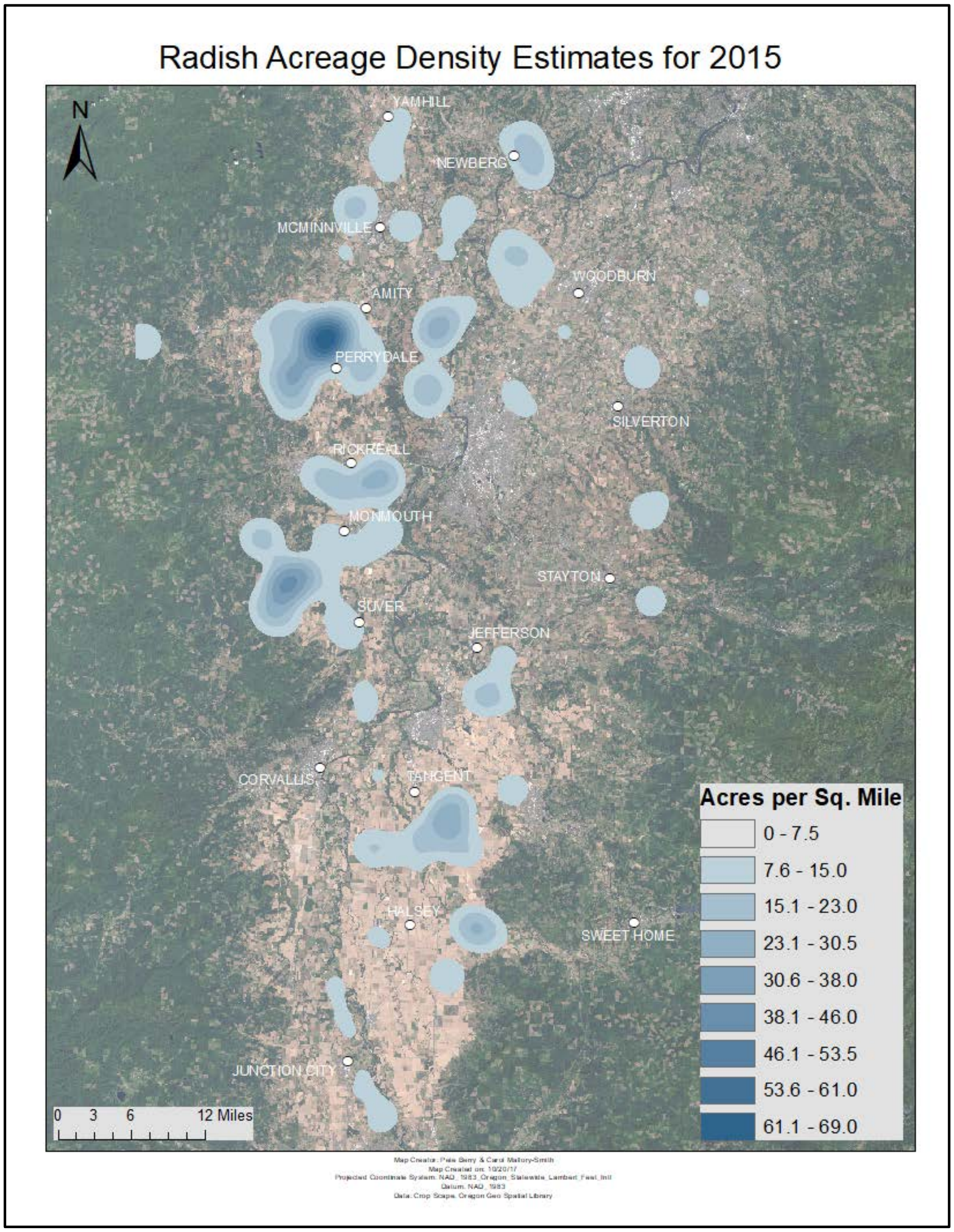


Figure 4. Density map of radish production in 2014 determined by Crop Scape acreage.

Based on professional experience, grower input and testimony (Hadley 2015), growers are seeking a broadleaf crop to use in rotation with grass seed crops. Often, wheat is used in the rotation after grass seed crops are removed. The number of acres of wheat grown each year in the same eight counties used to predict *Brassica* acreage are shown in Table 5 (NASS 2017). Number of grass seed acres were provided by Dr. Thomas Chastain, OSU (Chastain 2017).

Table 5. Combined acreage of wheat and grass seed produced in Benton, Clackamas, Marion, Linn, Lane, Polk, Washington, and Yamhill counties.

Year	WV Wheat Acreage	WV Grass Acreage	Total grass/cereal Acreage
2012	88,400	387,270	475,670
2013	62,600	391,690	454,290
2014	44,800	392,350	437,150
2015	37,300	379,190	416,490
2016	33,200	372,320	405,520
Average	53,260	384,564	437,824

Many of the acres that are used to produce grass seed and wheat are not conducive for the production of *Brassica* vegetable seed crops due to lack of irrigation, the correct soil type, or appropriate microclimate. There are approximately 900,000 acres in production in the Willamette Valley without irrigation. Grass seed acreage fluctuates depending on available contracts and price. Wheat is a commodity crop so production acreage fluctuates with price or when other contracts are not available. More than 50,000 acres of wheat on average have been planted each year over the past 5 years. Therefore, acres planted to grass seed and wheat represent acres where canola could potentially be grown, a decision that would be driven by economics and rotational goals of each grower.

Monitoring Results - Volunteers, Insect, and Disease

Findings:

- Canola volunteer persistence was not different for turnip, daikon radish, or forage rape.
- Volunteer control was effective using available herbicides.
- Volunteer plants associated with monitored fields have not spread along roadsides or to adjacent areas.
- No insect pest was unique to winter canola, nor more prevalent than related fall-seeded crops.
- In general, spring-seeded Brassicaceae crops (daikon radish and spring canola) had greater insect activity than fall-seeded Brassicaceae (winter canola, turnip, and forage rape).
- Canola did not exhibit an overall greater incidence or severity of diseases relative to turnip or forage rape seed crops in western Oregon.
- Daikon radish seed crops had fewer diseases and lower disease levels compared to all other *Brassica* crops examined during this research.
- Brassicaceae weeds with black leg and light leaf spot were found along Interstate-5 within 20 miles of Washington and California and along roadsides in the Willamette Valley. These weed populations likely lead to wider spread of the diseases.

Objectives

Per Oregon State Legislature House Bill 2427, a multi-disciplinary team of researchers at Oregon State University monitored pests (crop volunteers, plant pathogens, and insects) that occurred in Brassicaceae seed crops from 2013-2016. Field monitoring was conducted to determine if there were differences in volunteer persistence or pest occurrence among related Brassicaceae crops. The crops chosen for monitoring were canola (*Brassica napus*), forage rape (*B. napus*), turnip (*B. rapa*), and daikon radish (*Raphanus sativus*) grown for cover crop seed production. The cover crop seed fields were chosen for monitoring because they are produced in larger fields and overall on greater acreage which is comparable to how canola could potentially be grown. They are also grown in areas where canola might be a desirable rotational crop. Theoretically, these crops and canola would be hosts for the same insect pests and diseases as other Brassicaceae crops including vegetable seed crops.

General Methods

Beginning in 2013-2014, approximately 1,500 acres, 500 acres per crop: canola, turnip, daikon radish were monitored. Forage rape (*B. napus*) fields monitored were included in the turnip acreage. Fifteen hundred new acres were added during both 2015 and 2016 (500 acres of each crop). Volunteers were monitored in all fields in all years for a total of approximately 4,500 acres (71 fields) by the end of the study because the seed bank could persist for multiple years and produce volunteers each year. Insect and disease monitoring was focused on the current cropping cycle each year because the subsequent rotational crops were not hosts. Monitoring included multiple sampling methods to assess volunteer occurrence and persistence, insect pests, and disease occurrence (see respective sections for details).

Canola fields were chosen with the help of the Willamette Valley Oilseed Producers Association (WVOPA), and turnip and daikon radish fields with the assistance of members of the Willamette Valley Specialty Seed Association (WVSSA). Fields were pinned using the WVSSA digital pinning system. Fields were chosen to represent a diverse area from Amity to Coburg and from Rickreall to 4 miles east of Silverton (Figure 5). Crop history, tillage practices, chemical applications and timings, and cropping sequence were recorded, although not all factors were utilized in analysis. One turnip field was removed during the study due to crop failure, and one forage rape field was removed from data analysis due to lack of cooperation by the new owner.

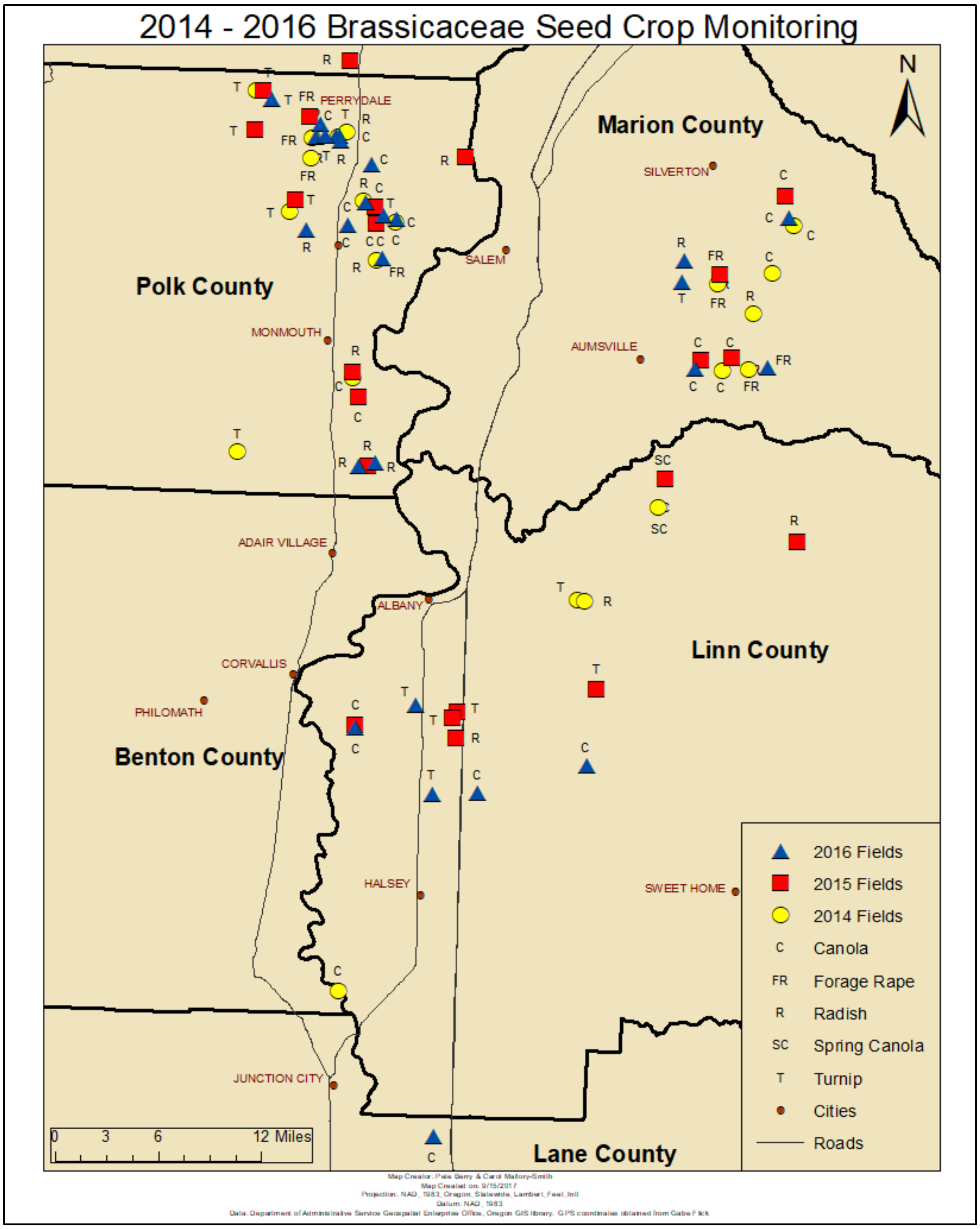


Figure 5. Brassicaceae fields monitored during the study.

Volunteer Brassicaceae Seedling Monitoring Results

Brassicaceae Crop Volunteers

Anecdotal observations from industry personnel and producers suggested that differences exist in the persistence of Brassicaceae crop seeds within the soil seedbank. Canola seed was found to remain viable in Canada for at least 5 years after production (Legere and Simard 2001). Canola enters secondary dormancy under certain environmental stresses such as high temperatures, limited moisture, and the absence of light, all of which contribute to seed persistence (Pekrun et al. 1998). However, there has been no comparison of persistence among different Brassicaceae crops. Volunteer seedling numbers were taken monthly to bi-monthly depending on the season using a rating scale for volunteer density (Table 6).

Analysis of the data, containing points from all fields and all three harvest years, indicated that crop species was not a significant factor in volunteer persistence. Volunteer density was primarily driven by seasonality (Figure 6). The first rain events each year following Brassicaceae harvest resulted in large flushes of volunteers. In subsequent years a similar response was seen each fall after harvest and when tillage operations were performed. Volunteer ratings for all species followed the same trends across years, excluding the initial fall rating after each harvest. This initial difference among species likely occurred because of the variation in time between harvest and the first major rain event. Turnip is harvested in late June to early July, canola in late July, and daikon radish from August to September. Volunteer numbers decline over time as long as volunteers are not allowed to flower and reseed.

Subsequent crop choice within rotations was observed to effect volunteer density ratings. Emergence was less when the crop following the Brassicaceae crop was grass seed, with the exception of fine fescue. Perennial crops also reduced volunteer emergence until the crop was removed with tillage at which time many seeds germinated. However, it is hard to draw conclusions about the influence of rotational cropping choice from this survey as the sample size was small, fields in this study could not be randomized due to pinning requirements, and there are other confounding variables such as crop variety, management, and equipment used by each grower. Volunteer plants associated with monitored fields have not spread along roadsides or to adjacent areas.

Table 6. Rating scale used for estimating number of Brassica volunteers.

Rating	Description
0	No volunteers
1	A few on field or road edge
2	Very few plants noted in field, scattered
3	1/10,000 - 1/1,000ft^2 or a small patch
4	2/1000 - 1/100ft^2 or a medium patch
5	2/100 - 1/10ft^2 or a large patch
6	2/10 - 1/ft^2
7	2 - 5/ft^2
8	6 - 10/ft^2
9	11 - 15/ft^2
10	>15/ ft^2

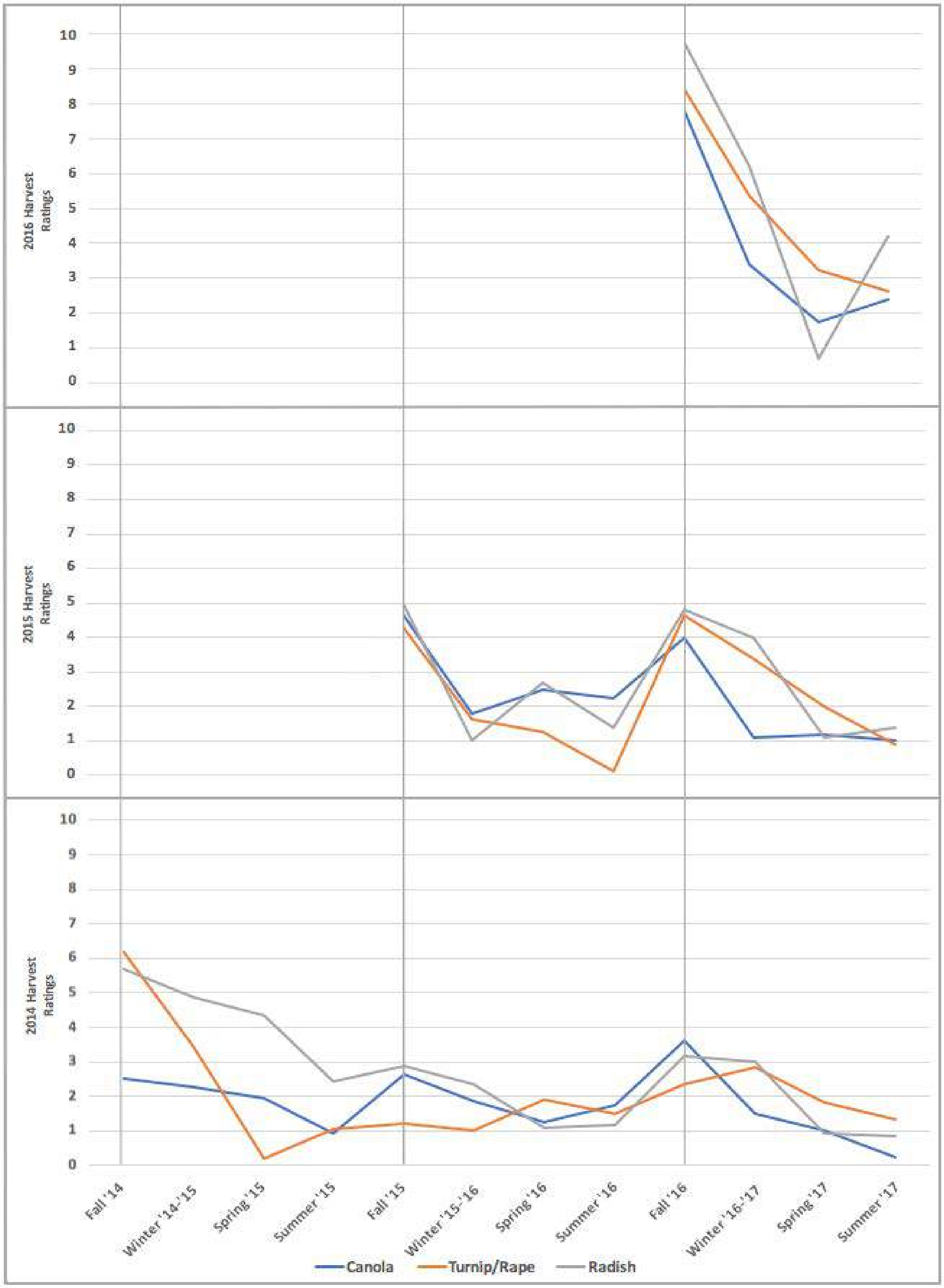


Figure 6. Volunteer density ratings by harvest year for each crop.

Harvest losses

Seed left on the soil surface in each field were collected immediately following harvest. Debris was collected from three to four 1 ft^2 quadrats which were placed randomly within and among combine chaff trails. A vacuum was used to collect seed and debris and seed was separated in the lab with hand held screens. After counts, subsamples were combined and a germination test conducted to calculate the total amount of viable seed/ac (Table 7). Five fields were sampled in 2015 and six were sampled in 2016.

Seed losses from harvest operations ranged from 30 to 567 lbs/ac (Table 7), which agrees with numbers reported from other studies (Gulden et al. 2003, Price et al. 1996). Average seed loss was 70 lbs/ac for turnip, 255 lbs/ac for canola and 308 lbs/ac for forage rape. For comparison, the recommended seeding rate is 2 to 8 lbs/ac. Direct comparison of losses in lbs/ac between these crops may not reflect volunteer potential in subsequent years due to differences in seed size. Turnip, canola, forage rape, and daikon radish in this study averaged 170,000, 94,000, 94,000, and 32,000 seeds per pound, respectively.

There are many factors that can affect harvest losses, from crop maturity to combine settings, which were not part of this study. It is important to note that despite seed loss differences among crops, volunteer recruitment and density were not significantly different (Figure 6).

Table 7. Estimated viable seed left after Brassicaceae crop harvest.

Harvest year	Crop	Viable seed left in the field (lbs/acre)	Viable seed (no/acre)
2015	Turnip	30	5,074,740
2015	Turnip	56	9,553,820
2015	Turnip	224	38,041,833
2015	Canola	567	53,268,677
2015	Canola	157	14,728,077
2016	Turnip	35	5,938,698
2016	Canola	116	10,875,480
2016	Canola	180	16,915,861
2016	Forage rape	447	41,974,797
2016	Forage rape	169	15,895,044
2016	Daikon radish	96	3,084,281

Herbicide Trials

Four trials, three in canola and one in forage rape were conducted to test the efficacy of currently-labeled herbicides for *Brassica* volunteer control in grass seed and small grain rotation crops. One-hundred percent volunteer control was achieved with all treatments in grass seed (data available upon request). All treatments in wheat provided excellent control except pyroxasulfone alone. Timing was a critical factor as is generally true for all herbicide applications. Delaying application until most volunteers emerged was important for volunteer *Brassica* seedling control in grass seed but even more crucial in wheat because wheat formed a less-dense leaf canopy than grass seed crops.

Tillage Trial

During fall 2014, a trial was established at the OSU Hyslop Research Farm to determine the long-term effects of three commonly used tillage regimes: no tillage, shallow tillage, and deep tillage, on the persistence of shattered seeds of canola, daikon radish, and turnip. Treatments were designed to mimic those after harvest. Seed was spread at rates equivalent to harvest losses, with tillage treatments applied annually. Counts were taken after rain events when seedlings emerged followed by the application of non-selective, contact herbicides to remove volunteers and ensure that no seed was returned to the plots.

Emergence over time can be an indication of the ability of seeds to persist. The initial count was separated from subsequent counts for statistical analysis. Emergence immediately after trial establishment was high with over 50% of seed spread germinating in shallowly tilled plots (Figure 7). The lowest initial emergence was recorded in deep tilled plots because the seeds were buried when the soil was inverted. After three years, daikon radish seedlings emerged in greater numbers than canola or turnip seedlings. Lowest emergence occurred in no-till treatments with near-zero levels of canola and turnip volunteers by the end of year two. Canola and turnip seeds appear to be similar in their ability to persist over time. Daikon radish emergence was greater for both shallow and deep tillage over all three years of study (Figure 8). Soil cores will be taken to confirm viable seed remaining in the seedbank in November 2017.

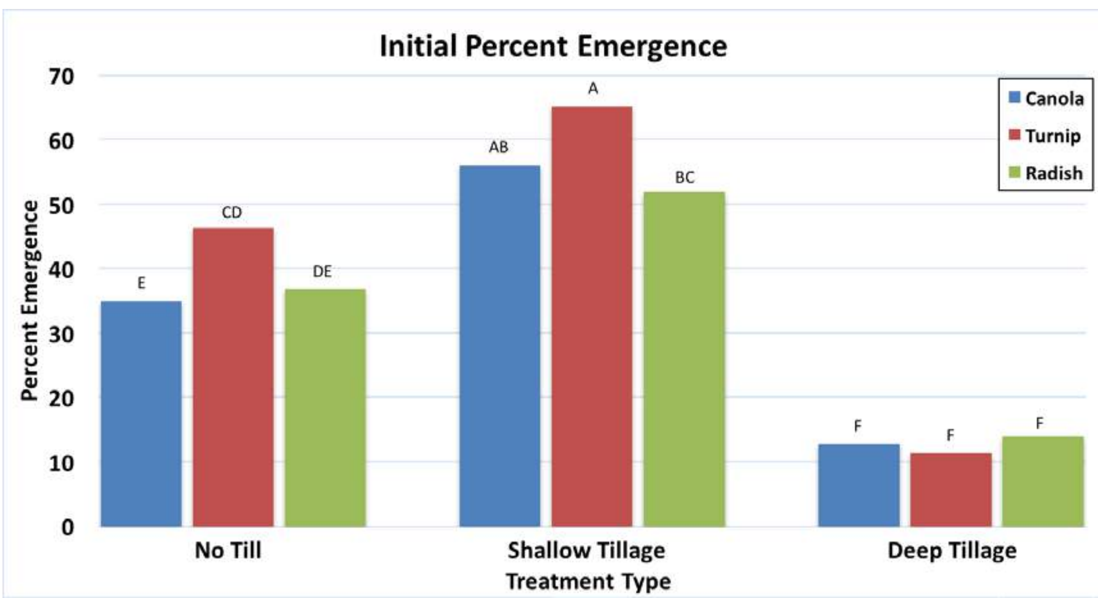


Figure 7. Initial count taken 41 days after treatment. The Y axis is a percentage of total seed spread. Bars with the same letter are not different at p = 0.05.

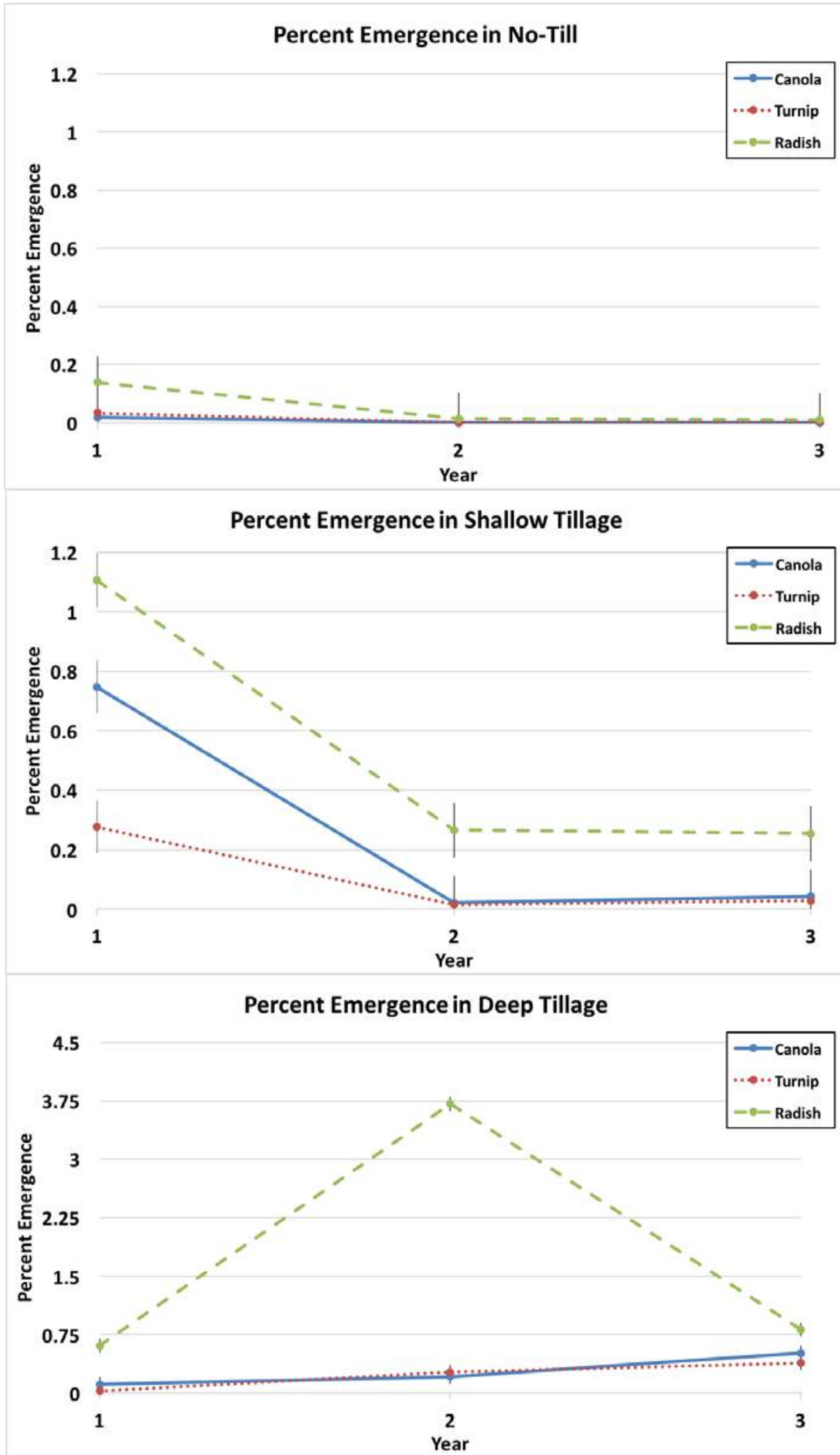


Figure 8. Percent cumulative seedling emergence by year under different tillage regimes. Data points are mean ± standard error.

Conclusions

Overall, in this study, persistence was not different for any crop. Volunteer persistence was not affected by crop choice following Brassicaceae production even though crop choice within rotations was observed to effect density ratings. In the OSU Hyslop Research Farm study, canola and turnip seed persistence was similar under the same tillage management system. Precipitation levels and timing of management practices on individual farms have a greater impact on volunteer persistence than the type of Brassicaceae grown. In this study, there were producers of each crop species who had volunteer levels greater than the overall grower average indicating that time of tillage, time of herbicide application, or herbicide chemistry is more important than crop species for volunteer management.

Insect Pest Monitoring in Willamette Valley Brassicaceae Crops

The objective of the insect monitoring component was to quantify pest activity by estimating insect populations and determining if notable differences occurred between crops. This report encompasses data collected between October 22, 2013, and August 23, 2016.

A variety of standard sampling methods were utilized to estimate insect pest activity in each of the 71 monitored fields. Methods included yellow sticky traps, sweep net samples, wing traps and pheromone lures, leaf pulls, yellow pan traps, and mature seedpod evaluations (Table 8, Figure 9). Yellow sticky cards and pheromone traps were placed approximately 16 ft from field edges and kept clear from foliar debris by removing vegetation and elevating the traps depending on crop growth stage. Cards and trap liners were replaced as needed and pheromone lures were replaced every 4 weeks. Sweep net sampling was performed using a 15-inch diameter hoop equipped with a muslin bag. Sweep net samples and leaf pulls were conducted by walking a “W” sampling pattern across 0.5 to 2 acres of each field and averaging findings from 5-10 sampling locations for each field. Sampling was conducted from planting date to harvest within each field. Frequency varied by season (weekly May to Oct, bi-weekly Nov to Apr). Most identification occurred onsite, but when necessary samples were taken to OSU for positive identification.

Statistical analysis was conducted using SAS 9.4 on non-transformed values of number of insects per day. Insect count data tend to be non-normally distributed (ATLAS 2015) but means were too small for the fit of the statistical model to be adequately described by Poisson (Wood 2002) so a general linear model (GLM) was used. Fall seeded crops (forage rape, turnip, and winter canola) were analyzed separately from spring-seeded crops (daikon radish and spring canola) due to potential temporal differences in insect activity.

Figure 9. Methods of field monitoring for insect pests included pheromone traps, sweep netting, and direct examination.

Pest Profiles and Results

There are many insects that affect Brassicaceae crops, some are generalist feeders and others prefer *Brassica* plants, specifically. This 'suite' of insect pests can occur simultaneously (Kok 2004). However, not all are of equal importance, either because the damage caused can be tolerated by the crop, pest pressure may not influence oil content or quality (Brown et al. 1999), timing of infestations does not coincide with crop development (Renwick 2002, Dosdall 2005), pest abundance is limited, and so forth.

Figure 10 serves as a visual guide when considering insect damage to Brassicaceae seed crops, and how the damage inflicted might affect crop performance and subsequent yield. Insects that feed directly on seedpods (P) might seem most important, but if injury occurs during early growth stages (E, R), overall crop health, flowering (F), and subsequent pod production can be negatively affected.

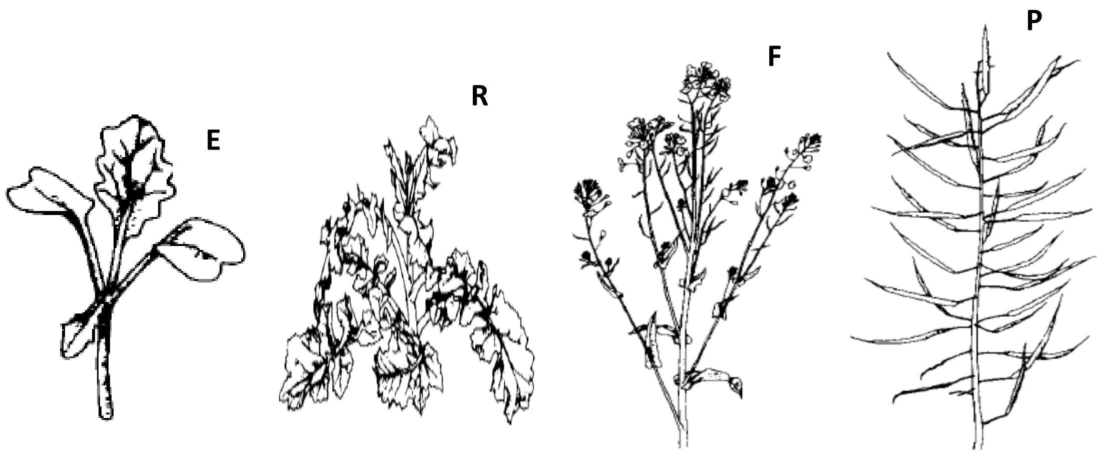


Figure 10. Growth stages of canola and related Brassicaceae seed crops. Plants progress phenologically from seedling establishment (E), through rosette and stem elongation (R), flowering (F), and pod development (P). From Hack, 1992; drawings ©1990 BASF Ag.

Much of the existing literature on pest monitoring in canola comes from Europe, Australia, and Canada (Dosdall 2010, Williams 2010, Gu et al. 2007). Pests that are listed as incidental for other countries might be more common in a temperate region like western Oregon (Brown 1999). Conversely, some of the worst pests in the EU, including turnip moth and rape stem weevil, are not known to be present in the United States (NCAPS 2017). Tables 8 and 9 list insects that have the potential to be pests on canola and other Brassicaceae crops in Oregon. Monitoring tactics for each pest are suggested, as well as economic thresholds (ET). Economic thresholds refer to the level of pest activity that will justify an insecticide application. Thresholds are not known for every pest, and depend on many factors including crop value, cost of inputs, estimated yield loss, etc.

Table 8. Insect pests present in this region and known to affect Brassicaceae hosts. Damage potential to each crop growth stage is indicated by letters (E-establishment; R-rosette and stem elongation; F-flowering and bud stage; P-pod development. See also Figure 10). Suggested scouting methods and economic thresholds (ET; if available) are provided.

Taxonomic Order	**Common Name**	**Scientific name**	**Damage Potential and Monitoring**				
			-- affected crop stage --				scouting and thresholds
COLEOPTERA							
	Cabbage Seedpod Weevil	*Ceutorhynchus assimilis* syn. *C. obstrictus)*			F	P	Sweep netting and visual scans, focus on field edges. Adults can be found on early flowering hosts (wild mustard, flixweed, hoary cress, stinkweed, and volunteer canola). Scout 2x per week when crop plants are at 10-20% bloom. Collect pods and examine for larval exit holes. ET: 20+ adults per 10 sweeps.
	12-Spot Beetle	*Diabrotica undecimpunctata*		R		P	Yellow sticky traps are placed just above the crop canopy. Mark the date that you place the trap. Come back in seven to ten days. Calculate the beetles per trap per day. Sweep netting in rosette stage.
	Pollen Beetle Rape Beetle	*Nitidulid* spp. *Meligethes aeneus*			F		Yellow sticky traps prior to bloom. Sweep netting samples should be taken from the field margins.
	Crucifer Flea Beetle	*Phyllotreta cruciferae*	E			P	Inspect seedlings at each of 10 sites per field. Sites should include field edges, within-field locations, and topographic features such as tree lines, hedgerows, and bluffs. Yellow sticky traps. ET: 25% of cotyledons with pits.
HEMIPTERA							
	Tarnished Plant Bug	*Lygus lineolaris*			F	P	Sweep netting is the most effective way to detect Lygus bugs. Nymphs are often mistaken for aphids, but lack cornicles (pointy appendages on tip of abdomen), and have 5 black dots on the back. Calculate the average number of adults per 10-arc sample. ET: ≥ 20 adults per sweep sample (of 10 arcs).
DIPTERA							
	Cabbage Maggot and related species	*Delia radicum, D. floralis, D. planipalpis, D. platura*	E	R			Place yellow pails filled with soapy water along the field edges at intervals of 100 feet. Empty every 4 to 6 days. Scout for egg clumps on lower stems and at the base of plants just below soil level using a fine paintbrush.
	Brassica Pod Midge, Swede Midge	*Dasineura brassicae, Contarinia nasturtii*		R		P	Pheromone is available but still very expensive. Traps can also attract other gall midges and identification is difficult. Examine leaf bases, flower buds and growing points of poorly-performing plants for small yellow maggots. They create a soupy wet area that can sometimes look like rot. ET: 5 males per trap per day.

Table 8 (Continued).

LEPIDOPTERA							
	Diamondback Moth	*Plutella xylostella*		R	F	P	Steps across rows pull ten leaves from each stop and examine them for 'windowpane' damage and larvae. Pheromone traps are used to capture adult moths ET: 1-2 larvae per plant at early flowering, 2-3 at pod stage.
	Beet Webworm‡	*Loxostege sticticalis*		R	F	P	Sweep net for larvae, pheromone traps for adults.
	Cabbage White Butterfly	*Pieris rapae*		R			Visual scans for adults, erratic and distinctive flight, sweep netting for larvae, they appear 'fuzzy' and have lateral small yellow dots.
	Cabbage Looper	*Trichoplusia ni*		R	F		Sweep netting for larvae, light green with lateral white stripe and 3 abdominal prolegs. Pheromone traps for adults.
	Cutworms and Armyworms	*Mamestra configurata* *Spodoptera praefica,* many others		R	F	P	Scout underside of leaves for egg masses, visual scan for scattered 'strikes', large areas of defoliation and/or stem cutting at soil level. Pheromone trapping are used to trap adult moths. ET: 10-30 per m², depending on value and cost of control.
OTHER							
	Grey Field Slug‡	*Deroceras reticulatum*	E	R			Scout, paying particular attention during emergence and seedling establishment.
	Cabbage Aphid‡ Green Peach Aphid‡	*Brevicoryne brassicae* *Myzus persicae*		R	F		Cross field in W-pattern, pull and examine leaves from 10+ areas for aphids. Cabbage aphids have a gray, waxy appearance and form colonies. Peach aphids are solitary and have longer cornicles.

‡ Not monitored as part of this study

Table 9. Insect pests not yet detected in the United States as of January 2017. Damage potential to each crop growth stage is indicated by letters (E-establishment; R-rosette and stem elongation; F-flowering and bud stage; P-pod development).

Order	Common Name	Scientific name(s)[1]	Damage Potential				Current Distribution
			--- affected crop stage ---				
COLEOPTERA							
	Rape Stem Weevil and Cabbage Stem Weevil	*Ceutorhynchus napi, Ceutorhynchus pallidactylus*		R			Widespread throughout Europe
	no common name, a stem weevil	*Baris coerulescens*	E	R	F	P	France, Germany, Serbia, Uzbekistan
HEMIPTERA							
	Rape Bug	*Eurydema oleracea*		R	F	P	Europe, Russia, N. Africa
LEPIDOPTERA							
	Old World Bollworm	*Helicoverpa armigera***		R	F	P	Asia, Africa, Europe, S. America, Oceania
	Cluster Caterpillar Egyptian Cottonworm	*Spodoptera litura**, Spodoptera littoralis*		R			Asia, Africa, Europe, Oceania
	Large White Butterfly	*Pieris brassicae**		R			Europe, Asia, Russia
	Cabbage Moth	*Mamestra brassicae**		R			Europe, Asia
	Turnip Moth	*Agrotis segetum*	E	R			Asia, Africa, Europe

[1] Indicates status as a 2018 prioritized pest of economic and environmental importance (**) or an additional pest of concern (*) by the National Cooperative Agricultural Pest Survey (CAPS) Committee

COLEOPTERA (beetles and weevils)

Adult beetles can be defoliating herbivores or predators on other insects. Larvae chew on root tissue or reproductive structures (flowers, seeds). One of the major concerns in seed crop production is the presence of weevils because they attack different parts of the plant at different times. Weevils tend to be a greater problem when there are periods of variable temperature patterns (cool temperatures followed by warm, then cool, etc.) (Juran et al. 2010).

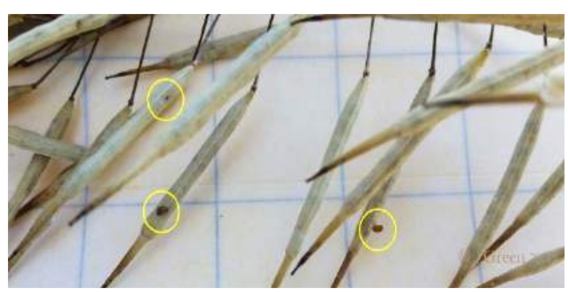


Figure 11. Cabbage seedpod weevil damage is hard to detect, and is estimated by the evidence of larval exit holes from mature pods.

Cabbage Seedpod Weevil (*Ceutorhyncus obstrictus*, CSPW) adults deposit eggs in developing seedpods. Yield-limiting economic damage to the crop is through larval feeding within the pods. When mature, larvae chew an opening in the pod wall (Figure 11), then drop to the soil surface and pupate in an earthen cell. Pod sampling is considered the most accurate way to determine damage caused by CSPW. In years 2 and 3, subsamples of 400 pods were collected just prior to swathing and examined for exit holes. Results indicate that CSPW activity did not differ among fall-seeded crops in either year (Figure 12). Sticky trap counts of CSPW were highly variable between crops and years (Table 10).

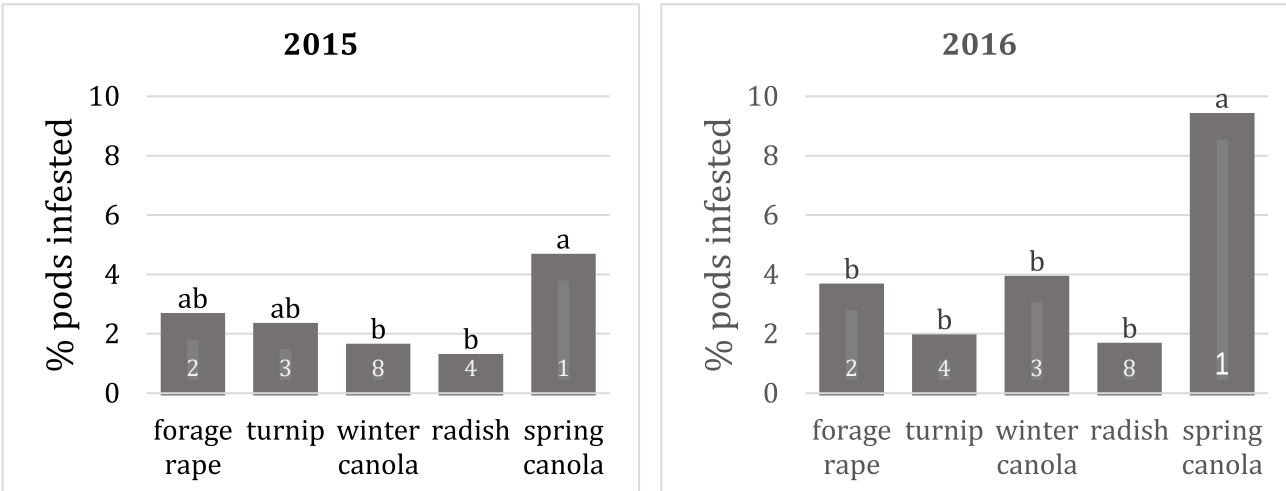


Figure 12. Percent (%) of sampled pods with cabbage seedpod weevil damage by crop. Letters indicate statistical difference (p=0.05), white numbers at the base of each column refer to number of fields sampled.

Western 12-Spotted Cucumber Beetle (*Diabrotica undecimpuntata* var. *undecimpuntata,* SP12) is considered a generalist feeder, but is thought to prefer plants from the Cucurbitaceae family (cucumbers and squash) to Brassicaceae. Concurrent OSU-IPM studies in vegetable crops indicate that 2014 and 15 were record years for SP12 populations, with up to 10 beetles per day detected in sweet corn and snap bean fields (www.blogs.oregonstate.edu/vegnet). Trap counts from this study were markedly lower (less than 1 beetle per trap per day), but did increase in forage rape and turnip fields in year 2 (Table 10). The overwintering capacity of adult beetles means that SP12 could theoretically use fall-seeded Brassicaceae crops as a refuge.

Pollen Beetles (*Nitidulid* spp., *Meligethes aeneus*, NITD) are most active from bud stage through bloom. This pest is of particular concern because of the propensity to migrate en masse, and shift hosts as flowering progresses from one crop to the next. Migration capacity is strong; estimated at 0.18 mi per hour, regardless of wind direction (Mauchline et al. 2017). Adult beetles feed on pollen in the buds and flowers. Crops are most susceptible to yield-decreasing damage by the pollen beetle at the early bud stage and become less susceptible as plants develop. Spring-sown crops are often in the bud stage when NITD are colonizing crops, and thus are more affected. In this study, activity of NITD beetles was greatest in daikon radish in years 2 and 3 (Table 10).

Crucifer Flea Beetle (*Phyllotreta cruciferae*, CFB) is known mostly as an 'establishment pest', which means damage to newly emerged seedlings can be extensive. Plants are able to compensate for pest damage after about the 5-leaf stage. Flea beetles can overwinter in weedy areas, and move into crops on warm days (> 59°F) to feed but most activity occurs after 200 growing degree days (GDD base 50) (Delahaut 2005). In the Willamette Valley, 200 GDD_{50} occurs in early to mid-May so fall-planted *Brassicas* are well past the critical establishment period when flea beetle pressure is greatest. This pattern was reported in a Canadian study, which confirmed higher flea beetle pressure in spring seeded canola compared to fall seeded canola (Dosdall and Stevenson 2005). Pod damage from flea beetles was observed in daikon radish, which is unusual and only occurs when populations are unusually high. Thousands of flea beetles were detected on sticky traps, with spring crop values ranging from 66 to 79 beetles per day in years 1 and 2 (Table 10).

HEMIPTERA (true bugs)

True bugs damage plant tissue by piercing plant tissue and sucking juices via a straw-like mouthpart. They can also vector plant pathogens. Both adults and nymphs cause damage. Nymphs are often mistaken for aphids. All above-ground plant tissues are susceptible to attack. Damage to developing flowers causes bud blast, in which buds turn white and fail to develop. Feeding on seeds causes them to become shrunken and dark, and can result in small dark circles on the pod surface.

<u>Tarnished Plant Bug</u> (aka lygus bug, *Lygus lineolaris*, LYGS) and the related *Lygus hesperus* are considered major pests in many cropping systems including forage crops, orchards, and vegetables. They overwinter successfully in western Oregon, and emerge early in the season, moving freely from weed host plants to developing crops as blooming progresses. For spring-seeded Brassicaceae, LYGS activity was greatest in daikon radish in years 1 and 3; in year 2, the greatest activity of LYGS occurred in spring canola (Table 10). Lygus bugs were significantly more prevalent in turnip vs. other fall *Brassicas* in year 2 only (Table 10).

Table 10. Seasonal mean values (± SE) of pest insects (Cabbage Seedpod Weevils (CSPW), Western Spotted Cucumber Beetles (SP12), Pollen Beetles (NITD), Flea Beetles (FLEA), and Tarnished Plant Bugs (LYGS)) per crop, as monitored by yellow sticky traps. Bold and shaded values indicate greater activity (Fisher's protected LSD, α=0.1) within season. Asterisks indicate significance ((** or *, p≤0.05 or p≤0.1); ns=not significantly different).

2014	Crop	# obs.	Pest species (insects*day^{-1})									
			CSPW		**SP12**		**NITD**		**FLEA**		**LYGS**	
			Mean	*SE*	Mean	*SE*	Mean	*SE*	Mean	*SE*	Mean	*SE*
FALL	**forage rape**	10	1.84	*0.87*	0.05	*0.03*	0.04	*0.03*	0.07	*0.04*	0.03	*0.02*
	turnip	20	0.81	*0.42*	0.04	*0.01*	0.31	*0.19*	0.07	*0.05*	0.05	*0.05*
	winter canola	27	1.51	*0.53*	0.07	*0.03*	0.06	*0.04*	1.03	*0.84*	0.06	*0.04*
	FPLSD (α=0.1)		1.67, ns		0.07, ns		0.30, ns		1.75, ns		0.11, ns	
SPRING	**radish**	23	0.69	*0.40*	0.24	*0.10*	0.07	*0.03*	29.62	*17.92*	0.30	*0.08*
	spring canola	4	0.26	*0.25*	0.32	*0.32*	0.03	*0.03*	66.35	*70.95*	0.14	*0.16*
	FPLSD (α=0.1)		1.6, ns		0.5, ns		0.10, ns		83.0, ns		0.41, ns	

2015	Crop	# obs	Pest species (insects*day^{-1})									
			CSPW		**SP12**		**NITD**		**FLEA**		**LYGS**	
			Mean	*SE*	Mean	*SE*	Mean	*SE*	Mean	*SE*	Mean	*SE*
FALL	**forage rape**	8	1.70	*0.87*	0.25	*0.21*	0.08	*0.06*	2.00	*1.81*	0.06	*0.05*
	turnip	22	4.31	*0.42*	0.20	*0.10*	1.37	*0.89*	0.94	*0.84*	**0.22**	*0.11*
	winter canola	21	0.10	*0.05*	0.06	*0.03*	0.31	*0.18*	0.03	*0.01*	0.00	*0.00*
	FPLSD (α=0.1)		5.65, ns		0.24, ns		1.75, ns		2.0, ns		0.21, *	
SPRING	**radish**	15	0.75	*0.47*	0.34	*0.20*	3.62	*2.03*	30.15	*22.60*	0.30	*0.11*
	spring canola	5	1.11	*0.59*	0.05	*0.04*	0.24	*0.11*	104.34	*46.66*	**2.51**	*2.03*
	FPLSD (α=0.1)		1.52, ns		0.61, ns		6.22, ns		81.9, ns		1.95, *	

2016	Crop	# obs	Pest species (insects*day^{-1})									
			CSPW		**SP12**		**NITD**		**FLEA**		**LYGS**	
			Mean	*SE*	Mean	*SE*	Mean	*SE*	Mean	*SE*	Mean	*SE*
FALL	**forage rape**	4	0.01	*0.01*	0.03	*0.02*	0.03	*0.03*	**0.07**	*0.08*	0.03	*0.03*
	turnip	13	0.24	*0.14*	0.06	*0.03*	0.13	*0.12*	0.03	*0.02*	0.05	*0.04*
	winter canola	24	0.28	*0.14*	0.04	*0.01*	0.05	*0.03*	0.00	*0.00*	0.06	*0.03*
	FPLSD (α=0.1)		0.49, ns		0.06, ns		0.21, ns		0.05, **		0.09, ns	
SPRING	**radish**	10	0.08	*0.04*	0.09	*0.06*	0.44	*0.17*	0.99	*0.81*	0.38	*0.22*
	spring canola	0					n/a					
	FPLSD not available											

DIPTERA (flies)

Adult rootflies (*Delia* spp.) lay eggs in the soil near the base of plants, which quickly hatch into maggots. Maggots are small (≤ 0.5 cm), creamy white, and legless. Identification to species is difficult, as adult flies must be examined for wing venation, presence and length of hairs on the thorax and legs, and other minute characteristics. Therefore, rootflies are generally regarded as a group, although differences in egg-laying and tissue feeding do occur. Maggots use their mouthparts to tunnel into root or stem tissue. They reduce crop health by limiting water and nutrient uptake, causing structural damage, increasing chance for lodging, and perhaps most importantly, increasing the risk of fungal and bacterial infection caused by soil microbiota such as *Fusarium* or *Erwinia*.

<u>Cabbage Maggot</u> (*Delia radicum,* CRF) is difficult to manage because maggots cause extensive damage and seedcoat insecticides provide only marginal protection. Flies have a long activity season (Apr-Nov) and produce multiple generations per year. Adult rootflies (*Delia* spp.) were sampled with sticky traps (all crops) as well as water pan traps in daikon radish, turnip, and winter canola. In all years sampled, there were more adult rootflies detected on sticky traps in daikon radish versus any other Brassicaceae seed crop (Table 11). Water pan traps placed at field edges (30 Apr to 30 Jun 2015) confirmed high CRF activity in daikon radish and winter canola, with an average of 2.8 and 2.1 rootflies per day, respectively, compared to 0.40 per day in turnip (data not shown). By comparison, pan trap monitoring in *Brassica* vegetable fields from 28 Apr to 19 May 2014 averaged 4.6 rootflies per day (www.blogs.oregonstate.edu/vegnet).

Although there were no significant differences in CRF among fall-seeded crops (forage rape, turnip, and winter canola) (Table 11), an increase in Brassicaceae crops may lead to increased populations of CRF. According to a growing degree day model established for this region, CRF exhibits two peaks of flight activity, spring and fall (www.uspest.org, Dreves 2006). Cabbage rootflies prefer cooler weather, and the potential for year-round development exists (Finch 1989).

Table 11. Seasonal mean values (± SE) of adult rootflies per crop as monitored by yellow sticky traps. Bold and shaded values indicate significantly greater activity (Fisher's protected LSD, α=0.1). Asterisks indicate significance ***, ** or * (p≤0.01; p≤0.05; p≤0.1); ns=not significantly different.

Season	Crop	# obs.	Rootflies (*Delia* spp.) detected on yellow sticky traps							
		2014			**2015**			**2016**		
		n	Mean	*SE*	n	Mean	*SE*	n	Mean	*SE*
FALL-SEEDED	**forage rape**	10	1.12	*0.23*	8	0.53	*0.37*	4	0.67	*0.61*
	turnip	20	2.10	*0.82*	22	0.39	*0.09*	13	0.18	*0.10*
	winter canola	27	0.79	*0.22*	21	0.35	*0.10*	24	0.98	*0.45*
	FPLSD (α=0.1)		1.38, ns			0.38, ns			1.47, ns	
SPRING-SEEDED	**radish**	23	3.45	*0.88*	15	2.38	*1.07*	10	4.70	*2.78*
	spring canola	4	0.98	*0.33*	5	0.12	*0.08*	0	n/a	
	FPLSD (α=0.1)		3.6, ns			3.3, ns			n/a	

LEPIDOPTERA (moths and butterflies)

Caterpillar is the common term describing the larval, damaging life stage of this group. Larvae consume large amounts of tissue in a short time by cutting stems just above the soil surface or defoliating leaves. Adults are not damaging because they feed on nectar. There are many other cutworms and armyworms that are considered generalist feeders.

Armyworms, Cutworms, and Loopers. Bertha armyworm, winter cutworm, and cabbage looper were identified as part of this study, but sample sizes were too small to make any inferences. Due to the potential for extensive crop damage by this pest group, it would be wise to conduct a comparative study of Lepidoptera pressure in Brassicaceae seed and vegetables crops. Cutworm and armyworm species have become more prevalent in grass seed and rotation crops in the Willamette Valley since 2014 (http://bit.ly/2xvIAoz), and many of the pests have wide host ranges that include Brassicaceae crops. Cabbage looper and winter cutworm larvae were found in February and March. The year-round presence of suitable hosts could contribute to population buildups of these two species over time.

Diamondback Moth is a major concern for Brassicaceae growers. Mild winters may allow for continual reproduction of DBM in this region (i.e. adults do not die off in winter like other insects) (Mao and Kessing 2007, Butts and McEwen 1981). Combined with annual migration from southern latitudes, pest populations can increase rapidly. Additionally, DBM is known to be resistant to many classes of insecticides commonly used by Brassicaceae growers. Although sampling of forage rape was limited to 2 fields in year 2, DBM activity was significantly greater than other fall-seeded *Brassicas* (Table 12). In year 3, DBM activity within daikon radish fields averaged 4.6 moths per day, compared to 0.4, 1.7, and 0.2 in forage rape, turnip, and winter canola, respectively (Table 12). A spring canola field was not available for comparison in year 3.

Table 12. Seasonal mean values (± SE) of diamondback moths as monitored by pheromone traps. Bold and shaded values indicate significantly greater activity (Fisher's protected LSD, α=0.1). Asterisks indicate significance ***, ** or * (p≤0.01; p≤0.05; p≤0.1); ns=not significantly different.

Season	Crop	# obs.	Diamondback moths (*P. xylostella*) Per day				
		2015			**2016**		
		n	Mean	*SE*	n	Mean	*SE*
FALL-SEEDED	**forage rape**	3	10.17	*3.85*	2	0.44	*0.44*
	turnip	1	0.20	*n/a*	7	1.69	*1.22*
	winter canola	4	3.40	*1.25*	12	0.15	*0.05*
	FPLSD (α=0.1)		9.6, *			2.26, ns	
SPRING-SEEDED	**radish**	7	21.03	*10.26*	2	4.56	*1.95*
	spring canola	3	13.56	*0.95*	0	n/a	
	FPLSD (α=0.1)		11.7, ns			n/a	

BENEFICIAL INSECTS (predators and parasitoids)

Generalist predators and parasitoids can keep pest insect populations regulated, and their importance should not be underestimated. During the course of this study, the presence and relative abundance of predators (ladybeetles and lacewings), and parasitoid wasps were noted. Rove beetles (*Aleochara bilineata*) were observed throughout the study, and serve as an important predator and parasitoid of root maggots, but were not quantified by yellow sticky traps because they are ground-dwelling. Parasitoid activity was greatest within daikon radish fields in year 2, and in general, increased from year 1 to year 3 (Table 13). There were more lacewings detected in year 3 than other years, and they were found in turnip and daikon radish fields more than other crops. In general, spring-seeded Brassicaceae crops exhibited greater pest activity in this study, yet it is important to note that they also had significantly higher numbers of beneficial insects (Table 13).

Conclusions

The data collected provide valid, science-based insight into pest activity differences between Brassicaceae seed crops in the years studied. Insect pest patterns are known to change year to year (Williams 2010), and are related to percent of total host plant acreage (Feeny 1977). For instance, the presence of *Brassica* crops actively growing throughout fall and winter may provide a 'green bridge' for pest species to continue development, especially given the mild winters common in western Oregon and Washington. An increase in Brassicaceae crop acreage could lead to increased insect pressure in these crops.

In general, spring-seeded Brassicaceae crops (daikon radish and spring canola) had greater insect pest activity than fall-seeded crops, but also had greater numbers of beneficial insects. There was no pest issue that was unique to winter canola, nor more prevalent than what was observed in related fall-seeded crops. There was an overall increase in pest activity in year 2 versus years 1 and 3, marked by higher counts for most species. Pest activity in each crop is a useful metric, but it should be cautioned that these counts do not provide the whole picture of how insect populations can change over time.

Table 13. Seasonal mean values (± SE) of beneficial insect counts per crop. Bold and shaded values indicate significantly greater activity (Fisher's protected LSD, α=0.1), as monitored by yellow sticky traps. Predators (LACE - Chrysopa spp., lacewings); (LADY - Hippodamia convergens, Harmonia axyridis, and other ladybeetles), and parasitoids (Diadegma insulare, Microctunus spp., and others). Asterisks indicate significance ***, ** or * (p≤0.01; p≤0.05; p≤0.1); ns=not significantly different.

Year	Crop	# obs.	Taxonomic group (insects*day^{-1})			
2014			**PREDATORS (LADY and LACE not separated in 2014)**		**PARASITOIDS**	
			Mean	SE	Mean	SE
	forage rape	10	**0.12**	*0.06*	0.02	*0.02*
	turnip	20	0.06	*0.02*	0.02	*0.02*
	winter canola	27	0.04	*0.02*	0.05	*0.03*
	FPLSD (α=0.1)		0.06, *		0.07, ns	
	radish	23	0.07	*0.03*	0.09	*0.08*
	spring canola	4	0.18	*0.20*	0.00	*0.00*
	FPLSD (α=0.1)		0.16, ns		0.33, ns	

Year	Crop	# obs.	Taxonomic group (insects*day^{-1})					
2015			**PREDATORS-LADY**		**PREDATORS-LACE**		**PARASITOIDS**	
			Mean	SE	Mean	SE	Mean	SE
	forage rape	8	0.16	*0.11*	**0.08**	*0.03*	0.00	*0.00*
	turnip	22	0.15	*0.04*	0.06	*0.02*	0.06	*0.04*
	winter canola	21	0.08	*0.05*	0.00	*0.00*	0.01	*0.01*
	FPLSD (α=0.1)		0.13, ns		0.04, ***		0.07, ns	
	radish	15	0.12	*0.03*	0.10	*0.03*	0.24	*0.15*
	spring canola	5	0.34	*0.30*	0.05	*0.04*	0.00	*0.00*
	FPLSD (α=0.1)		0.26, ns		0.09, ns		0.44, ns	

Year	Crop	# obs.	Taxonomic group (insects*day^{-1})					
2016			**PREDATORS-LADY**		**PREDATORS-LACE**		**PARASITOIDS**	
			Mean	SE	Mean	SE	Mean	SE
	forage rape	4	**0.17**	*0.10*	0.04	*0.10*	0.00	*0.00*
	turnip	13	0.04	*0.02*	**0.21**	*0.02*	0.14	*0.10*
	winter canola	24	0.02	*0.01*	0.02	*0.01*	0.06	*0.03*
	FPLSD (α=0.1)		0.07, ***		0.17, **		0.20, ns	
	radish	10	0.10	*0.05*	0.25	*0.09*	0.18	*0.11*
	spring canola	0	*n/a*					
	FPLSD (α=0.1)		*n/a*					

Disease Monitoring

The primary pathology objective in the OSU HB2427 research was to determine whether canola in the Willamette Valley would exhibit greater levels of common diseases, or additional diseases, compared to forage rape, daikon radish or turnip seed crops. Diseases are a concern for Brassicaceae vegetable seed, fresh and processing vegetables, and oilseed crops in the northern latitudes of the USA, where more severe disease outbreaks can occur, including on cauliflower and cabbage in New York and Michigan, radish and turnips across the northern USA (Farmham 2000), and canola across the northern USA (including the PNW) into southern Canada.

Plant disease surveys conducted over the three years of this research showed that pathogens commonly found on the monitored seed crops also occurred on canola, except for white rust, which was not observed on canola. Canola did not exhibit an overall greater incidence or severity of diseases relative to turnip or forage *Brassica* seed crops in western Oregon. Infected crop residues persisted more than 18 months after harvest, windblown ascospores produced on canola and turnip residues infected trap plants during October through May that were deployed weekly throughout the cropping cycle. Daikon radish seed crops had fewer diseases and lower disease levels compared to all other *Brassica* crops examined during this research. Serious disease outbreaks (black leg, light leaf spot, and white leaf spot) were detected during the first year of the surveys in canola, turnip, and forage rape seed fields, and in *Brassica* crops in the western Oregon. Infected crops included fresh market and seed crops of bok choy, pak choi, broccoli, cabbage, Chinese cabbage, collards, kale, mizuna, mustard greens, red radish, rutabaga, and turnip as well as cover crop and forage fields. The cause of the outbreak has not been identified but was likely an infected seed source of an unknown Brassicaceae source. Canola seed planted in all of the research fields every year was certified as black leg-free and fungicide-treated so the outbreak of 2014 was not the result of planting canola in the research fields during 2013.

Because black leg epidemics had not occurred since the 1970s, and light leaf spot is new to North America, the pathology efforts for this research project were expanded due to the potential economic threat to Oregon producers and the need to understand how canola might impact the disease complex.

Survey of Brassicaceae research sites for diseases

Research sites were fields of canola, and seed crops of forage rape, daikon radish, and turnip seed throughout the Willamette Valley (Figure 5). During all years of study, the fields were planted, managed, and harvested by the growers as commercial production fields, except for the plantings on the OSU Hyslop Farm during 2013-2015. Canola, forage rape and turnip fields were fall planted except for two fields of spring canola. Daikon radish was spring planted. Crops were harvested in the summers of 2014, 2015, and 2016. During the 2013-2014 season, seven canola fields were surveyed for disease beginning in October while five turnip, three forage rape, and five daikon radish fields were surveyed beginning in spring. During the 2014-2015 and 2015-2016 crop cycles, disease surveys were initiated in designated canola, turnip, and forage rape seed research fields beginning in October. Eight canola, five turnip, two forage rape and seven daikon radish seed fields were surveyed in 2014-2015 and nine canola, seven turnip, and three forage rape seed fields were surveyed in 2015-2016. Disease surveys consisted of examination of plants along a 10 ft length of row in each of 10 transects arranged in a V-shaped pattern along one or two sides of each field. Disease incidence and severity were estimated in the field; symptomatic plant samples were collected for disease confirmation through laboratory examination and testing. Leaf severity ratings were estimated using the leaf models developed by Conn et al. (1990).

A number of common diseases werefound in western Oregon on *Brassica* vegetable seed crops in earlier specialty seed surveys conducted by Ocamb (2009-2013). Although these diseases are common in the PNW on *Brassica* crops, the specialty seed industry has been successful controlling these problems using integrated management strategies. Diseases that were commonly observed in the earlier surveys included black spot, gray mold, downy mildew, Fusarium wilt, powdery mildew, Sclerotinia stem rot and white rust; more information on these common diseases can be found on-line at PNW Plant Disease Management Handbook (pnwhandbooks.org/plantdisease/host-disease). Black spot was found in 6 of 7 canola fields, 3 of 5 turnip, 1 of 3 of the forage rape and all daikon radish seed research fields harvested during 2014, but was less frequent during 2015 where it was observed in 1 of 8 canola fields, 2 of 5 turnip, and all the daikon radish fields (Table 16). Downy mildew was observed less frequently in canola than the other crops. It was found in 1 out 7 canola fields and all turnip, forage rape and daikon radish research fields harvested during 2014 (Table 15) and in 2 of 8 canola fields, 4 of 5 turnip fields, 1 of 2 forage rape field, and all the daikon radish research fields in 2015 (Table 16). Canola generally did not exhibit higher incidence levels of black spot or downy mildew compared to the other crops examined. Powdery mildew and white rust were observed infrequently in the research fields while gray mold occurred occasionally (Tables 15 and 16). Sclerotinia stem rot was detected in two canola and two turnip fields during 2015 (Table 16). The field of spring-planted canola appeared healthy during 2014. During 2014, three diseases, black leg, light leaf spot, and white leaf spot, were found (Table 15) that had not been observed in earlier OSU surveys of *Brassica* vegetable seed fields conducted during 2009-2013. These diseases can cause economic impacts in *Brassica* crops in general, potentially causing significant losses in seed crops, so are of greater concern to the *Brassica* seed industry than the commonly-occurring diseases observed previously.

Black leg

Black leg is a serious fungal disease of *Brassica* crops (Rimmer and van den Berg 2007). Black leg has caused significant yield losses in *Brassica* crops across the globe for many years. Black leg epidemics had not occurred in the PNW since the 1970's, until the widespread outbreaks in 2014 in the Willamette Valley. Black leg has been observed in specialty *Brassica* seed fields inspected for disease-free certification prior to the outbreaks 2014 (Table 14). However, it should

Table 14. Voluntary Brassicaceae specialty seed field certification inspections conducted by the Oregon Department of Agriculture.

Year	Total no. seed fields inspected	Total Brassicaceae acreages	No. radish fields	Total *Raphanus* acreage	No. *Brassica* fields	Total *Brassica* acreage	No. black leg infected fields
2009	112	1715	44	948	68	767	7
2010	123	2305	58	1406	65	899	10
2011	134	2170	61	1391	73	779	9
2012	166	2543	78	1745	88	798	2
2013	147	2418	79	1605	68	813	0
2014	107	1675	51	1101	56	574	3
2015	104	1572	48	1025	56	547	4

be noted that prior to 2014, black leg disease outbreaks detected in field certification inspections occurred at low incidence levels and were not widespread within affected fields (Osterbauer 2017).

Black leg has recently been detected in canola in eastern Oregon (Weaver 2016), Washington (Paulitz et al. 2017) and Idaho (Agostini et al. 2013). The fungi which cause black leg, *Leptosphaeria maculans* and *L. biglobosa*, can cause spots on leaves, stem cankers, plant stunting, and death of *Brassica* and radish plants. The fungus survives and reproduces both sexually and asexually. Fruiting bodies of the sexual stage form on infected plant debris and release the sexual spores called ascospores that can be windblown at least several miles during cool and moist weather. Ascospores form on infected plants residues that remain on the soil surface after harvest until they decompose. Asexual spores which develop on infected plants or plant residues, are dispersed by splashing water (rain or irrigation), and lead to disease build-up in affected plantings. The black leg fungus can survive in infected plant residues, potentially producing both spore types, until the infected plant debris decomposes fully. The black leg fungus also is seedborne and is reported to survive for years in infected seed.

Light leaf spot

Light leaf spot, caused by the fungus *Pyrenopeziza brassicae*, is economically important in Europe, Australia, and Asia where it causes severe stunting and defoliation in oilseed crops (McCartney and Doughty 2007). Light leaf spot has eclipsed black leg for economic losses in oilseed rape produced in the UK for six of the seven years of disease surveys conducted between 2008 and 2014 (https://secure.fera.defra.gov.uk/cropmonitor/cmsReport.cfm?id=30). The lifecycle of light leaf spot is similar to black leg; *P. brassicae* produces windblown ascospores on infected crop residues and rain-splashed conidia on infected plants. Light leaf spot was not reported in North America until the disease was found in 2014 in western Oregon (Ocamb et al. 2015), and was subsequently detected in 2016 in the Skagit Valley in northwestern Washington (Carmody; Carmody et al. 2016). In the UK, light leaf spot infections can remain asymptomatic (McCartney, and Doughty 2007) after ascospores are released during late summer or early fall (Gilles et al. 2001), symptoms may develop weeks to months after infection. Light leaf spot symptoms developed on fall-planted *Brassica* crops in Oregon during February 2015 and 2016, and January 2017. Light leaf spot was observed during June on spring-planted specialty seed crops in 2014 and 2015, and on some turnip trap plants deployed during the spring of 2016 (data not shown), suggesting that ascospores of this pathogen are being produced and may be released over an extended period in the PNW. Although the presence of ascospores, or the spore-bearing structure that produces them, have not yet been identified in the PNW, the widespread outbreak observed in multiple counties during 2014 and reoccurrence during 2015 and 2016 suggest that ascospore production has occurred.

White leaf spot

White leaf spot, caused by the fungus, *Mycosphaerella capsellae (syn. Neopseudocercosporella capsellae)*, causes leaf spots and stem infections (Inman and Fitt 2007) and can lead to severe plant defoliation. The disease cycle of white leaf spot is similar to black leg and light leaf spot; *M. capsellae* produces windblown ascospores on infected crop debris and windblown conidia on infected plants. White leaf spot has been considered a minor disease on *Brassica* vegetables grown in the USA (Koike 1997, Koike et al. 2007) while significant yield losses have been reported for white turnip as well as Indian mustards and oilseed *Brassicas* in Australia, Germany, and Canada (Gunasinghe et al. 2014). White leaf spot had not been detected in Oregon specialty seed fields until spring 2014, when severe disease outbreaks were first observed in a subset of the fields examined.

Results specific to black leg, light leaf spot and white leaf spot

Black leg, light leaf spot and white leaf spot were detected in widespread outbreaks during 2014 and 2015 in our research fields (Tables 15 and 16) as well as in specialty *Brassica* vegetable seed crops, fresh-market vegetables, and weed hosts in the Willamette Valley and in a *Brassica* cover crop and a forage crop (Tables 17 and 18). Black leg was not observed on daikon or red radish, but light leaf spot and white leaf spot were observed on daikon radish (Table 16) and red radish in 2015 (Table 4). Black spot and downy mildew were commonly encountered in radish seed crops not part of the OSU HB 2427 research fields, and light leaf spot was found in these other radish seed fields surveyed during 2014 and 2015 (Tables 17 and 18). Several new plant hosts for black leg were identified in western Oregon, including arugula (*Eruca sativa* Mill.) and the ornamental cruciferous flower species, Siberian wallflower (*Cherianthus allioni* hort. Ex Bois) and globe candytuft (*Iberis umbellate* L.) (Ocamb et al. *in preparation*). The lower stems of these plants are colonized but it is unknown at this time if infected plant residues of these new hosts would produce the windblown ascospore stage of black leg.

Table 15. Disease occurrence as percentage of plants affected (DI: disease incidence) and range of % leaf area affected on diseased leaves (DS: disease severity) in survey of OSU HB 2427 research fields conducted in Brassicas during April-May 2014 and daikon radish during June-July 2014.

Crop and Field #[1]		Black leg[2,3]		Black spot[3]		Downy mildew[3]		Gray mold[3]		Light leaf spot[3]		Powdery mildew[3]		White leaf spot[3]		White rust[3]	
Canola	**Count**	**DI**	**DS**	**DI**	**DS**	**DI**	**DS**	**DI**	**DS**	**DI**	**DS**	**DI**	**DS**	**DI**	**DS**	**DI**	**DS**
14-1	Polk	50	1-10	20	1-5							20	1-20	80	1-20		
14-2	Polk	10	1	50	1-10			10	1					90	1-5		
14-4	Yamhil	90	1-5	50	1					20	1			70	1-5		
14-6	Polk	70	1	20	1	10	1-10	30	1	10	1			80	1-20		
14-7	Marion	10	1	20	1-5			10	1	10	5-30			40	1-5		
14-8*	Linn																
OSUFarm	Benton	+		10	1					10	1			90	1-50		
Turnip																	
14-9	Polk	25	1			10	1-5					10	1	70	1-5		
14-10	Yamhil	40	1	90	1-5	70	1-20			70	5-20						
14-11	Yamhil	70	5-10	10	5	70	5-40							40	5-10		
14-12	Linn	20	1			40	1			90	1-20			10	1		
14-13	Polk	20	1	20	1	10	1-20										
Forage rape																	
14-14	Polk	70	1-5	40	5-10	50	1-5			10	1						
14-15	Marion	10	1			10	1	60	1-30							1	1
14-16	Marion	10	1			10	1							80	1-10		
Daikon*																	
14-17	Polk			50	<1	90	<1										
14-19	Polk			50	<1	10	1-10										
14-20	Polk			50	<1	90	<1										
14-21	Linn			1	<1	5	1										
14-22	Polk			90	<1	90	<1										

[1] Spring-planted crops are indicated by *.
[2] + = disease observed but incidence and severity were not determined.
[3] Absence of data indicates that no plants surveyed in that field had obvious disease at the time of survey.

Table 16. Disease occurrence as percentage of plants affected (DI: disease incidence) and range of % leaf area affected on diseased leaves (DS: disease severity) in survey of OSU HB 2427 research fields conducted in Brassicas during December 2014-March 2015 and daikon radish during February-July 2015.

Crop and Field #		Black leg[3]		Black spot[2,3]	Downy mildew[2,3]		Light leaf spot[2,3]		Powdery mildew[2, 3]	Sclerotinia stem rot[2,3]	White leaf spot[2]	
Canola	**County**	**DI**	**DS**	**DI**	**DI**	**DS**	**DI**	**DS**	**DI**	**DI**	**DI**	**DS**
15-2	Polk	100	20								10	1
15-3	Marion	100	10		10	1						
15-4	Linn	100	10				+			+		
15-5	Polk	100	30				+			+		
15-6	Polk	100	10-20				+					
15-7	Marion	100	10									
15-8	Marion	100	10									
OSUfarm	Benton	100	1-10	+	+				+			
Turnip												
15-10	Linn	100	1-10	+	10	40	50	1-5		+	100	10
15-11	Yamhill	10	1-5		10	1	10	1-5			10	1-5
15-14	Polk	100	1-10		10	1	50	1-5			100	
15-16	Linn	100	1-5							+	100	50
15-17	Yamhill	100	1-10	+	10	1	50	1-5			100	10
Forage rape												
15-12	Polk	80	1-5		10	1						
15-13	Marion	50	1-5									
Daikon*												
15-22	Polk			+	+							
15-23	Polk			+	+							
15-24	Polk			+	+							
15-25	Polk			+	+							
15-26	Marion			+	+							
15-A	Marion			+	+		+				+	
15-B	Marion			+	+		+					

[1] Spring-planted crops are indicated by *.
[2] + = disease observed but incidence and severity were not determined.
[3] Absence of data indicates that no plants surveyed in that field had obvious disease at the time of survey.

Table 17. Diseases detected in additional Brassicaceae fields and weeds surveyed April-June 2014.

County	Crop[1]	Black leg[2,3]	Black spot[2,3]	Downy mildew[2,3]	Light leaf spot[2,3]	White leaf spot[2,3]	Other diseases observed
Specialty seed crops							
Polk	cabbage	+	+				Sclerotinia stem rot
Marion	cabbage	+	+				
Marion	cabbage		+	+			
Marion	cabbage		+	+			
Linn	Chinese cabbage	+	+	+			
Linn	Chinese mustard	+	+				
Benton	collards	+	+	+			Cladosporium leaf spot
Benton	kale	+					
Benton	kale	+	+				
Benton	kale	+	+	+			
Benton	kale	+	+	+			
Marion	kale		+	+			
Marion	kale	+					Sclerotinia stem rot
Marion	kale	+	+	+		+	
Polk	radish		+	+	+		
Linn	turnip		+	+	+		
Linn	turnip		+	+	+		
Linn	turnip		+	+		+	
Yamhill	turnip		+	+	+	+	
Yamhill	turnip		+	+	+		
Vegetable crops							
Benton	§radish			+			
Forage & Cover crops							
Marion	*_Brassica_ cover crop			+	+		
Marion	*forage turnip	+	+		+	+	
Volunteers & Weeds							
Linn	#volunteer mustard	+	+	+	+	+	
Linn	#volunteer radish		+				
Polk	#volunteer turnip				+		
Yamhill	#volunteer turnip	+			+	+	
Yamhill	#volunteer _Brassica_	+					
Marion	#birdsrape mustard	+	+	+	+		
Marion	#birdsrape mustard	+	+		+		
Marion	#black mustard	+	+		+	+	
Polk	#mustard			+			
Marion	#wild radish		+	+	+		
Polk	cabbage	+	+				Sclerotinia stem rot
Marion	cabbage	+	+				
Marion	cabbage		+	+			
Marion	cabbage		+	+			
Linn	Chinese cabbage	+	+	+			
Linn	Chinese mustard	+	+				
Benton	collards	+	+	+			Cladosporium leaf spot

[1] Fields were seed crops unless noted with § for fresh market vegetable crop, * for a forage or cover crop field, or # to designate a weedy plant. Black leg was observed as a leaf spot on plants.
[2] + = disease was observed but incidence and severity were not determined.
[3] Absence of data indicates that no plants surveyed in that field had obvious disease at the time of survey.

Table 18. Diseases detected in additional Brassicaceae fields and weeds surveyed Dec. 2014 - April 2015.

County	Crop[1]	Black leg[2,3]	Black spot[2,3]	Downy mildew[2,3]	Light leaf spot[2,3]	White leaf spot[2,3]	Other diseases observed
Specialty seed crops							
Benton	arugula	100	+	+		+	
Marion	cabbage		+				
Linn	cabbage	100					Sclerotinia stem rot
Lane	cabbage				+		Sclerotinia stem rot, Gray mold
Lane	cabbage	100	+	+	+		
Lane	cabbage	100	+	+	+		
Lane	cabbage	100	+	+	+	+	
Benton	Chinese cabbage	+		+		+	
Benton	Chinese cabbage	100	+	+		+	
Marion	Chinese cabbage			+	+		
Marion	forage rape	99			+		
Benton	kale			+		+	Sclerotinia stem rot
Marion	kale	40					
Marion	kale	100					
Marion	kale	40					
Marion	radish		+	+	+		
Marion	radish			+	+		
Benton	turnip	+		+			Powdery mildew
Benton	turnip	100	+		+		
Linn	turnip	100		+			Sclerotinia stem rot
Linn	turnip	100		+			Sclerotinia stem rot
Linn	turnip	100	+	+	+	+	
Linn	turnip	100			+		White rust
Linn	turnip	100			+		
Marion	turnip	100			+	+	
Yamhill	turnip			+			
Yamhill	turnip	100		+			
Vegetable crops							
Marion	§bok choy	+	+		+		
Benton	§broccoli	100		+			Sclerotinia stem rot
Marion	§broccoli	1		+			
Marion	§Brussels sprouts	+					
Benton	§Brassicas		+	+			
Benton	§collards		+	+			
Marion	§collards	+					Sclerotinia stem rot
Benton	§kale	100			+	+	
Marion	§kale	+		+		+	Sclerotinia stem rot
Marion	§kale	5					Sclerotinia stem rot
Benton	§rutabaga	100	+	+			
Volunteers & Weeds							
Yamhill	#volunteer *Brassica*	100					
Polk	#*B. rapa* weed	30			30	30	
Clackamas	#birdsrape mustard			+	20	60	
Marion	#birdsrape mustard	50		+	50		
Marion	#cruciferous weeds			+			
Marion	#cruciferous weed			+			
Marion	#cruciferous weed				70		
Polk	#cruciferous weed	20			60	20	
Polk	#*Sinapis* weed	20	+	+	40		
Lane	#wild radish				+		

[1] Fields were seed crops unless noted with § for fresh market vegetable crop, * for a forage or cover crop field, or # to designate a weedy plant. Black leg was observed as a leaf spot on plants.
[2] Average incidence is presented; + is used to indicate that disease was observed but incidence was not determined.
[3] Absence of data indicates that no plants surveyed in that field had obvious disease at the time of survey.

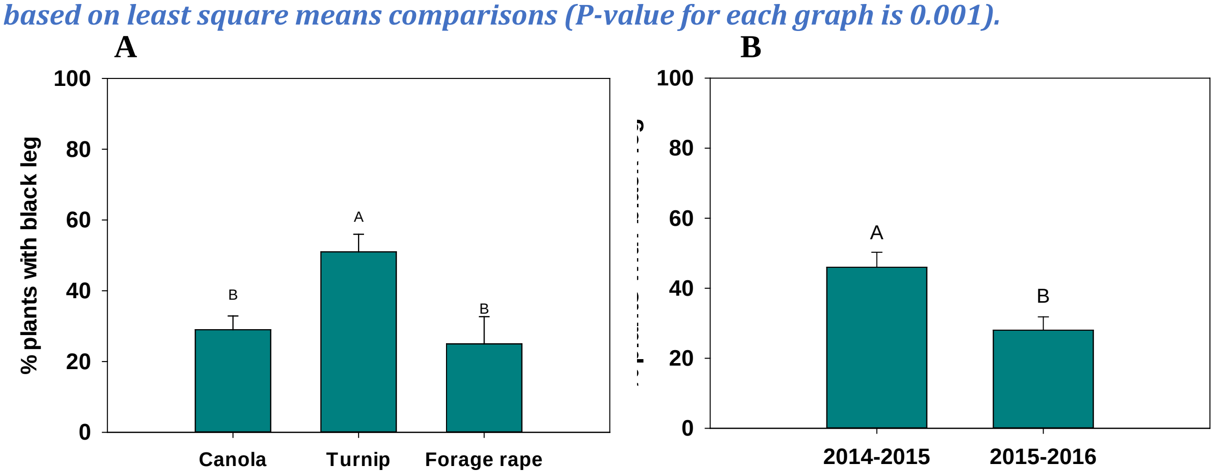
Black leg, light leaf spot and white leaf spot came to the forefront of the disease survey work, especially black leg, due to the potential economic threat for the *Brassica* industries. Seed crops, vegetables, forages, and cover crops can all be impacted by these three diseases. By June in 2014, black leg, light leaf spot, and white leaf spot were identified in 37, 21, and 17 of 59 sites, respectively, in six counties: Benton, Linn, Marion, Polk, Washington and Yamhill. Black leg and white leaf spot appeared across a range of *Brassica* crops; daikon and red radish appear to be less susceptible to both of these diseases at this time. However, greenhouse studies with black leg and red radish showed that radish is susceptible to the black leg pathogen present in western Oregon. *Brassica* and radish (both daikon and red) crops were susceptible to light leaf spot. These three diseases reappeared each year following the widespread outbreaks first detected in 2014, and were subsequently found during 2015 in Lane County in a few commercial *Brassica* seed fields. Black leg incidence was initially estimated at <1% of canola, forage rape, and turnip plants when first observed during 2014. But black leg spread across affected fields, causing more leaf spots on affected plants and infecting new plants within a field. Often the majority of the stand was infected within 4 to 6 weeks in the absence of active disease management such as foliar fungicide applications or rogueing of infected leaves and plants. During the fall of 2014, black leg appeared in new plantings during the latter half of October and initially, incidence levels of lack leg were 1% or less, but reached peaks up to 100% during December, or a month thereafter, in the absence of active disease management. Black leg incidence varied among the research fields but canola, forage rape, and turnip varieties planted during the fall in the Willamette Valley were susceptible to black leg during all years of survey (Table 19). During 2015 and 2016, the *Brassica* research fields were surveyed after harvest for black leg incidence on the lower stalk remnants of canola and forage rape as well as on turnip storage roots (Figure 13). Turnip seed fields had a greater incidence of black leg than either canola or forage rapeseed fields (Figure 13A). There was a significant difference in overall incidence between the two survey years (Figure 13B) (Claassen 2016).

Table 19. Disease incidence and leaf spot severity of black leg in 2014 through 2016 research fields.

2013-14 fields	Black leg[1]		2014-15 fields	Black leg[2]		201516 fields	Black leg[3]	
Canola	DI	DS	Canola	DI	DS	Canola	DI	DS
14-1	50	1-10	15-2	100	20	16-1	23	1
14-2	10	1	15-3	100	10	16-2	100	5
14-4	90	1-5	15-4	100	10	16-3	63	1
14-6	70	1	15-5	100	30	16-4	80	1
14-7	10	1	15-6	100	10-20	16-5	65	1
OSUFarm	+		15-7	100	10	16-6	90	5
			15-8	100	10	16-7	43	1
			OSUFarm	10	1-10	16-8	48	1
						16-9	75	1
Turnip			Turnip			Turnip		
14-9	25	1	15-10	100	1-10	16-1	80	5
14-10	40	1	15-11	10	1-5	16-2	25	1
14-11	70	5-10	15-14	100	1-10	16-3	35	1
14-12	20	1	15-16	100	1-5	16-4	50	1
14-13	20	1	15-17	100	1-10	16-5	80	1
						16-6	43	1
						16-7	28	1
Forage rape			Forage rape			Forage rape		
14-14	70	1-5	15-12	80	1-5	16-1	75	1
14-15	10	1	15-13	50	1-5	16-2	50	5
14-16	10	1				16-3	30	1

[1] Ratings conducted during April-May 2014. + = disease observed but incidence and severity were not determined.
[2] Ratings conducted during December 2014 and January-March 2015.
[3] Ratings conducted during March 2016.

Figure 13. Average incidence of black leg by crop type (A) and year (B) found in post-harvest surveys conducted during 2015 and 2016. Bars with different letters are significantly different based on least square means comparisons (P-value for each graph is 0.001).



Seedborne pathogens in Brassicaceae crops

The fungi that cause black leg and light leaf spot are reported to infect seed, and subsequently these pathogens can be transported to other regions with the movement of infected seed. *Leptosphaeria* spp., which causes black leg, are known to survive for years on seed (Rimmer and van den Berg 2007). The vegetable seed industry has a low tolerance for the presence of the black leg pathogen on seed where canola seed harvested for oil can better tolerate the presence of black leg. *Leptosphaeria* spp. on *Brassica* seed is regulated in many seed markets and *Leptosphaeria*-free seed is required for planting in many regions, including Oregon and Washington.

The light leaf spot fungus was reported to have a short duration of survival on seeds (McCartney and Doughty 2007) but recent work has shown that seed can remain infected for at least one year (Carmody 2017, Carmody et al. 2016). The potential and importance of seedborne infection by the white leaf spot fungus is not understood. White leaf spot infections can be found on seed pods and infected seed have been found in infected pods elsewhere but seed infection is reportedly rare (Inman and Fitt 2007). Carmody (2017) did not find infected seed after repeated inoculations with the white leaf spot fungus during flowering and pod set of two different Brassica crops in greenhouses studies. Crop residues are cited as the primary cause of white leaf spot epidemics in Europe; seedborne sources are not considered important in oilseed rape production.

Fungicides for black leg, light leaf spot, and white leaf spot management in *Brassica* crops in Oregon

Seed treatments

Pyraclostrobin + boscalid, iprodione, and thiabendazole are the most effective seed treatments for seedborne black leg in *Brassica* crops and are currently registered for seed treatment for seed crops grown (see *pnwhandbooks.org/plantdisease/host-disease* for more information on registered fungicides recommended for seed treatments). Although fungicides are registered for black leg control on *Brassica* seed crops (du Toit et al. 2005, Schneider et al. 2017a, Schneider et al. 2017b), additional seed treatments are needed for *Brassica* vegetable crops, and research is needed to assess the efficacy of these and other treatments for seed lots infected with the light leaf spot fungus, and potentially, the white leaf spot fungus. Currently, for organic seed and vegetable crops hot water is the only approved seed treatment for black leg management in Oregon. Steam, disinfectant, and biological seed treatments need further investigation for these three pathogens on seed.

Foliar treatments

Protective foliar fungicide for control of black leg, light leaf spot, and white leaf spot became critical for producers of *Brassica* seed crops in western Oregon after disease outbreaks commenced in 2014. During the spring of 2014, there was little information on the efficacy and timing of protective fungicide applications for these three diseases in western Oregon, and few fungicides were registered for efficacious disease control in conventional or organic specialty *Brassica* crops in 2014. Fungicides were evaluated by OSU; turnip plants were sprayed biweekly from October 2015 through April 2016. Three different fungicides showed good control of black leg and light leaf spot (difenoconazole, prothioconazole, and fluxapyroxad + pyraclostrobin) among the 19 different fungicides tested (Ocamb et al. 2017). None of the fungicides tested gave sufficient control of white leaf spot. Several fungicide registrations have been pursued for specialty seed crops. A Special Local Needs label was obtained in 2015 for use of a highly effective fungicide (prothioconazole), and label expansion occurred for several other fungicides for black leg and light leaf spot control in specialty seed crops. However, a limited number of fungicides are currently available for managing black leg and light leaf spot in seed crops (see *pnwhandbooks.org/plantdisease/host-disease* for information on recommended fungicides), with few choices in leafy, head, and stem *Brassica* crops. No effective fungicides are currently registered for black leg and light leaf spot management in root crop Brassicas and fungicides for white leaf spot are lacking for all *Brassica* crops. Additional registrations are needed for more effective management of these three diseases.

Improvements accomplished for disease diagnosis.

Confirmation of black leg and light leaf spot when outbreaks first occurred in western Oregon in 2014 required microscopic examination of the respective fungi after isolated from infected plants. It required one to two weeks to confirm black leg, and up to two months to confirm light leaf spot. Since that time, OSU developed more rapid tests using molecular protocols on infected plant tissues (Thomas et al. *in preparation*) which decreased the time required for disease diagnosis to less than one week. The more rapid diagnosis allows for a faster reaction to disease outbreaks and application of management strategies.

Brassicaceae weed survey

There are many different Brassicaceae weed species found in the Willamette Valley (Table 20). Because some of these species are known to serve as alternate hosts for either insects or diseases or both, a weed survey was conducted in the area of more intense Brassicaceae crop production. Brassicaceae weeds were found to be wide spread (Figure 14). Some of these species are present during the year when the crops are not, so they may serve as refuges for insects and diseases. The prevalence of Brassicaceae weeds reinforces the need to control feral crop populations as well as related weed species and the need for control within crops and areas adjacent to fields in order to reduce pest pressure. It is also apparent that there has been movement of some species from production fields, namely Indian mustard, radish, turnip, and white mustard to roadsides and waste areas.

Table 20. Brassicaceae weed species present in the Willamette Valley.

Weed species[1]	**Common Name**
*Brassica rapa**	birdsrape mustard; turnip
*Brassica nigra**	black mustard
*Brassica juncea**	Indian mustard
Brassica kaber	wild mustard
*Sinapsis alba**	white mustard
Barbarea orthoceras	American yellow rocket
Cardamine oligosperma	little bittercress
Capsella bursa–pastoris	Shepherd's-purse
Raphanus raphanistrum	wild radish
*Raphanus sativus**	radish
Rorippa curvisiliqua	curvepod yellow cress
Rorippa sylvestris	perennial rorippa
Sisymbrium irio	London rocket
Sisymbrium officinale	hedge mustard
Thlaspi arvense	field pennycress

[1] Populations likely the result of crop seed movement are indicated by *.

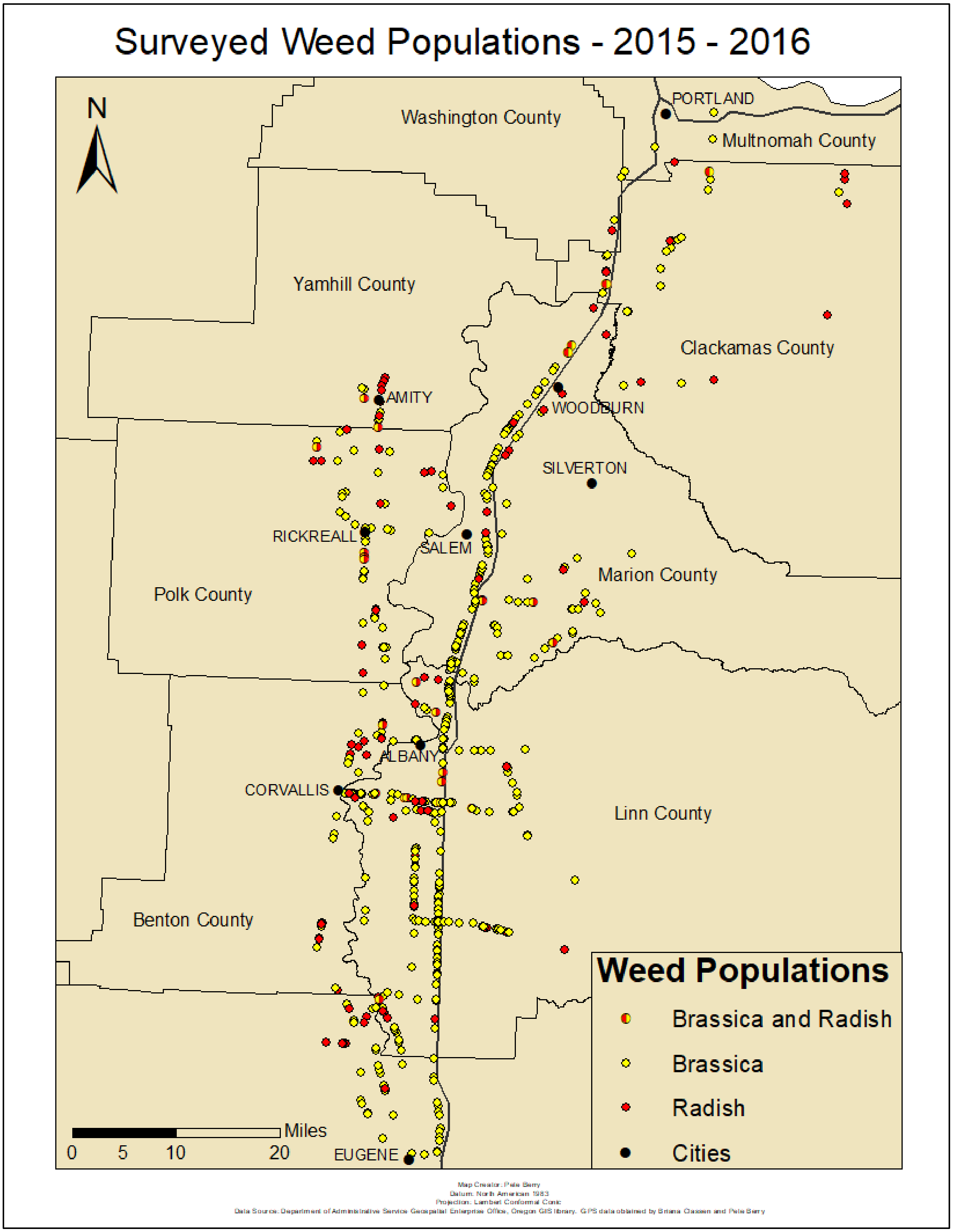


Figure 14. Surveyed weed populations 2015-2016.

Diseases found in surveys of Brassicaceae weeds

Black leg and light leaf spot were detected on weeds in western Oregon, including: birdsrape mustard, black mustard, and wild radish (Claassen 2016; Claassen et al. *in preparation*). The pathogens observed on all weed samples were confirmed by molecular tests. Numerous other weed hosts have been reported for black leg (Rimmer 2007). White leaf spot and light leaf spot have been found on shepherd's purse in Oregon and the UK, respectively, and white rust has been commonly observed on shepherd's purse in western Oregon. We detected a new host for black leg, a weed native to western Oregon, curvepod yellowcress (*Rorippa curvisiliqua*) (Claassen et al. 2017). Surveys during April 2016 along a 333-mile long portion of interstate roadsides in western Oregon showed widespread distribution of Brassicaceae weed populations (Figure 14). A total of 298 Brassicaceae weed populations were mapped and 63 of these populations were surveyed for diseases. Light leaf spot and/or black leg were found at all 63 sites (Claassen 2016). Disease occurred on two weed species, at 61 sites the weed host was birdsrape mustard (*B. rapa)*, and at the other two sites, host plants were wild mustards (*Sinapis* spp.). Weeds infected by *L. maculans* (black leg) were found at 65% of the sites. Light leaf spot was found on weeds at 48% of the sites while both diseases occurred at 30% of the sites. Black leg and light leaf spot were detected on weeds within 20 miles of the Washington border while black leg occurred within 20 miles of the California border (Figure 15). It appears that, *P. brassicae* (light leaf spot) has moved to weed plants along the interstate throughout western Oregon since being introduced and these infected weed populations may potentially act as a long-term reservoir for light leaf spot as well as black leg in the PNW.

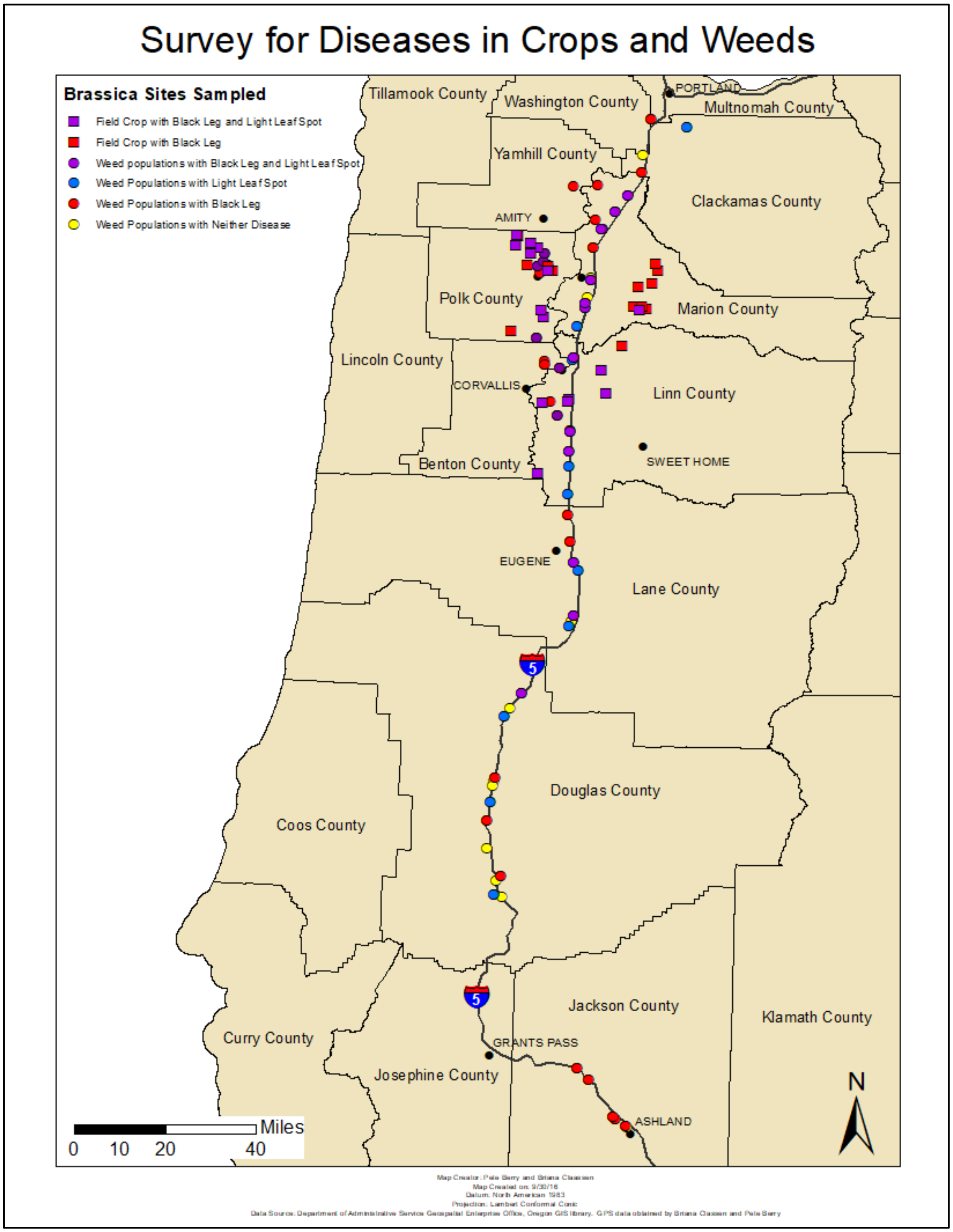


Figure 15. Black leg and light leaf spot detections in Brassicaceae weeds found in a survey of western Oregon roadways.

Monitoring windblown spore infection by black leg via trap plants

The presence of infected plant material on the soil surface after harvest has potentially allowed black leg to infect new plantings in western Oregon through the production of windblown ascospores that may be produced during moist, cool conditions when there are intermittent rain showers and daily mean temperatures around 46-60°F. After widespread epidemics in spring 2014, initial black leg infections in new research fields appeared as leaf spots beginning in October during 2014 through 2016.

Because ascospores are dispersed aerially, trap plants were used to monitor ascospore release from a subset of research fields containing infected crop residues (Figure 15). Turnip plants were grown in pots, individual trap plants were deployed weekly outside of each of seven fields around the beginning of October (Table 21) (Figure 16). Plants were collected and returned to OSU for disease assessments. Leaf spots caused by ascospores of the black leg fungus were observed on trap plants deployed mid-October, and black leg was detected in eight different weekly time periods in the 2014-2015 trapping cycle (data not shown). During the following two growing seasons, multiple trap plants were deployed weekly to research field sites; four trap plants were placed outside of each field. Trap plants began showing black leg symptoms in October or November, depending on the year, and infections continued to develop into April or May (Figure 17). Light leaf spot was detected on trap traps deployed to two sites during late November and early December during 2016, when trap plants underwent a longer incubation period in the greenhouse upon returning from the field. The trap plant deployment and subsequent black leg infections as leaf spots show that infected crop residues in western Oregon can result in repeated intervals of ascopore production throughout the growing season. Onset and occurrence of peak population of ascospores are influenced by rainfall and other environmental conditions when infected crop residues are present on the soil surface. The presence of multiple infectious periods create challenges for controlling black leg in Brassicacea seed crops for as long as infected crop residues are present in the Willamette Valley.

Table 21. Turnip trap plant deployment for monitoring black leg infections in western Oregon.

Start date of weekly trap plant	Ending date of weekly trap plant	Year of harvest	Crop (residues)	# trap plants deployed weekly
1-Oct-14	25-Jun-15	2014	mizuna	1
1-Oct-14	25-Jun-15	2014	kale	1
1-Oct-14	25-Jun-15	2014	canola	1
1-Oct-14	25-Jun-15	2014	canola	1
1-Oct-14	25-Jun-15	2014	turnip	1
1-Oct-14	25-Jun-15	2014	radish	1
1-Oct-14	25-Jun-15	2014	forage rape	1
24-Sep-15	2-Jun-16	2015	canola	4
24-Sep-15	2-Jun-16	2015	turnip	4
24-Sep-15	2-Jun-16	2015	turnip	4
24-Sep-15	2-Jun-16	2014	canola	4
11-Oct-16	9-Jun-17	2014	canola	4
11-Oct-16	9-Jun-17	2016	turnip	4
11-Oct-16	9-Jun-17	2016	turnip	4
11-Oct-16	9-Jun-17	2016	canola	4
11-Oct-16	9-Jun-17	2016	turnip	4

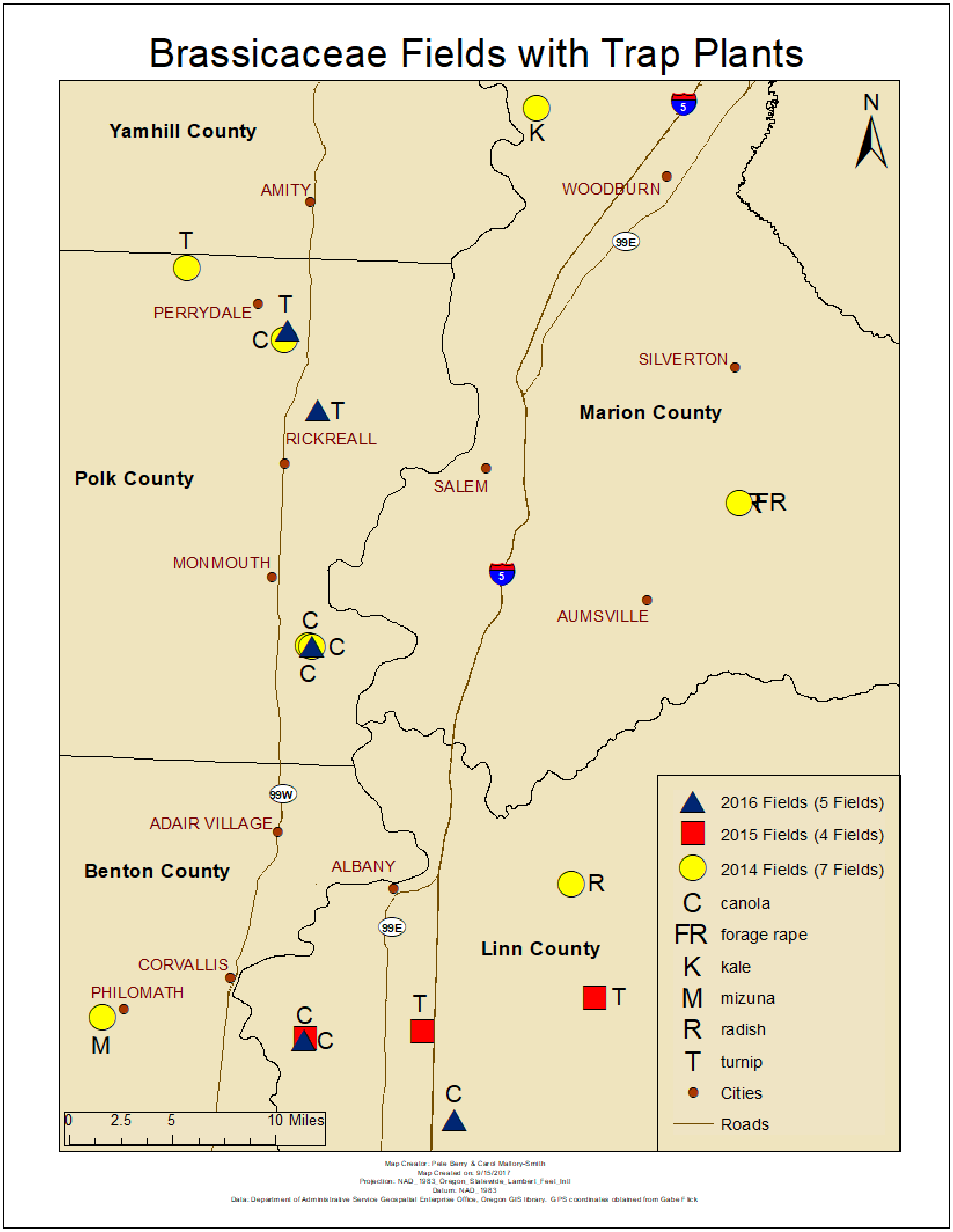


Figure 16. Distribution of trap plants during 2014-2016.

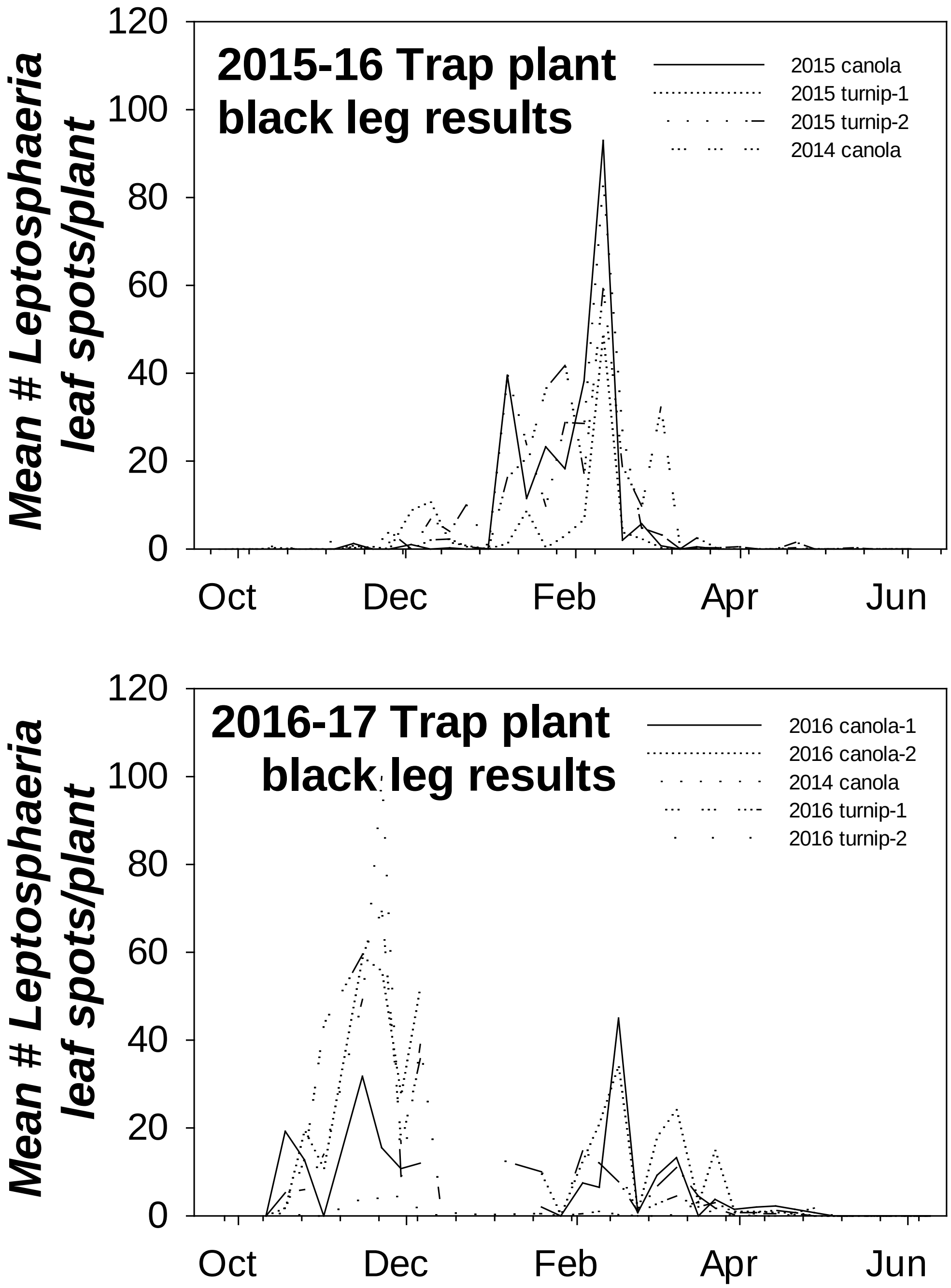


Figure 17. Average number of leaf spots caused by black leg detected on turnip trap plants deployed weekly during the 2015-2016 and the 2016-2017 monitoring cycles. Four trap plants were deployed weekly outside of each field.

Comparison of infected crop residue levels in canola and turnip fields

Because of the results obtained from the trap plants, two canola and two turnip research fields harvested during 2014 were surveyed for the presence of black leg-infected crop residues during February 2016, nearly 20 months after harvest. *Brassica* debris pieces that had any portion on the soil surface were collected. Debris was sampled at 15 points along a V-shaped pattern on one side of each field with approximately 120 ft between sample points. The presence of the black leg fungus on individual pieces of *Brassica* debris was determined in laboratory evaluations. The black leg fungus was observed sporulating on a subset of debris pieces recovered from each of the four commercial fields. Canola had a significantly greater number of debris pieces with black leg fungal sporulation present as well as a greater biomass of black leg-infected crop residues compared to turnip in this preliminary study (Table 22). Cultural practices for the management of residues as well as subsequent crops planted and their associated cultural practices were not accounted for in these fields. Management of black leg-infected *Brassica* debris is crucial through the burial/removal of infected material for *Brassica* producers as well as neighboring growers of *Brassica* crops (Rimmer and van den Berg 2007).

Table 22. Occurrence of black leg on 2014 Brassica crop residues examined in February 2016.

Crop	Total # debris pieces	Mean no. debris pieces with black leg[1]	Mean wt (oz) of air-dried debris with black leg[1]
canola	76	2.6522 a	0.059 a
turnip	28	0.5714 b	0.005 b

[1]Black leg presence was determined by the presence of active sporulation by *Leptosphaeria* sp. Means with different letters are significantly different based on at $P = 0.05$ by Fisher's F-protected Least Significant Difference (LSD) test.

Decomposition of Turnip, Forage Rape, Radish, and Canola Residues in the Willamette Valley

Because blackleg was found on crop residues, a greater understanding of decomposition rates in the Willamette Valley is necessary to determine the impacts residues could have on disease levels. Crop residues and the subsequent decomposition of these residues left in fields after harvest are an important cultural management considerations of agricultural production systems. Conservative tillage (shallow or minimal tillage), flailing (chopping), or leaving untreated residue on the soil surface are common methods for Brassicaceae residue management in the Willamette Valley. Minimal soil disruption using conservative tillage compared with deeper tillage is used to reduce the potential for Brassicaceae seeds to survive in soil (Quick 1961, Long et al. 2015). Deep tillage (plowing) buries residues and crop seeds and could lead to volunteers occurring for years if seeds are brought back to the soil surface (Schneider et al. 2006).

Canola, forage rape, turnip, and radish seed crops have between 5,500 and 7,000 pounds of residue per acre remaining after seed harvest. With shallow tilling, flailing or leaving residue untreated, substantial amounts of residue are left on the soil surface. In Canada, where similar practices have been adopted and canola is produced on greater acreages, increased crop residue on the soil surface led to increased plant disease pressure (Schneider et al. 2006). The plant fungal pathogens that cause black leg and Sclerotinia stem rot, if present on residues, can infect adjacent and subsequent plantings during future growing seasons.

Due to potential for plant pathogen to remain on infected crop residues and how diseases may be related to residue management, a study was conducted to compare the decomposition of canola, forage rape, turnip, and radish. The study evaluated: a) the decomposition of Brassicaceae seed crop residue under standard management practices in the Willamette Valley and b) whether there were differences between the decomposition of canola and other commonly produced Brassicaceae seed crops.

Methods

Study fields included 2014 fall planted turnip, forage rape, and two canola fields with acreages of 30, 95, 60, and 70, respectively, and 2015 fall planted forage rape and radish fields with acreages of 100 and 75, respectively (Figure 18). During both years, the fields were planted, managed, and harvested by the growers. In 2015, an additional study was established at the OSU Hyslop Research Farm near Corvallis where turnip, canola, and radish fields were planted to expand the research on Brassicaceae crop residue decomposition.

After harvest in the summers of 2015 and 2016, fields with residue and stubble were left untreated. The study design was a randomized strip-plot block with four replications. Treatments consisted of shallow tillage, flailing, and untreated. Each plot was 15 by 30 ft. Residue was randomly collected after treatments were applied and placed in nylon mesh bags. The bags were weighed and placed back in the field on top of the soil or 2.5 inches below the soil surface. The samples were collected each month for 12 months, washed, dried and re-weighed to determine mass loss. The rate of decomposition was determined using an exponential decay rate standard equation and analyzed using a t-test and a one-way ANOVA (Berg and McClaugherty 2003).

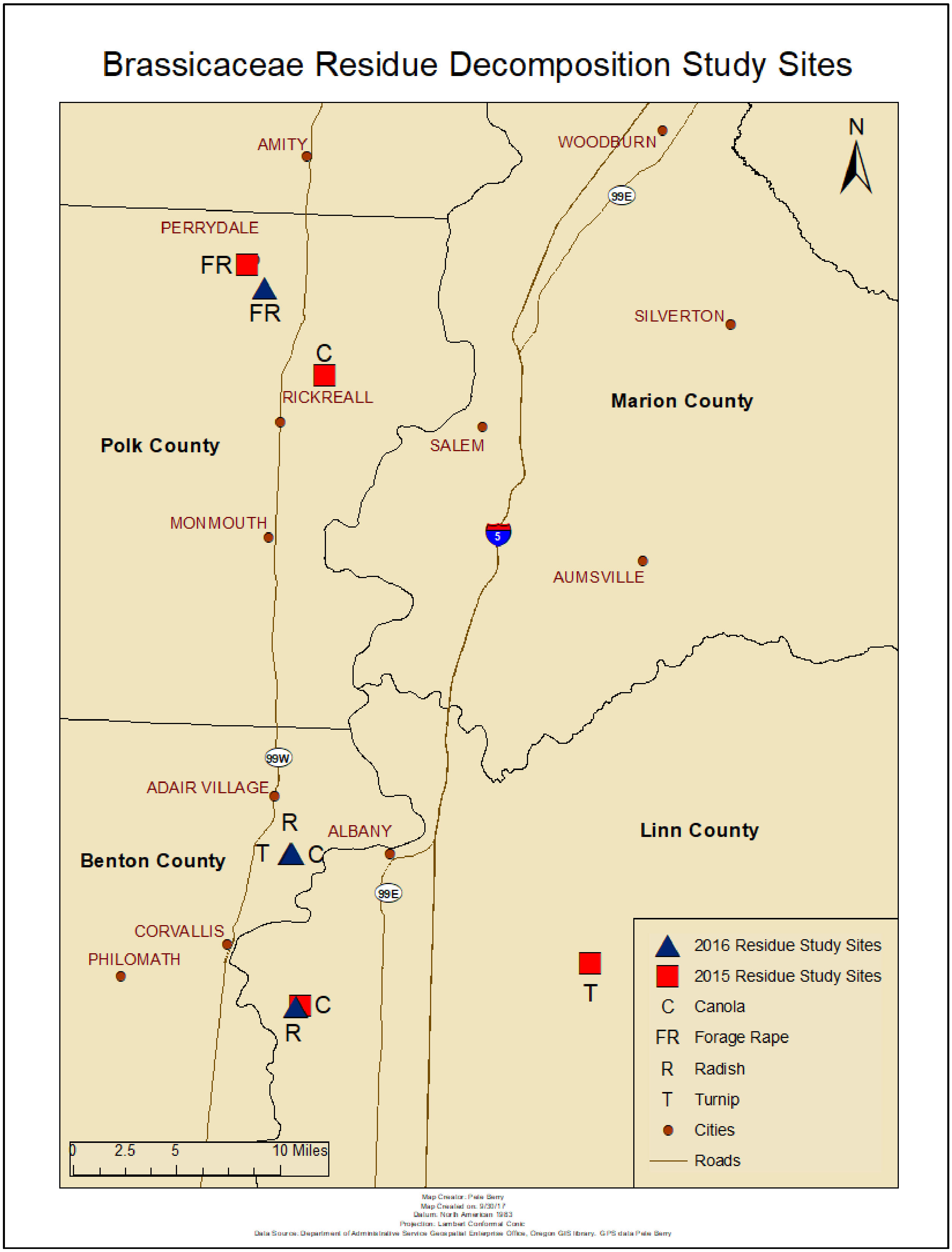


Figure 18. Locations of Brassicaceae decomposition studies in 2015 and 2016

Results

Flailing or shallow tillage did not accelerate aboveground residue decomposition compared with the control (untreated) at different sites (Figure 19). The results of the two years were similar so only results from 2016-2017 are shown (data for 2015-2016 available upon request).

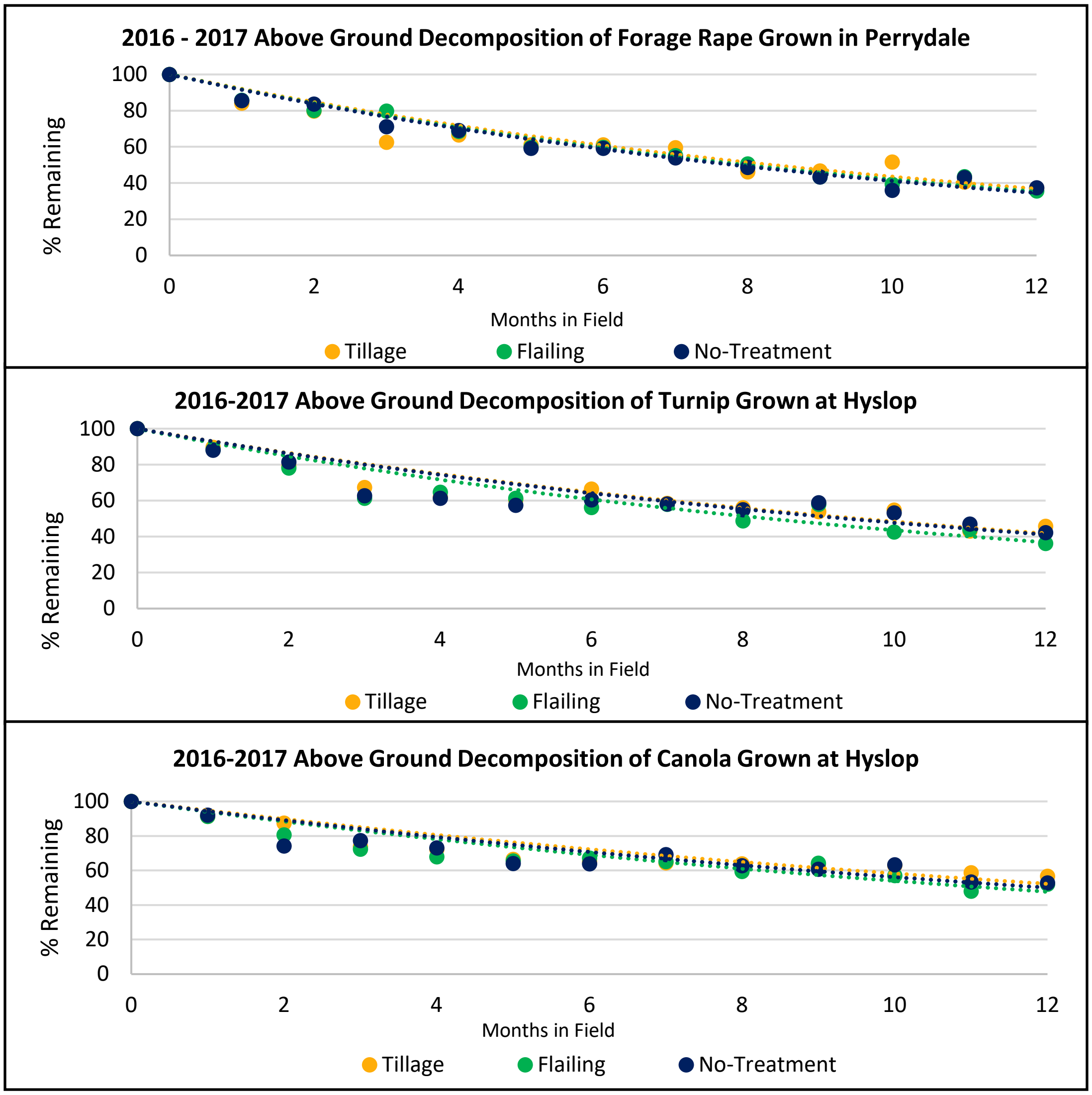


Figure 19. 2016-2017 decomposition of forage rape, turnip, and canola under different tillage treatments. There were no statistically significant differences between treatments (ANOVA, p-value < 0.05).

Radish residue decomposed more quickly with tillage when either left on the soil surface or buried compared with either flailing or untreated in the 2016-2017 Hyslop trial (Figure 20).

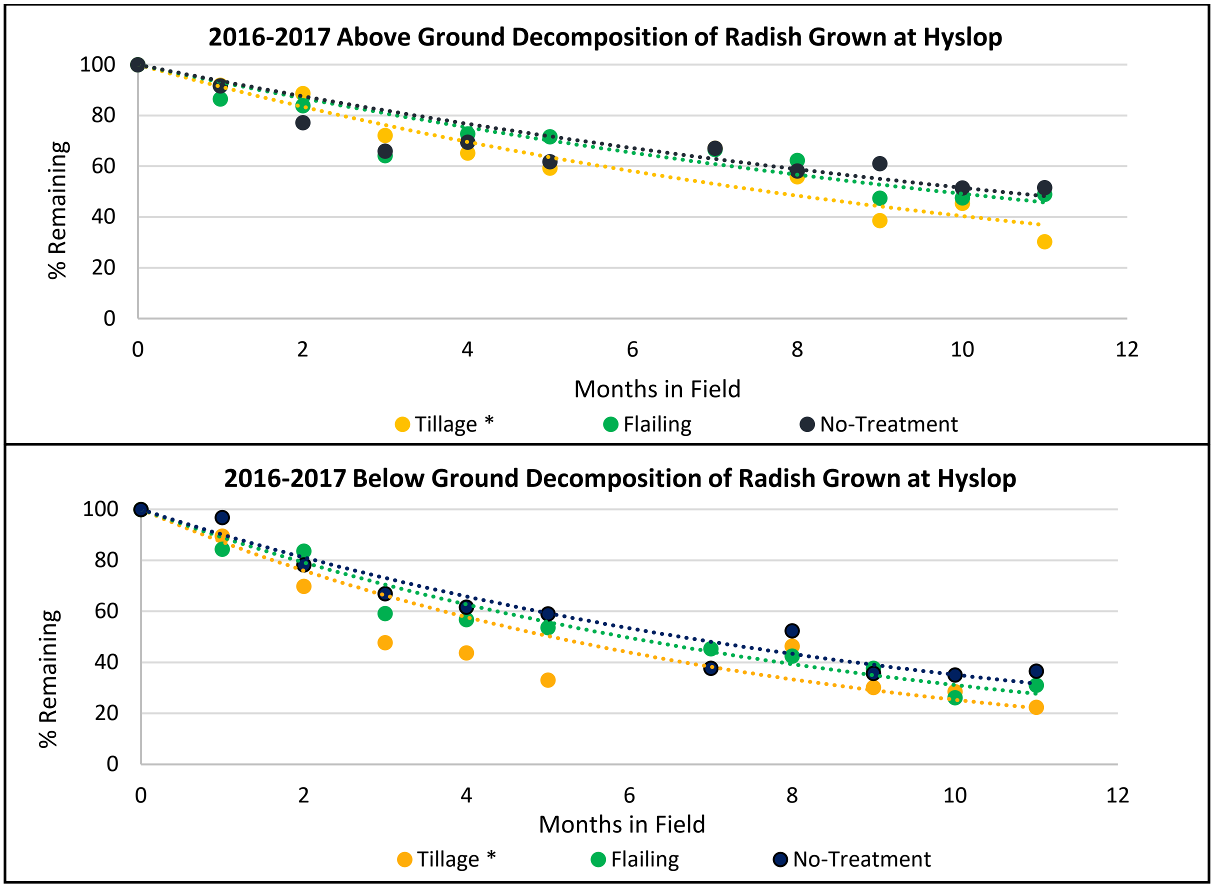


Figure 20. 2016-2017 decomposition of radish under different tillage treatments. *Statistically significant differences occurred between tillage and the other treatments in both above ground and below ground residue placement (ANOVA, p-value < 0.05).

Rates of decomposition between residue on the soil surface and buried residue showed on average that buried residue decomposed at a greater rate (Table 23). Turnip and radish residues that were buried decomposed at a greater rate compared with residues left on the soil surface for each treatment. There was no difference between the below ground and above ground decomposition of forage rape for any treatment in either year. Canola decomposed at a greater rate below ground compared to above ground except there was no difference in decomposition between flailed residue placed on the soil surface and buried in the 2016-2017 trial.

Table 23. Average percent decomposition of canola, forage rape, turnip, and radish residue left on the soil surface and residue buried 2.5 inches after 12 months. * Statistically significant differences between above ground and below ground decomposition treatments (T-test, p-value<0.05).

% Residue Remaining by Treatment After 12 Months							
Canola *				**Turnip ***			
	Above	**Below**	**% Change**		**Above**	**Below**	**% Change**
Tillage	49%	34%	15%	**Tillage**	52%	37%	15%
Flailing	46%	30%	16%	**Flailing**	59%	34%	26%
No-Treatment	46%	29%	16%	**No-Treatment**	56%	35%	20%
Forage Rape				**Radish ***			
	Above	**Below**	**% Change**		**Above**	**Below**	**% Change**
Tillage	39%	38%	1%	**Tillage**	30%	22%	8%
Flailing	37%	34%	2%	**Flailing**	49%	31%	18%
No-Treatment	39%	35%	5%	**No-Treatment**	52%	37%	15%

There were no differences for above ground decomposition of turnip, canola, and forage rape whether tilled or flailed when combining the 2015 and 2016 field data for those crops. The tilled residues of radish and turnip left on the soil surface had increased decomposition compared to canola during the 2016-2017 Hyslop experiment. There was no difference in decomposition between crops when flailed residues were left on the soil surface. Canola and forage rape had similar rates of decomposition of the below ground residues for all the treatments. Radish and turnip had increased rates of decomposition compared with canola and forage rape for each below ground treatment and radish had an increased rate of decomposition in the tillage treatment compared to turnip.

Canola, forage rape, and turnip residue decomposition on the soil surface was not altered by the tillage treatments. Canola and forage rape residues buried below ground also was not altered by different tillage treatments. Literature suggests smaller residue pieces decompose faster (Vigil et al. 1995, Iqbal et al. 2014). However, this was not the case in this study in the Willamette Valley where flailed residue did not increase the rate of decomposition compared with the untreated residue. Some studies conducted in non-agricultural environments include smaller residue pieces such as leaves which readily degrade compared with the structural plant materials, hemi-cellulose, cellulose, and lignin (Berg and McClaugherty 2003). For the crops in this study, leaves were fully senesced prior to harvest. Therefore, the primary type of residue remaining on the field was structural, limiting rapid decomposition in any of the treatments. The environment in the Willamette Valley can limit the time of year when decomposition occurs. The hot dry summers limit microbial decomposition due to limited precipitation, preventing diffusion of microbes to residue. The wet, cool months can create saturated soils which limit oxidation reactions by aerobic microbes and the cool temperatures can slow the activity of many microbes. There was little decomposition from October 15, 2016, through April 15, 2017, demonstrating the impacts wet, cool winters can have on decomposition in the Willamette Valley (Figure 21). The combination of primarily structural plant material and water saturated soils likely limited observable differences between treatments and in some cases, crops.

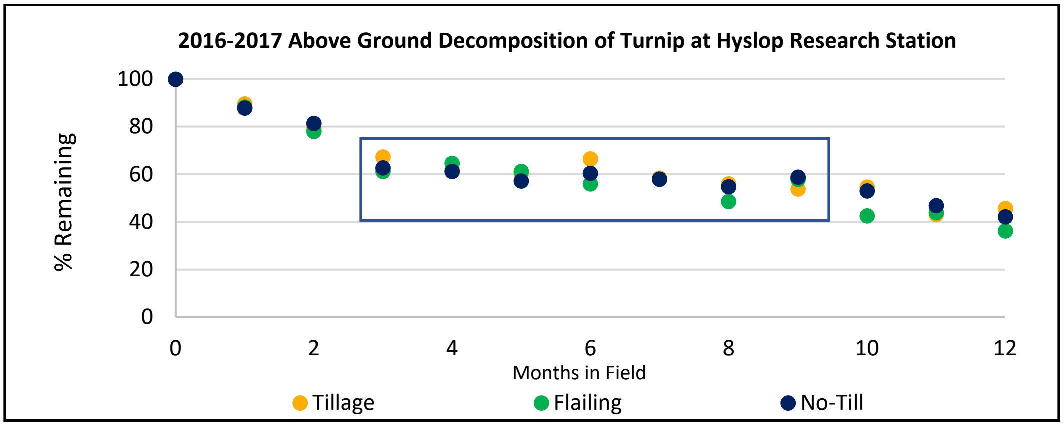


Figure 21. Aboveground decomposition of turnip at the Hyslop research station from July 2016 through July 2017. Dates covered in box October 15, 2016, through April 15, 2017.

In both the above ground and below ground treatments, tilled radish residue decomposed at a faster rate compared to residue in the untreated and flailed treatments. The increase in decomposition is likely due to the large storage roots of radish becoming accessible to microbial degradation when they were brought to the soil surface. The reduced rates of decomposition of forage rape and canola compared to the other crops when placed below-ground is likely because they are structurally different from turnip and radish. Preliminary results indicate forage rape and canola plant parts contain higher levels of lignin compared with turnip and radish (Berry unpublished), which decomposes slower than other plant material.

Conclusions

Results of our study show forage rape, canola, and turnip residue decomposition after 12 months are not affected by common tillage practices, and there was little difference in the rates of decomposition between these crops when left on the soil surface. The results indicate that burying residue increased the rates of decomposition compared to leaving residue on the surface. With this knowledge, it seems appropriate that growers bury residue. The increased rate of decomposition that occurs when residue is buried can reduce pathogen pressure as greater amounts of infected crop residues would be degraded. In addition, blackleg ascospores only appear if infected debris is exposed to solar radiation (Schneider et al. 2006). Infected residues as small as 0.08 inches can produce blackleg ascospores and once buried, growers should limit bringing residue back to the surface to reduce infected residues from releasing ascospores (Sosnowski et al. 2006). Growers that produce Brassicaceae crops are encouraged to rotate the crop every four years to limit blackleg infection due to residues that remain from previous crops (Kutcher et al. 2013).

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ATTACHMENTS 1-2
HB 2427 and HB 3382

Enrolled

House Bill 2427

Sponsored by Representative GELSER, Senator EDWARDS, Representative HOYLE; Representatives BARNHART, HOLVEY, NATHANSON, TOMEI (Presession filed.)

CHAPTER ....

AN ACT

Relating to canola; appropriating money; and declaring an emergency.

Be It Enacted by the People of the State of Oregon:

SECTION 1. (1) As used in this section:

(a) "Canola" means plants of the genus Brassica:

(A) In which seeds having a high oil content are the primary economically valuable product; and

(B) That have a high erucic acid content suitable for industrial uses or a low erucic acid content suitable for edible oils.

(b) "Raising" means personal or commercial growing for oil, seed, forage, cover crop or other use.

(c) "Willamette Valley Protected District" means the area encompassed within a rectangle formed by the point in Tillamook County that is the northwest corner of township 1 north, range 6 west, the point in Multnomah County that is the most northeastern point of township 1 north, range 2 east within Oregon, the point in Lane County that is the southeast corner of township 19 south, range 2 east and the point in Lane County that is the southwest corner of township 19 south, range 6 west.

(2) The amount of canola planted per year within the Willamette Valley Protected District may not exceed 500 acres. Any canola grown within the protected district must be grown for the purpose of allowing the College of Agricultural Sciences of Oregon State University to carry out the research duties of the college under section 4 of this 2013 Act. Any growing of canola within the protected district is subject to prior approval by the State Department of Agriculture.

(3) The department may assess a civil penalty, not to exceed $25,000, against a person that raises canola in violation of subsection (2) of this section.

SECTION 2. Section 1 of this 2013 Act applies to the growing of canola planted on or after the effective date of this 2013 Act.

SECTION 3. Section 1 of this 2013 Act is repealed on January 2, 2019.

SECTION 4. (1) As used in this section, "Willamette Valley Protected District" has the meaning given that term in section 1 of this 2013 Act.

(2) Subject to the Willamette Valley Protected District production cap established in section 1 (2) of this 2013 Act, the State Department of Agriculture may authorize the growing of canola to allow the College of Agricultural Sciences of Oregon State University to carry out the research duties of the college under this section. Any authorization for the

growing of canola under this section must be limited to canola crop production cycles that are completed prior to January 1, 2017.

(3) Canola may be grown for purposes of research under this section only if the isolation distance between the canola and other crops equals or exceeds the industry-recommended isolation distance between Brassica specialty seed crops and other crops.

(4)(a) The college shall use field monitoring and other research to develop information and recommendations regarding whether, and under what conditions, canola growing in the Willamette Valley Protected District is compatible with the growing of other crops. The information must include, but not be limited to, a comparison of the compatibility of canola with the growing of other crops to the compatibility of other Brassica seed with the growing of other crops. The assessment shall include, but not be limited to, a review of available published materials and historical data on canola and Brassica specialty seed production.

(b) In addition to any other required content, the information and recommendations described in paragraph (a) of this subsection must include, but not be limited to, a map of the Willamette Valley Protected District showing the places within the district where plants of the genus Brassica could be grown while maintaining typical isolation distances from vegetables, vegetable seeds and other crops.

(5) All research described in subsection (4) of this section must be peer reviewed.

(6) The college shall complete its research under this section and submit a report containing information and recommendations as described in subsection (4) of this section to an interim committee of the Legislative Assembly dealing with agriculture no later than November 1, 2017.

SECTION 5. To the extent that the College of Agricultural Sciences of Oregon State University deems practicable, the college shall conduct field monitoring on the acreage that has been used to grow canola for purposes of research under section 4 of this 2013 Act, and on adjacent lands used for the research, for a period of five years after completing the research. Monitored areas adjacent to the acreage that has been used to grow canola must include, but need not be limited to, fields planted in forage turnip seed crops, tillage radish seed crops and Brassica specialty seed crops. Any monitoring of acreage that has been used to grow canola or of fields planted in forage turnip seed and radish seed crops must include monitoring for volunteer plants, diseases and insects. Any monitoring of fields planted with Brassica specialty seed crops, other than acreage that has been used to grow canola, must include monitoring for diseases and insects.

SECTION 6. In addition to and not in lieu of any other appropriation, there is appropriated to the Oregon Department of Administrative Services for allocation to the Oregon University System, for the biennium beginning July 1, 2013, out of the General Fund, the amount of $679,000, which may be expended for carrying out the duties of the College of Agricultural Sciences of Oregon State University under sections 4 and 5 of this 2013 Act.

SECTION 7. This 2013 Act being necessary for the immediate preservation of the public peace, health and safety, an emergency is declared to exist, and this 2013 Act takes effect on its passage.

Passed by House June 25, 2013

....
Ramona J. Line, Chief Clerk of House

....
Tina Kotek, Speaker of House

Passed by Senate July 1, 2013

....
Peter Courtney, President of Senate

Received by Governor:

........................M.,.., 2013

Approved:

........................M.,.., 2013

....
John Kitzhaber, Governor

Filed in Office of Secretary of State:

........................M.,.., 2013

....
Kate Brown, Secretary of State

Enrolled
House Bill 3382

Sponsored by Representatives WITT, CLEM; Representatives HUFFMAN, KRIEGER, MCKEOWN, REARDON, SPRENGER, WHISNANT, Senators HANSELL, OLSEN, ROBLAN, THOMSEN

CHAPTER ....

AN ACT

Relating to canola in the Willamette Valley Protected District; creating new provisions; and amending sections 3, 4 and 5, chapter 724, Oregon Laws 2013.

Be It Enacted by the People of the State of Oregon:

SECTION 1. **(1) As used in this section:**

(a) "Canola" means plants of the genus Brassica:

(A) In which seeds having a high oil content are the primary economically valuable product; and

(B) That have a high erucic acid content suitable for industrial uses or a low erucic acid content suitable for edible oils.

(b) "Willamette Valley Protected District" means the area encompassed within a rectangle formed by the point in Tillamook County that is the northwest corner of township 1 north, range 6 west, the point in Multnomah County that is the most northeastern point of township 1 north, range 2 east within Oregon, the point in Lane County that is the southeast corner of township 19 south, range 2 east and the point in Lane County that is the southwest corner of township 19 south, range 6 west.

(2) Notwithstanding sections 1, 2 and 4, chapter 724, Oregon Laws 2013, the State Department of Agriculture may authorize the growing of canola within the Willamette Valley Protected District for commercial purposes as provided in this section. The amount of canola planted under this section within the Willamette Valley Protected District may not exceed 500 acres per year.

(3) The College of Agricultural Sciences of Oregon State University shall use the results of research and field monitoring conducted under sections 4 and 5, chapter 724, Oregon Laws 2013, and any information or recommendations developed under those sections, to identify acreages on which canola may be grown within the Willamette Valley Protected District in a manner that is compatible with the growing of other crops, including but not limited to, the maintenance of isolation distances between the canola and other crops that equals or exceeds the industry-recommended isolation distance between specialty seed crops of the genus Brassica and other crops.

(4) Any growing of canola within the protected district is subject to prior approval by the department. The department may authorize the growing of canola under this section only:

(a) On acreages identified by the college under subsection (3) of this section that were not used for growing canola under chapter 724, Oregon Laws 2013;

(b) In a manner that the college has determined to be compatible with the growing of other crops; and

(c) Under the same conditions that the college imposed by contract for growing canola under chapter 724, Oregon Laws 2013.

(5) Any authorization for the growing of canola under this section must be limited to canola crop production cycles that begin on or after July 1, 2016, and are completed no later than December 31, 2019. The growing of canola in a canola crop production cycle that begins after July 1, 2019, is not subject to this section.

(6) The department may assess a civil penalty, not to exceed $25,000, against a person that raises canola in violation of the terms of any authorization issued to the person under this section.

<u>**SECTION 2.**</u> **(1) The State Department of Agriculture shall develop recommendations regarding means for ensuring the coexistence of the production of canola and the production of other agricultural crops. The recommendations shall include, but need not be limited to, means for providing protections adequate to maintain the unique attributes of the specialty seed industry in this state. The department shall develop the recommendations based upon the information and recommendations reported by the College of Agricultural Sciences of Oregon State University under section 4, chapter 724, Oregon Laws 2013.**

(2) The department shall report the recommendations developed by the department under subsection (1) of this section in the manner provided by ORS 192.245, and may provide recommendations for legislation, to an interim committee of the Legislative Assembly dealing with agriculture no later than November 15, 2018.

<u>**SECTION 3.**</u> **Section 1 of this 2015 Act is repealed January 2, 2020.**

<u>**SECTION 4.**</u> Section 3, chapter 724, Oregon Laws 2013, is amended to read:

Sec. 3. Section 1 [*of this 2013 Act*]**, chapter 724, Oregon Laws 2013,** is repealed on [*January 2*] **July 1**, 2019.

<u>**SECTION 5.**</u> Section 4, chapter 724, Oregon Laws 2013, is amended to read:

Sec. 4. (1) As used in this section, "Willamette Valley Protected District" has the meaning given that term in section 1**, chapter 724, Oregon Laws 2013** [*of this 2013 Act*].

(2) Subject to the Willamette Valley Protected District production cap established in section 1 (2)**, chapter 724, Oregon Laws 2013** [*of this 2013 Act*], the State Department of Agriculture may authorize the growing of canola to allow the College of Agricultural Sciences of Oregon State University to carry out the research duties of the college under this section. Any authorization for the growing of canola under this section must be limited to canola crop production cycles that are completed prior to January 1, 2017.

(3) Canola may be grown for purposes of research under this section only if the isolation distance between the canola and other crops equals or exceeds the industry-recommended isolation distance between Brassica specialty seed crops and other crops.

(4)(a) The college shall use field monitoring and other research to develop information and recommendations regarding whether, and under what conditions, canola growing in the Willamette Valley Protected District is compatible with the growing of other crops. The information must include, but not be limited to, a comparison of the compatibility of canola with the growing of other crops to the compatibility of other Brassica seed with the growing of other crops. **The college shall submit the information for review by experts having sufficient knowledge of vegetable seed production to provide a thorough and proper evaluation of the quality, significance and originality of the research.** The assessment shall include, but not be limited to, a review of available published materials and historical data on canola and Brassica specialty seed production **from northern France and from England and New Zealand and a review of how western Washington, western Idaho and central and eastern Oregon manage canola for seed production**.

(b) In addition to any other required content, the information and recommendations described in paragraph (a) of this subsection must include, but not be limited to, a map of the Willamette

Valley Protected District showing the places within the district where plants of the genus Brassica could be grown while maintaining typical isolation distances from vegetables, vegetable seeds and other crops.

(5) All research described in subsection (4) of this section must be peer reviewed.

(6) The college shall [*complete its research under this section and*] submit a report containing **preliminary study** information and recommendations as described in subsection (4) of this section to an interim committee of the Legislative Assembly dealing with agriculture no later than November 1, 2017.

SECTION 6. Section 5, chapter 724, Oregon Laws 2013, is amended to read:

Sec. 5. (1) To the extent that the College of Agricultural Sciences of Oregon State University deems practicable, the college shall conduct field monitoring**:**

(a) On the acreage that has been used to grow canola for purposes of research under section 4 [*of this 2013 Act, and*]**, chapter 724, Oregon Laws 2013;**

(b) On the acreage that has been used to grow canola for commercial purposes under section 1 of this 2015 Act; and

(c) On [*adjacent*] lands **adjacent to acreage** used for the research **under section 4, chapter 724, Oregon Laws 2013, or used for commercial purposes under section 1 of this 2015 Act**, for a period of five years after completing the research **under section 4, chapter 724, Oregon Laws 2013**.

(2) Monitored areas adjacent to the acreage that has been used to grow canola must include, but need not be limited to, fields planted in forage turnip seed crops, tillage radish seed crops and Brassica specialty seed crops. Any monitoring of acreage that has been used to grow canola or of fields planted in forage turnip seed and radish seed crops must include monitoring for volunteer plants, diseases and insects. Any monitoring of fields planted with Brassica specialty seed crops, other than acreage that has been used to grow canola, must include monitoring for diseases and insects.

Passed by House April 17, 2015

Repassed by House June 22, 2015

....
Timothy G. Sekerak, Chief Clerk of House

....
Tina Kotek, Speaker of House

Passed by Senate June 17, 2015

....
Peter Courtney, President of Senate

Received by Governor:

........................M.,..., 2015

Approved:

........................M.,..., 2015

....
Kate Brown, Governor

Filed in Office of Secretary of State:

........................M.,..., 2015

....
Jeanne P. Atkins, Secretary of State

ATTACHMENT 3

Oregon State University Research Proposal

Research Proposal Submitted in Response to Request in HB2427

The following are summary points of research on Brassicacea, the mustard family which includes both *Brassica* and *Raphanus* (radish) species, proposed by Oregon State University. The outcome of this research will be to provide data for the legislative process on the production of canola for seed within the Willamette Valley and to determine if canola should be regulated differently than the other Brassicacea species. In order to conduct a valid scientific study with defendable results, all of the elements need to be included. Our null hypothesis for this work will be that if there are no significant differences in pest incidence or volunteer plant occurrence among radish, turnip and canola fields of similar size, then these crops should be treated equitably in any regulatory processes.

The success of the research will depend upon: 1) cooperation from the Willamette Valley Specialty Seed Association (WVSSA) and the Willamette Oilseed Producers Association; 2) availability of acres in the control area for canola production; 3) access to current interactive pinning maps and supporting data are required in order to select canola field locations and follow Brassicaceae production over time. Without these items the work cannot be done successfully and should not be done.

Objectives:

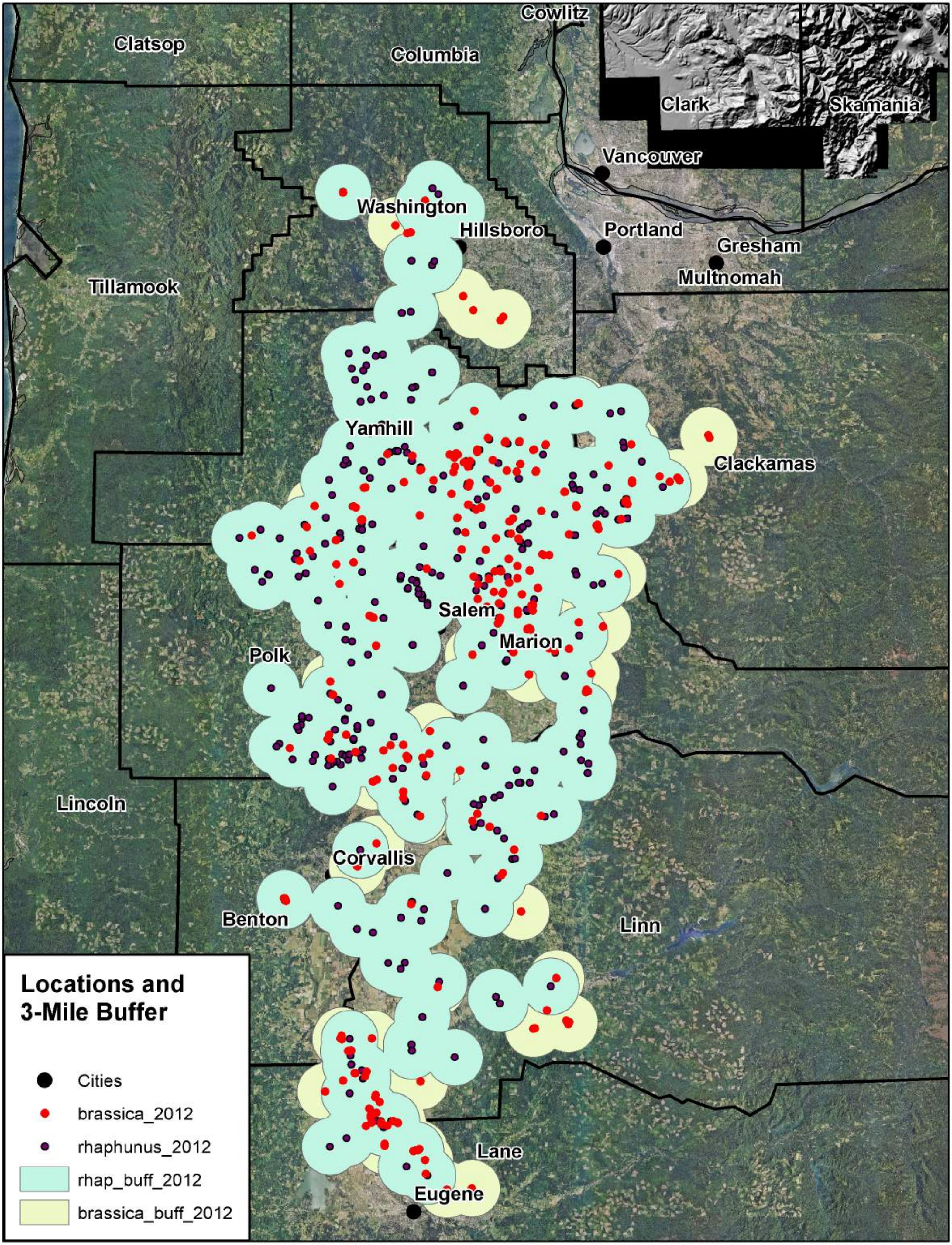
Objective 1. Conduct a comprehensive literature review of Brassicacea production.

Objective 2. Monitor 5 fields of canola, turnip, and radish over 3 years. Fields would be 50 to 100 acres in size (maximum of 500 acres within the control area with 500 acres outside of control area). In order to ensure research results, at least 8 fields of canola would need to be planted in each year. Fields have been lost in the past due to winter injury or poor stands and the additional fields are required to ensure that there are 5 suitable test locations. Similar sized canola, turnip and radish fields will be monitored for diseases, insects and volunteers in subsequent crops. In addition, *Brassica* specialty seed fields will be monitored for diseases and insects. Field margins and roadsides will be monitored for off field movement of canola, turnip, and radish. Monitoring will continue for all research fields for 3 years; thus in year 3, 45 fields will be monitored. This objective will require on-going cooperation from specialty seed growers for access to fields of radish, turnip and *Brassica* specialty seed crops.

Objective 3. Map the Willamette Valley for available acres to determine how many acres of Brassicacea species can be grown (including typical isolation distances) and still maintain the viability of the specialty seed industry. Mapping will require access to data held by the WVSSA. Data needed from the WVSSA includes number of acres of each variety and location of fields that have produced a Brassicaeae crop in the past 5 years and the 3 years of this project. The increase or decrease of Brassicacea crops during this period will provide insight into what the growth potential in acres of those crops is in the near future. In order to reduce the budget for this objective, we will need full cooperation from the WVSSA for use of the pinning map programs already produced by OSU, ODA and WVSSA.

ATTACHMENTS 4-9

Willamette Valley Specialty Seed Association Maps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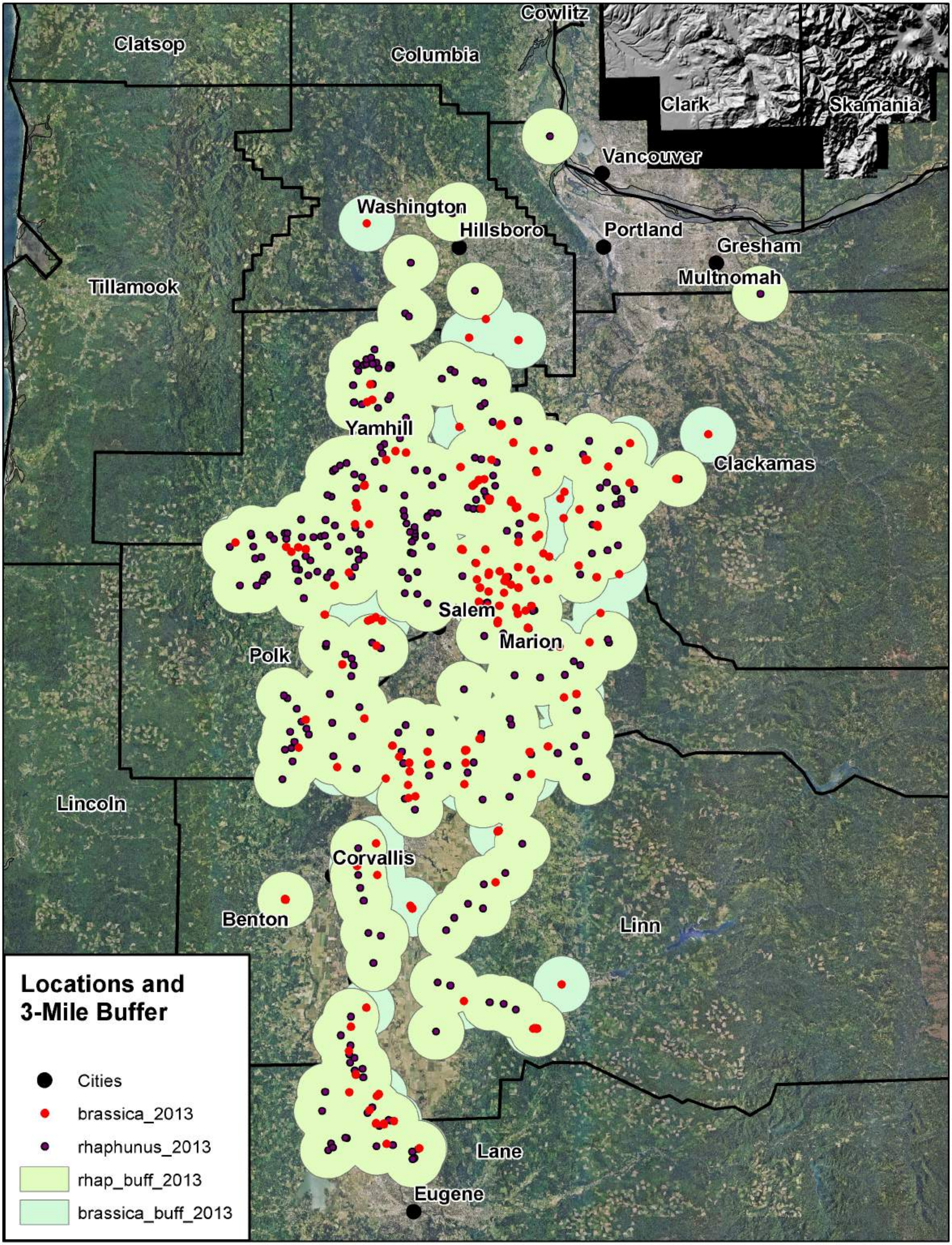
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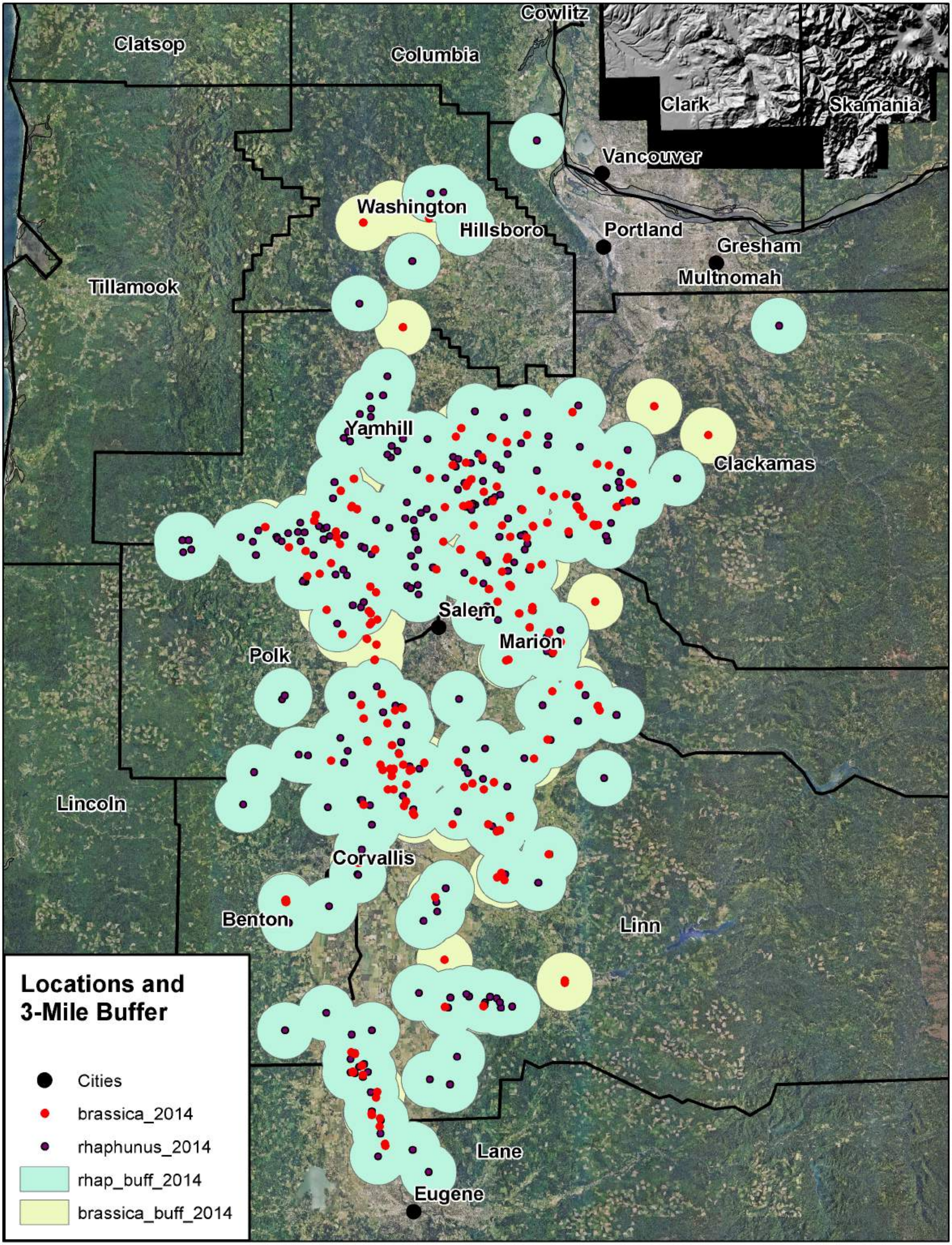
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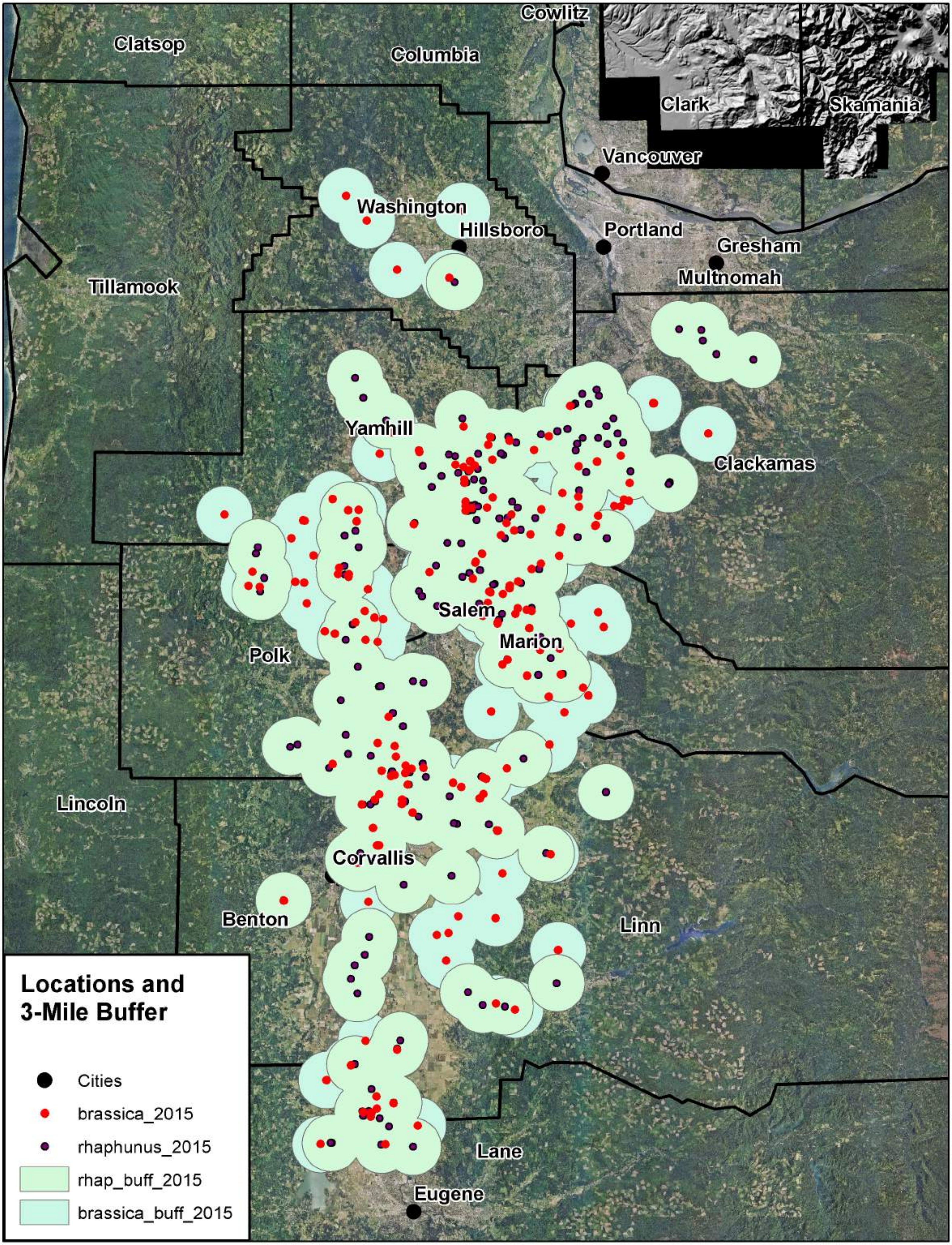
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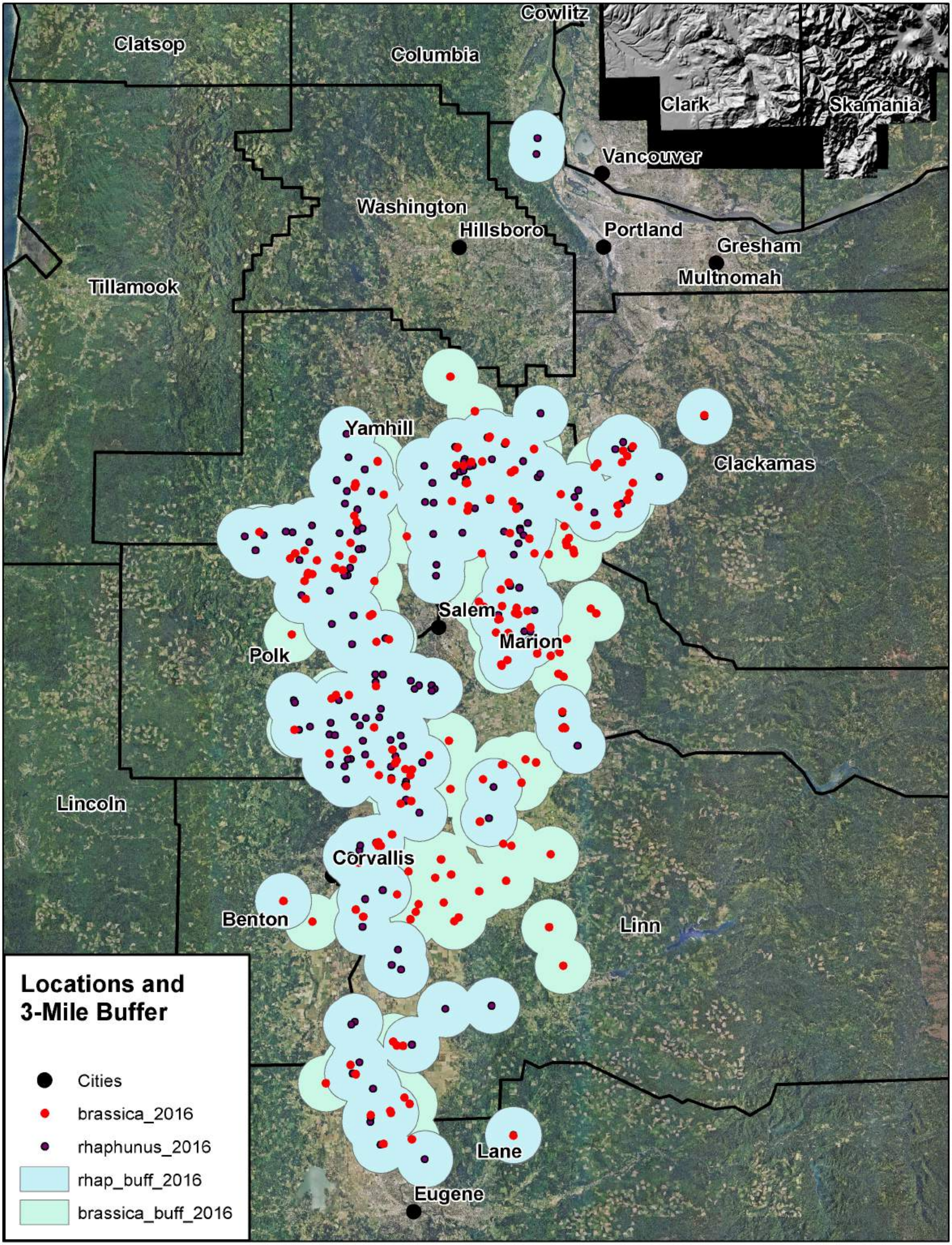
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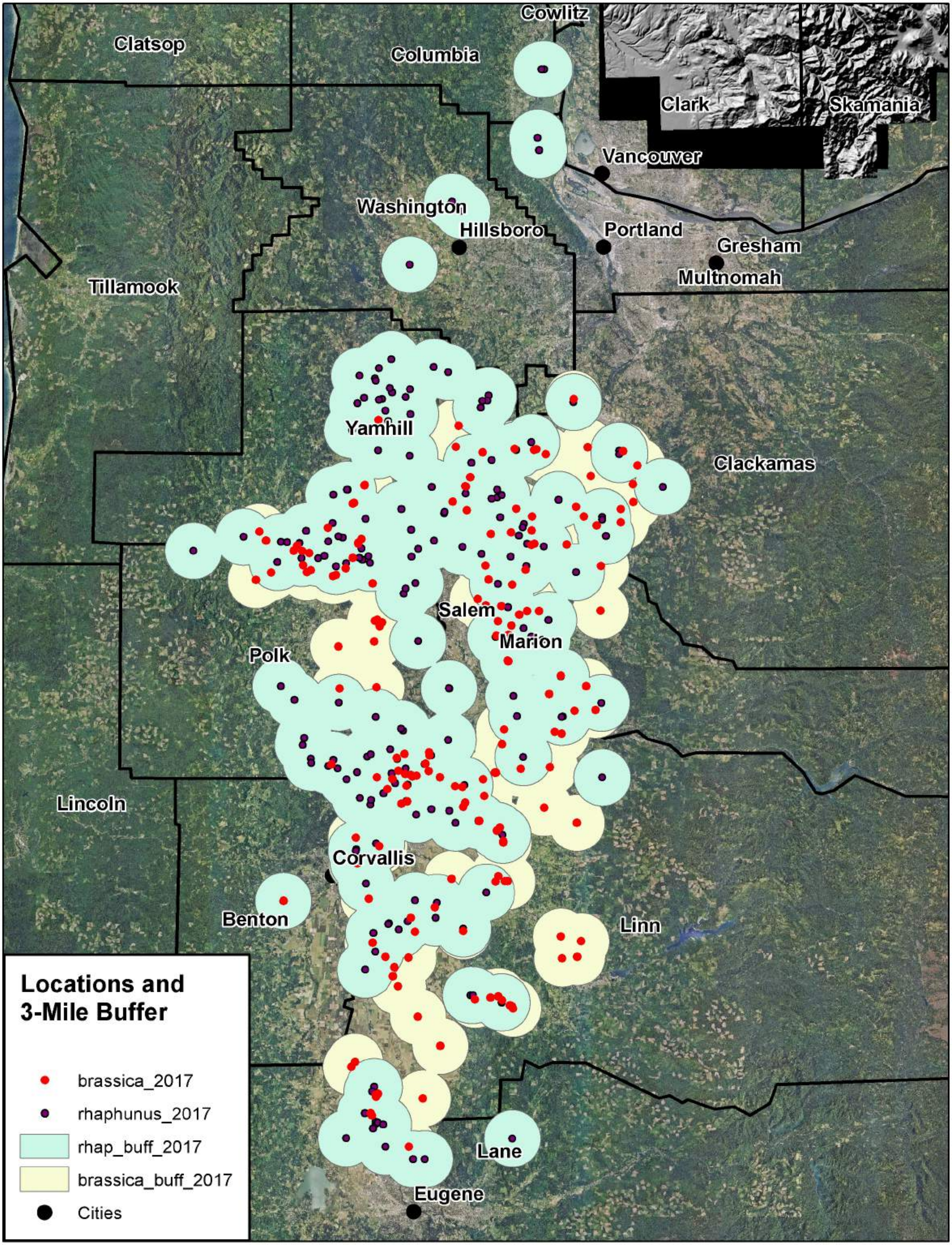

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ATTACHMENT 10

Letter from Governor Kitzhaber

JOHN A. KITZHABER, MD
Governor

August 14, 2013

The Honorable Kate Brown
Secretary of State
136 State Capitol
900 Court Street, NE
Salem, OR 97301

Dear Secretary Brown:

Today, I have signed Enrolled House Bill 2427 relating to canola and I am writing to express my expectations regarding implementation of the bill. As you know, this legislation directs Oregon State University (OSU) and the Oregon Department of Agriculture to conduct further research regarding the effects of growing canola in the Willamette Valley. In particular, section 4 of this bill requires OSU to conduct research that will require the cooperation of the Willamette Valley Specialty Seed Association (WVSSA) and its members. The elements of that required cooperation are set out in the "Cooperative Agreement on Canola Research Principles/Issues," between OSU, ODA and the WVSSA.

The public record for HB 2427 includes the Research proposal submitted by OSU in conjunction with this legislation. As taken directly from the proposal, "The outcome of this research will be to provide data for the legislative process on the production of canola for seed within the Willamette Valley and to determine if canola should be regulated differently than the other Brassicacea species. In order to conduct a valid scientific study with defendable results, all of the elements need to be included. Our null hypothesis for this work will be that if there are no significant differences in pest incidence or volunteer plant occurrence among radish, turnip and canola fields of similar size, then these crops should be treated equitably in any regulatory processes." The specific objectives for the research include:

1. Conduct a comprehensive literature review of Brassicacea production;
2. Monitor 5 fields of canola, turnip and radish over 3 years. This objective will require on-going cooperation from specialty seed growers for access to fields of radish, turnip and Brassica specialty seed crops;
3. Map the Willamette Valley for available acres to determine how many acres of Brassicacea species can be grown and still maintain the viability of the specialty seed industry. Mapping with require access to data held by the WVSSA.

It is my expectation in signing this legislation that the WVSSA and its members will cooperate in the specified manner. If that cooperation is not forthcoming, I will work with interested legislators to resolve conflicts between the specialty seed industry and canola growers,

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WWW.OREGON.GOV

recognizing that the specialty seed industry has made it impossible to base that resolution on productive research.

Sincerely,

John A. Kitzhaber, M.D.
Governor

LJR/smg