THE CENTER FOR
FOOD SAFETY

25 January 2013

To:
Canola Hearings Officer
Oregon Department of Agriculture
635 Capitol St. NE
Salem, OR 97301-2532
Submitted electronically to: canola-rulemaking@oda.state.or.us

Re:
Proposed Rule that "Amends control area and regulations for growing *Brassica spp*. and *Raphanus spp.* in Willamette Valley":
Amend OAR 603-052-0860, 603-052-0870 & 603-052-0880; Adopt OAR 603-052-0861, 603-052-0862, 603-052-0882, 603-052-0884, 603-052-0886, 603-052-0888, 603-052-0900 & 603-052-0920; Repeal OAR 603-502-0850 & 503-502-0852

These CFS Science Comments are submitted separately from Legal Comments from our organization. Supporting material has also been submitted, and the filenames of those documents correspond to the citations in this text (e.g. Van Acker et al. 2000).

Respectfully,

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Summary

The introduction of canola into the Willamette Valley would cause numerous serious harms to Oregon agriculture. First, canola would contaminate *Brassica* seed and vegetable crops, as well as clover, greatly reducing their value. This would occur via cross-pollination and seed admixture between canola and other Brassicas. The sources of contamination would be not only fields of canola grown as a crop, but also volunteer and feral canola, which would rapidly become abundant due to canola's weedy characteristics. Second, the vast majority of canola would be herbicide-resistant, primarily glyphosate-resistant varieties. Herbicide-resistance traits would exacerbate the contamination threat posed by canola, particularly in GMO-sensitive export markets; exacerbate the weediness of canola; and increase the toxicity and cost of weed control for all Willamette Valley producers by reducing the efficacy of glyphosate, the most widely used herbicide in virtually all sectors of Oregon agriculture. Third, large-scale canola planting would introduce pests and pathogens to *Brassica* seed crops, making cultivation of the latter more expensive and toxic for conventional producers, and perhaps impossible for organic seed growers. Comparatively low-value, high-acreage canola would not provide sufficient per acre returns to justify the careful monitoring and control of diseases and pests that the high value of vegetable production makes possible. Taken together, these impacts would put seed growers out of business, undermine the Willamette Valley as one of the world's leading production zones for vegetable seed crops, and harm all sectors of Oregon agriculture.

What's at stake

Oregon's vegetable seed industry

The Willamette Valley is one of just a handful of regions of the world with major production of vegetable seed crops, the others being western Washington state, the coastal areas of southwest British Columbia, parts of Chile, areas in the Mediterranean, and parts of Australia (Karow 2010) and New Zealand (Limagrain

UK 2009). It is the Willamette Valley's unusual climate – mild, wet winters and warm, dry summers – and rich soils that make it so well adapted to seed production.

The vegetable and flower seed industry in Oregon is valued at $30.8 million per year (ODA 2012). Brassica family seeds comprise the great majority of this value, or over $25 million (Karow 2010). The Willamette Valley produces over 90% of the European cabbage, Brussels sprouts, rutabaga and turnip seeds in the world; and 20-30% of the radish, Chinese cabbage and other Oriental *Brassica* vegetable seed (Karow 2010).

Vegetable seed production is highly profitable. Farm gate vegetable seed sales in Oregon averaged $1,872 per acre in 2007 (Census 2007, Table 35).[1] *Brassica* seeds range in value depending on the variety and whether open-pollinated or hybrid. A 1997 guide to vegetable seeds in Washington state shows that Oriental vegetable seeds bring in $1000-1,200 per acre, while other Brassicas range from $1,200-$2,000/acre for open-pollinated varieties to $4,000-$6,000 per acre for hybrid seeds (WA State 1997). Vegetable seed prices have likely risen substantially in the 15 years since these estimates were made. OSU estimates that Oregon farmers net from $500 to $1,500/acre for vegetable seed production (Karow 2010), which seems conservative given the farm gate values cited above.

The high value of vegetable seeds provides two interrelated benefits: opportunities for small farms to flourish; and a high level of employment relative to equivalent farmland area devoted to large commodity crops like wheat or canola. The average size of Oregon vegetable seed farms in 2007 was 56 acres (Census 2007, Table 35). CFS has not found employment figures for Willamette Valley's vegetable seed sector, but Nick Tichinin of Universal Seed Company gives a descriptive account (Tichinin 1st Declaration 2012). His company has 25 full-time employees, which include several agronomists, and 15-20 seasonal employees. Universal also contracts with 50+ independent farms in the Willamette Valley, which collectively must employ several-fold more workers than Universal does directly. Frank Morton of Wild Garden Seeds observes that young farmers in his area have shown tremendous interest in organic seed production, filling two classes he taught in 2011 to capacity. Many of these 65 farmers apparently already grow organic vegetables, and are looking to diversify and strengthen their operations by growing high-value vegetable seeds as well (Morton 1st Declaration 2012).

Not only does seed production generate many more jobs per acre than large-scale commodity crops, they are more highly skilled jobs. Ever fewer commodity farmers have the skills, time, resources or legal right to produce seed crops. The Willamette Valley has a unique constellation of perfect soils, climate and specialized expertise that make vegetable seed production among the highest-valued uses of its land. With the continuing trend of children of farming families leaving agriculture for reasons of economics and the unchallenging, cookie-cutter nature of modern

[1] Under "Vegetable Seeds," divide "value of sales" by "acres in the open."

industrial agriculture, modes of farming that are both highly profitable and make greater demands on the skills and intellect of farmers are most likely to keep families in farming.

Canola production presents a very different picture. It is a much lower value crop, with roughly 1/4th the per acre sales value of vegetable seeds. Canola sales averaged just $478 per planted acre and $517 per harvested acre in Oregon from 2009 to 2012 (OR Canola).[2] These figures would likely decline if canola expands from several thousand acres at present to several hundred thousand acres, as envisioned by ODA, for two reasons. First, roughly half of Oregon canola since 1992 has been grown on land with yield-enhancing irrigation (OR Canola);[3] and it is highly unlikely that half of canola could be grown on irrigated land with a huge jump in canola production. Second, the sales figures cited above are based on historically high canola prices of $0.17 to $0.23 per lb. (OR Canola), well above the $0.07 to $0.14/lb. range of the recent past (Chastain undated).[4] Canola prices have fallen before, and will likely do so again.

Canola is also a crop better suited to larger growers rather than small and medium-sized ones. In Oregon's limited experience with canola, it has been grown on larger farms, on average 196 acres per farm in Oregon (Census 1997 & 2007, Table 26, based on figures for 1992, 1997, 2002 and 2007), or about four-fold the size of the average vegetable seed farm. Greatly expanded canola acreage would push average canola acreage per farm much higher, for several reasons. Much of Oregon's past canola production has been grown in small-scale test plots that drag the average down. In addition, canola is intended as a rotation crop for grass seed and wheat (Chastain undated), for which per farm acreage is large and increasing. The average Oregon field and grass seed farm was 386 and 443 acres in 2002 and 2007, respectively (Census 2007, County Data, Table 27, "Field and Grass Seed Crops, All"). The average Oregon wheat farm grew massively, from 346 to 608 acres in size, from 1997 to 2007 (Census 2007, State Data, Table 1, "Wheat for Grain, All"), and wheat has become an increasingly popular crop in the Willamette Valley in recent years (Paul 2009). One would expect canola to be grown in roughly similar size plantings when rotated with these crops. In short, canola would preferentially benefit already large and expanding farmers, reinforce the trend of rapidly growing wheat farms, and introduce the "get big or get out" imperative to Willamette Valley agriculture.

Nutritious food

Vegetables are included with fruits, nuts, flowers and nursery stock in the definition

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[2] Russ Karow's estimate of $606/acre gross value is inflated, as it is based on a yield – 3,500 lbs./acre – that is 40% higher than Oregon's average canola yield (2009-2012) and 15% above Oregon's peak yield over this same period of 3,050 lbs./acre, recorded in 2011 (OR Canola).

[3] 46%, 38% and 77% of Oregon canola acres were irrigated in 1992, 1997 and 2007, respectively (Census 1997, 2007). CFS has not found data on irrigated land for canola since 2007.

[4] Historical data graphed in Chastain (undated) shows canola prices ranging from $0.07-$0.14/lb. from 1993 to 2004, with the peak price recorded in 1996.

of "specialty crops", as distinguished from "commodity crops" such as corn, soybeans, wheat and other grains, and livestock. However, lumping vegetables and fruits with Christmas trees and Football mums as "specialties" belies the central importance these crops have in maintaining human health. They provide most of the vitamins, antioxidants, soluble fiber, and other nutrients in the diet necessary for optimal functioning and prevention of disease.

Many of our most nutritious vegetables are in the Brassica plant family – the so-called "cruciferous vegetables", after the old family name "Cruciferae". These include various cabbages, kale, collards, cauliflower, broccoli, Brussels sprouts, kohlrabi, mustard greens and seeds, turnip roots and greens, rutabaga, Broccoli raab, arugula, watercress and other cresses, different radishes, horseradish and wasabi, bak choi, komatsuna, mizuna, tatsoi, and other Asian vegetables. Within each vegetable type there are often numerous varieties that differ in shape, color, nutrient content, disease resistance, and environmental requirements.

Also, Brassica family vegetables have specific disease fighting qualities: "In addition to vitamins, fiber and other beneficial components typical of many types of vegetables, cruciferous vegetables are special in that they also may help fight cancer (Navarro et al. 2011)."

The Willamette Valley is also a major producer of clover and grass seeds. Clover is a leguminous crop that is rich in nitrogen, making it valuable livestock forage;[5] experiments show that clover-fed dairy cows produce milk that is superior in nutrition to that of grass-fed cows. Clover also fixes atmospheric nitrogen, enriching the soil with this vital nutrient and reducing or eliminating the need for inorganic nitrogen fertilizer, which can wash into and degrade the quality of surface and groundwater.

The proposed rule would open up the Willamette Valley to large-scale cultivation of canola for biodiesel, food-grade oil, and canola meal for livestock and thereby endanger and displace a vegetable seed industry that is indispensible for production of healthy vegetables.

Contamination of vegetable seeds via cross-pollination with canola

Canola grown for edible oil and biofuels is mainly the species *Brassica napus*, although some canola varieties are the related species *B. rapa* (Gulden et al. 2008). Many of the vegetables in the Brassica family – the cruciferous vegetables – can

[5] http://www.dardni.gov.uk/ruralni/index/publications/press_articles/dairy-2/recent-5/role-of-clover.htm

cross with canola to form unwanted hybrid seeds in vegetable seed crops. Canola can also cross with related weed species, discussed later.

In order to address concerns about cross-pollination from vegetable seed growers in the Willamette Valley and with support from Oregon Department of Agriculture (ODA), agronomists at Oregon State University (OSU) reviewed the potential for out-crossing of canola to vegetable crops (Myers 2006, Mallory-Smith et al. 2007), and initiated laboratory and field studies on pollination and canola volunteers. Results of the OSU studies were summarized for ODA in 2010 (Karow 2010), with more details on cross-pollination and on volunteers published in a Ph.D. thesis by Quinn, under the direction of Mallory-Smith (Quinn 2011).

In addition to these OSU studies, there are a number of recent scientific reports that are relevant to the question of whether canola and vegetable seed production can coexist in the Willamette Valley without contamination of seed lots via pollination, and we discuss those as well.

In summary, canola grown for oil in the Willamette Valley is likely to cross-pollinate related vegetable seed crops, either directly from canola fields flowering within a few miles of compatible crops, or via volunteer and feral canola growing in unmanaged areas. The result of cross-pollination will be unwanted canola-vegetable hybrid seeds. Canola with herbicide resistance traits may be even more likely than conventional canola to persist in feral populations, increasing the chances of transgenic contamination of vegetable seed crops.

Vegetables in the Brassica family that have been shown to cross with canola

Canola has been shown to cross spontaneously with the following vegetable species (Fitzjohn et al. 2007):

- Vegetables in the same species as canola can cross readily with canola. For example, vegetables of the species *Brassica napus* include rutabaga and Siberian kale. *Brassica rapa* canola is the same species as Chinese cabbage, Chinese mustard, pai-tsai, broccoli raab and turnip (Myers 2006), as well as bok choy, mizuna, and some other Asian vegetables.

- *Brassica napus* canola also is likely to cross with the *B. rapa* vegetables listed above (Quinn 2011). There are many examples of *B. napus* forming hybrids with wild *B. rapa* weeds, showing that crossing with the species is likely (Fitzjohn et al. 2007); and Quinn obtained *B. napus* X *B. rapa* vegetable cultivar hybrids from crossing experiments using vegetable lines provided by Willamette Valley growers.

- It is less likely for *B. napus* or *B. rapa* canola to cross with vegetables of the *B. oleracea* species: broccoli, Brussels sprouts, cabbage, cauliflower, collards, kale and kohlrabi, (Myers 2006; Quinn 2011). However, in an OSU study, a vegetable cultivar *B. oleracea* var. *capitata* (cabbage group) did produce viable seed from *B. napus* canola pollination (Quinn 2011), showing that such crosses are possible and that more work needs to be done on this question. In addition, hybrids between canola and wild *B. oleracea* have been found in Great Britain (Ford et al. 2006).

- There are examples of *B. napus* and *B. rapa* crossing with wild *B. juncea*, as well, a species that includes cultivated brown mustard grown for condiment seed and as a leafy vegetable (Huangfu et al. 2011).

- Surprisingly, canola can also cross with both wild and cultivated radish species, *Raphanus raphanistrum* and *R. sativus*, respectively (Ammitzbøll and Bagger Jørgensen 2006).

Many of these Brassica family crops are grown for seed in the Willamette Valley, so concerns about contamination of seeds via pollination are valid.

Factors affecting likelihood of cross pollination

The likelihood that canola will cross with any of these compatible vegetable species grown for seed depends on whether viable pollen from canola reaches the vegetable plants when they are in flower, and then whether the specific cultivars that receive the canola pollen are capable of being fertilized by it. A number of factors relating to both pollen movement and seed dispersal need to be considered (e.g. Devos et al. 2008), including:

- **Pollinators:** Kinds and numbers of pollinators that are working the fields, influencing how far pollen is likely to be taken
- **Weather:** Wind conditions and other weather events that affect plant development, movement of airborne pollen, and also insect pollinator behavior
- **Size of canola pollen sources:** Acreage planted to canola and infested with volunteer or feral canola
- **Proximity:** How close the canola plants are to the vegetable plants, influencing the amount of pollen that will arrive by insects or wind
- **Weedy properties:** Characteristics of canola that facilitate its establishment outside of cultivated fields and its prevalence in feral (wild) populations
- **Flowering overlap:** Whether the flowering periods overlap in time, allowing canola pollen to encounter receptive vegetable stigmas
- **Cultivars:** Specific cultivars of both canola and the vegetable seed crops that affect crossing ability in the field

Many of these factors that influence the likelihood of canola crossing with vegetable seed crops are beyond the control of canola or vegetable seed growers. Although growers can work towards coordinating the size and location of fields, planting dates, and rotation of varieties to minimize out-crossing, volunteer and feral canola plants are likely to go undetected in unmanaged areas, increasing the chances that flowering canola will be near enough to cross-pollinate vegetable seed crops. There is little that can be done about weather conditions or activity of pollinators that can increase pollination distances. Also, most of the cultivars grown for vegetable seed have not been studied for their propensity to cross with particular cultivars of canola, so growers must assume that any cultivar is at risk. These factors are considered in more detail below.

Pollination by insects and wind

Canola flowers are self-compatible, meaning that they can and do pollinate themselves. In other words, male pollen from a particular flower can germinate on the female stigma from the same flower or other flowers on the parent plant, grow through the style and form fertile self-pollinated seeds. In addition, canola freely out-crosses. When canola pollen is moved by insects or wind, it can pollinate other canola plants within a particular field, or canola or other compatible species outside the boundaries of its field (Rieger et al. 2002; Timmons et al. 1995). This flexibility in modes of pollination makes it likely that canola itself will set lots of seeds, but difficult to predict exactly how much pollen will leave the confines of canola fields and travel how far to effect pollination of other species elsewhere.

A large number of different kinds of insect pollinators can move canola pollen away from canola fields. For example, in a recent study in France (Chifflet et al. 2011), researchers collected insects that visited canola flowers on bait plants that were set up at different distances from pollen sources, i.e. commercial canola fields. They found 26 species of insects that belonged to 9 families in three orders – Coleoptera (beetles), Diptera (flies) and Hymenoptera (bees and wasps) – visiting the bait plants. Interestingly, they only found a single honeybee, often common in canola, but no hives were in the study area. To determine whether these different insects were carrying viable canola pollen, they rubbed each insect specimen directly onto the stigma of male-sterile canola plants in a greenhouse (plants were male sterile so that no self pollination could occur, and in the greenhouse away from airborne pollen) and then counted the number of seeds that formed. Many species of insects carried viable pollen at least 1.1 km [0.7 mi] from the nearest canola pollen source (the longest distance that bait plants were placed in this experiment), including bees, syrphid flies, sawflies and sphecid wasps.

Chifflet and colleagues concluded that isolation distances of over a kilometer – the longest distance they tested – aren't enough to prevent cross-pollination by insects, especially if volunteer or feral plants are nearby:

> The bait points of MS [male sterile] plants in our experiment can be compared to small OSR [oilseed rape=canola] feral populations. Our data

> and model indicate that these plants could be pollinated by fields in the vicinity, but also from fields at distances of over 1.1 km [0.7 mi]. Resulting seeds could then remain in the seed bank for several years (D'Hertefeldt, Jørgensen & Pettersson 2008), and subsequently produce OSR feral populations contributing to gene flow at a landscape scale...To conclude, an isolation distance of 1.1 km between GM and conventional OSR fields is not sufficient to fully avoid transgene escape into conventional production, and OSR feral populations should be rigorously managed to eliminate relay points for pollen dispersal at the landscape scale. (Chifflet et al. 2011)

Of course, the types and numbers of insect pollinators will be specific to a locale (e.g. Pasquet et al. 2008), as will the weather conditions that influence pollinator behavior (Chifflet et al. 2011), so results of a particular study on pollination distances via insects are a guideline, not a rule.

In the Willamette Valley, honeybees are likely to be present in canola fields, along with wild pollinators. Karow (2010) summarized for ODA the distance bees might transfer pollen in *Brassica* crops: "Bees are reported to readily move up to 2.5 miles (studies in Oregon from 1960-70s and others around the world). As pollen transfer can occur within a hive, pollen movement of up to 5 miles is possible".

This estimate of 5 miles is consistent with studies of honeybee movement specifically in canola. Ramsay et al. (1999, as cited in Chrifflet et al. 2011) used genetically engineered traits as markers to determine whether pollen came from the same or different fields:

> Ramsay et al. (1999) showed that honeybee *Apis mellifera* L. colonies foraged up to 2 km [1.25 mi], and in some circumstances up to 4 km [2.5 mi]. In addition they used honeybees from a hive near a field of GM [genetically modified] OSR to hand-pollinate male-sterile (MS) OSR flowers. Pollen found on the body hair of these honeybees came from both GM and non-GM OSR, indicating either recent switching between these crops, or bee-to-bee contact within the hive as major means of effective pollen dispersal throughout the foraging area of the colony. (Chifflet et al. 2011)

A recent study of honeybee foraging in alfalfa seed production fields found that marked bees traveled even further, a maximum of almost 6 km [3.7 mi](Hagler et al. 2011). Since honeybees can also transfer recently collected pollen from the hive back out to fields, as noted above, this effectively doubles the theoretical pollination distance based on a single flight, to 7.4 mi for cross-pollination in this alfalfa field, for example.

Clearly, these studies show that insect pollinators are capable of moving pollen several miles away from canola fields, although the exact distances are impossible to determine since they depend on local factors that change from year to year: numbers and kinds of pollinators; weather conditions, topography and other physical factors that influence pollinator behavior; other flowering plants in the vicinity; and so on.

Wind also moves canola pollen long distances away from source fields. Most pollination experiments do not separate wind from insects. However, studies in Scotland with commercial fields of canola have shown that wind pollination alone can effect pollination at a distance of at least 1.5 - 2.5 km (~1 - 1.5 mi) (Timmons et al. 1995). And with wind, as for insects, local conditions of weather, topography, and so on will influence the actual distances pollen is moved, making accurate predictions of pollination distances impossible.

Almost certainly wind and insects will operate simultaneously to move canola pollen, and may not be independent of each other. For example, wind may influence the direction and distance some pollinators travel, as well as how far airborne pollen moves.

Size of canola pollen sources

For both wind and insect-mediated out-crossing, large commercial-scale canola fields are more likely to result in cross-pollination at longer distances. In the Timmons and colleagues' wind study:

> Wide day-to-day fluctuations in airborne pollen levels in both flowering seasons are in accordance with previous reports using smaller scale field plots of oilseed rape (e.g. McCartney & Lacey, 1991). The most striking feature of the present study, however, is the large disparity between the amount of airborne pollen we detected at all distances and those reported previously from trial plots. McCartney & Lacey (1991) report a reduction to 2-11 % of source emissions at 100 m compared with 27-69% reported here. Moreover, gene flow levels of 0.022% (Manasse & Kareiva, 1991) and 0.00033% (Schefler et al., 1993) at 47 m and 50 m, respectively, compare with 0 .08 and 1 .2% reported here at distances of at least 2 .5 and 1 .5 km, respectively. Differences in plot size represent the most probable explanation of these discrepancies (Levin & Kerster, 1974). If this is so, great care should be exercised before extrapolating information obtained from small-scale release experiments to predict the likely performance of genetically-modified crops under standard agricultural conditions. (Timmons et al. 1995)

An Australian study looking at pollination distances and also using commercial-scale fields, but not separating wind from insects, detected out-crossing as far as 3.0 km (over 1.8 mi) from the pollen source (Rieger et al. 2002). This study sampled 63 conventional canola fields that were near herbicide-resistant (HR) fields in 3 states of Australia, and used detection of the HR traits to determine whether cross-pollination had occurred. Although frequency of out-crossing was low, it did not drop off with distance until after 3.0 km: "Overall, some fields did show a decline in resistant individuals with distance, but the majority of fields, particularly those further from the source field, were more variable."

Regier and colleagues also conclude that the large size of their fields, compared to field tests, resulted in gene flow further from the source:

> This study is unique for several reasons: it was conducted with large commercial canola fields, used large sample sizes, and was conducted over one-third of Australia, which covers a range of environments. Another unique aspect of this investigation is that the pollen sources were large (25- to 100-hectare fields) [61- to 247-acre fields], unlike other studies where relatively small sources have been used. The use of large commercial fields rather than small, artificial pollen sources has revealed that there is a small amount of pollen-mediated gene movement up to 3 km from a source field…. The multiple pollinating agents (wind and insects) of canola and the large size of the source may contribute to the randomness of long-distance pollination events. (Rieger et al. 2002)

The studies above showing that experimental plantings do not predict pollen behavior of commercial plantings (Rieger et al. 2002; Timmons et al. 1995) are important in the context of canola in the Willamette Valley. Since canola for oil is grown on a much larger area than vegetable crops for seeds, this effect of scale works against the seed growers, increasing the likelihood of contamination via pollination.

Proximity of canola to vegetable seed fields

Although cross-pollination is possible at distances of several miles, as discussed above, the closer flowering canola is to vegetable seed fields, the more extensive contamination will be. Canola pollen sources can be either intentionally planted fields, or unintended, weedy populations. The biggest wild card in out-crossing from canola to vegetable seed crops is the unpredictable presence of weedy canola growing in unmanaged environments: roadsides, riparian zones, field edges, home gardens, construction sites, and other disturbed areas. These canola plants may be much closer to vegetable seed fields than canola in cultivated plots, and may flower at different times (Schafer et al. 2011) or more continuously (Kawata et al. 2008), making crosses more likely. Also, feral canola may persist in the seed bank to reappear in subsequent years, long after the initial canola plantings have been removed (D'Hertefeldt et al. 2008), making control even more difficult. Similarly, volunteer canola within fields may escape grower control in some situations and flower within the crop (Friesen et al. 2003).

Below, we discuss factors that influence the landscape prevalence of canola as crop or weed, and hence the likelihood of proximity to vegetable seed fields. It is important to keep in mind that under the proposed rule, volunteer and feral canola need only be controlled by canola producers within a quarter mile of their fields. It is highly unlikely that canola growers could or would be able to find and destroy all volunteer and feral canola within a quarter mile of their fields on a regular basis; but even if they could, such weedy canola would be found at much greater distances from commercial fields, and in a variety of habitats, and thus will often be found close enough to vegetable seed fields to cross-pollinate them. Four factors ensure that canola will frequently be found within cross-pollination distance of vegetable seed crops: 1) Large-scale canola planting; 2) Long crop rotations and canola's outsize "footprint"; 3) Weedy attributes; and 4) Ease of long-distance seed dispersal.

* Large-scale canola planting

It is impossible to predict the scale of canola planting in the Willamette Valley under the proposed rule, because although the rule stipulates a cap of 2,500 acres per year, an unspecified and unlimited amount of canola may be grown via "variances" at the edges of the Willamette Valley Protected District. Almost half or more of the Valley's 910,000 harvested acres are suitable for canola - 480,000 acres, according to ODA officials. OSU agronomists and ODA have bruited canola as a potential rotation crop for grass seed and wheat growers, and grass seed alone occupies 469,000 acres (Ehrensing undated), while wheat production is on the rise (Paul 2008). OSU agronomists have proposed ***at least*** 100,000 acres of annual canola production in the Willamette Valley alone (Chastain undated[6]), which as we discuss below is consistent with a 400,000 acre canola footprint. Finally, there appears to be sufficient demand, at least in the short term, for this much canola from biodiesel and canola food oil plants in Oregon and Washington.

* Long crop rotations ensure outsize canola "footprint"

While most major crops are grown either continuously every year on the same fields (e.g. cotton, wheat[7]) or in short two-year rotations (e.g. one year corn, the next soybeans), canola cannot be grown in this manner. If it were, disease agents and insect pests would proliferate to such an extent as to be uncontrollable and cause unacceptable levels of crop damage. This is why experts recommend that canola be grown just once every four years on any given field, and in rotations involving unrelated, non-*Brassica*, crops. This disease management imperative ensures that over a span of four years, canola's "footprint" is four times larger than that of a continuous monocrop, and double the size of a crop grown every second year.

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[6] PowerPoint by OSU agronomist Tom Chastain. One slide states: "If grown on 100,000 acres and producing a seed yield of 2,400 pounds per acre, a Willamette Valley canola crop could produce 63 million gallons of B20 biodiesel annually." Another slide presents a range of options for growing canola on from 80,000 to 1.5 million acres in Oregon as a whole.

[7] 73% of cotton acres in five major productions states (2000), and 47% of winter wheat acres in the top ten production states (2003) were not rotated (USDA ERS AREI 2006).

To illustrate, assume you wish to grow 1,000 acres of a certain crop every year. With continuous planting of corn, for instance, the same 1,000 acres would be planted to corn each year; the corn's footprint is equal to its annual acreage. In a two-year rotation, the corn would have to occupy different sets of fields totaling 1,000-acres in each year, for a 2,000-acre footprint over the rotation. In a four-year rotation, the canola's footprint is 4,000 acres, four times larger than its annual acreage.

Thus, to achieve an annual total of 120,000 acres of canola ever year – in line with the scenario put forth by OSU agronomists – would require planting the Willamette Valley's entire canola-suitable, 480,000 acres with canola at some point over a typical four-year rotation. This outsize footprint makes it quite likely that cultivated canola fields would be in proximity to vegetable or clover seed fields in at least one year of a four-year rotation. To exacerbate matters, canola's weedy properties (e.g. secondary dormancy) and ease of dispersal (discussed below) ensure that ***past years' canola fields will also remain a source of contamination and dispersal via abundant volunteers,*** as discussed further below.

* Canola has many "weedy" properties

Weediness is the ability of an undesirable plant to survive and spread without human care. Crop plants can also be weeds, when they interfere with production of other crops, or otherwise have undesirable impacts. Canola is much better adapted than most crop plants to become a problematic weed (Bagavathiannan & Van Acker 2008).

First, canola generates huge numbers of seeds, on the order of 200 million per acre in a mature crop (Friesen et al. 2003).[8] Each seed has the potential to become a volunteer – a plant that sprouts from unharvested seed to infest the following season's crop – or a feral canola weed.

Second, canola seedpods have a pronounced tendency to "shatter," which means that a high percentage of seeds (typically 10%, though in some circumstances much more) are lost during harvest operations. These seeds can then sprout to form problematic volunteers in the next season's crop. OSU experiments in 2007 and 2008 established that anywhere from 12 to 83 million seeds per acre were left in canola fields after harvest; and that roughly 10% of these seeds (1.2 to 10.6 million/acre) sprouted as volunteers by late fall (Karow 2010).

Third, canola seeds deposited in the soil often persist, only to sprout several to many years later when conditions are favorable. This property, known as "secondary dormancy," means that canola volunteers can sprout in, and interfere

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[8] Based on assumptions of Friesen et al. (p. 1346): Typical yield of 2,000 kg/hectare and average seed weight of 0.004 gram gives 500 million seeds per hectare, or 200 million per acre.

with, subsequent crops for not just one, but for many years following a canola planting. OSU states that "shattered seed will remain in the seedbank after two years time and…. some of these seeds will germinate to create a volunteer plant population after two years," and noted a Canadian study showing low level persistence of canola seed in the soil for up to four years (Karow 2010). Other studies have found canola seeds viable after 5 and 8 years (Bagavanathiann & Van Acker 2008, p. 3), and even 10 years (D'Hertefeldt et al. 2008), in the soil, suggesting that volunteer canola plants could emerge for as many years after a single planting.

These properties facilitate the survival of substantial numbers of canola plants both as volunteers in and around crop fields, and in feral populations that are found far from cultivated fields by virtue of the ease with which canola seeds are transported long distances.

* Canola seed spreads rapidly via wind, rain, animals and human actions

Canola seed can be moved great distances via wind, flooding, animals or human transport. Canola seed movement is facilitated by its small size[9] and feathery weight: a thousand seeds weigh approximately 4 grams (Friesen et al. 2003). In general, the scientific community is only beginning to appreciate the importance of seed (vs. pollen) movement as a means of long-distance plant dispersal, and in particular of the importance of rare "long-distance dispersal" (LLD) events (Bacles et al. 2006; Nathan 2006).

Canola dispersal via wind

Canola is most often harvested using a technique called "swathing" in which the plants are cut, arrayed in rows, and left to dry out in the field, typically for two weeks or more (NDSU 2006). Swathing allows earlier harvest and more even maturation of canola seeds than less popular direct harvesting techniques. However, swathes of canola can be blown in the wind, which shatters seedpods and scatters seeds over the soil, such that it is unharvestable. This is such a common occurrence that the Canola Council of Canada recommends mitigation measures for "areas where light fluffy swaths could be lifted and blown by the wind…" (CCC 2011). The problem is also quite common in North Dakota: "Swathed harvest of canola in the vast, open, rolling prairies of North Dakota can be problematic because of prevailing windy conditions that blow swaths in/off fields, resulting in high yield losses." (Johnson et al. 2005).

Windstorms this fall have moved huge numbers of swathed canola plants considerable distances, shattered seedpods, and scattered seeds along the way (Nickle 2012). A Saskatchewan farmer recently reported losing roughly half his canola crop due to strong winds (CBC News 2012); a video accompanying the article shows how easily swaths of canola can be carried off (CBC News Video 2012).

[9] http://www.uscanola.com/site/epage/102391_956.htm.

Observers reported swathes of canola lifted 30-40 feet into the air; and some swathes ended up in drainage ditches (Pratt S. 2012). It is estimated that 0.48 to 1.56 million tons of canola were lost this year due to winds and seed shattering in the Canadian Prairies (Ibid). One million tons of canola is equivalent to over 200 trillion seeds. It is thus not surprising that Grant McLean, cropping management consultant with Saskatchewan Agriculture, anticipates that "[t]he damage will trickle over to next spring, when herbicide-tolerant volunteer canola appears in fields throughout the Prairies" (Ibid).

Canola seed and seedlings are also susceptible to long-distance transport via wind at spring planting time. According to the Canola Council of Canada, a week of windy weather in mid-May "across most of the Prairies" dried out the topsoil and "some canola seed and seedlings have been blown out of the ground" (CanolaWatch 2012). Seeds blown long-distances in the spring are especially likely to sprout and establish feral populations.

Canola dispersal via heavy rains and flooding
Canola seeds can also be carried long distances by floodwaters triggered by heavy rains, leading to unwanted canola infestation of other farmers' fields, as recently reported by Australian farmer Bob Mackley (Heard 2011). Mackley reported that December floods brought large quantities of Roundup Ready canola seed into his fields; after January rains, substantial numbers of canola plants sprouted. Mackley was concerned that the Roundup Ready canola would result in unacceptable contamination levels, and/or force him to use more toxic and expensive herbicides to kill it off. Vegetable seed growers in the Willamette Valley are thus justified in their concerns that flooding would spread canola into their fields and nearby unmanaged areas, greatly increasing the likelihood of cross-pollination or seed contamination of their seed crops. These issues are discussed further below.

Mackley's experience would likely become quite common under the proposed rule, based on growing evidence that flooding is a major mode by which weed seeds of all sorts spread. The issue has received heightened attention the last few years in the context of efforts to control rampant glyphosate-resistant (GR) weeds. Arkansas weed scientist Ken Smith observes that two GR weeds – Palmer amaranth and Johnsongrass – were spread to Arkansas by rivers:

> [o]ur first discovery of resistant Palmer [amaranth] was next to the Mississippi River. The first confirmation of resistant Johnsongrass was right on the Mississippi River. And those spread right up the White River (Bennett 2011).

Smith is concerned that the seed of glyphosate-resistant waterhemp – prevalent upstream in Missouri and Illinois – arrived in Arkansas with spring 2011 floods. Norsworthy et al. (2008) have also found that Mississippi floodwaters have carried weed seed downriver to infest new areas via flooding.

According to Kentucky agronomist James Martin, both waterhemp and Palmer amaranth have become established in flood plains from seeds deposited during flood events; and these weed populations rapidly expanded to upland fields in subsequent years:

> Palmer amaranth and waterhemp may be present is as many as 19 counties, mostly in western Kentucky. They were first observed in fields located in flood plains or river bottoms but are now appearing in upland fields (Pratt K. 2012).

Waterhemp has also expanded dramatically in southern Minnesota sugar beet fields, thanks in part to heavy rains washing its seeds downriver (Stachler & Luecke 2010).

Both waterhemp and Palmer amaranth are pigweeds (genus *Amaranthus*) with small seeds roughly the same size as canola seeds.

Wind and heavy rains can also act together in the spread of canola seed. As noted above, heavy winds have swept canola swathes into drainage ditches (Pratt S. 2012), where a heavy rain could rapidly transport them to rivers, thereby infesting floodplain fields many miles downstream.

Canola dispersal via birds and other animals
Birds may also disperse canola seeds that can establish feral populations in habitats that are not along transportation routes or next to canola fields (Twigg et al. 2008, 2009). Researchers in western Australia investigated the ability of a variety of birds to spread viable seeds of canola, and found that canola was well-liked by many of the birds, and that viable seeds passed through the digestive system of ducks and were regurgitated in pellets of Australian magpies. They propose that such birds could deposit viable seeds up to 10 km (6.2) miles from their source. Also, spread of seeds by birds is likely to result in feral canola populations in riparian areas and other habitats away from transportation routes or canola fields, making it more difficult to find and control such plants.

In Canada migratory waterfowl and wild turkey have been observed eating canola seeds (Gulden et al. 2008). American goldfinches are so fond of canola seeds as they are developing on the plants that research plots had to be covered with bird netting to protect the crop (M. Crouch, personal experience, Indiana University, Bloomington, IN, 1980s; also described in Gulden et al. 2008).

There is also evidence that canola seeds eaten by sheep can be excreted in viable condition up to five days later (Stanton et al. 2003).

These studies and observations point to the likelihood that a variety of animals will eat canola seeds in the Willamette Valley, potentially dispersing them long distances over a number of days, resulting in volunteer and feral canola populations in unpredictable locations.

Canola dispersal via humans
Transport of canola harvests via truck and railway is an extremely important route in the establishment and spread of feral canola populations. Studies in Japan, Switzerland, Canada, Australia, North Dakota and California document substantial and often growing populations of feral canola that have become established along transport routes due to canola seed blown or spilled from trucks and rail cars (Switzerland: Schoenenberger & D'Andrea 2012; Japan: Aono et al. 2006, Kawata et al. 2008; Australia (CCWA PR & Report 2012); Canada: Yoshimuro et al. 2006, Knispel & McLachlan 2010; North Dakota: Shafer et al. 2011; California: Munier et al. 2012). These studies will be discussed further below. We discuss volunteer and feral canola in more detail in relation to weediness of canola, but here as a contributor to cross-pollination and thus potential for contamination of seed crops.

Volunteer and feral canola around the world

* Canada

Canada is the birthplace of canola, and canola is well established outside of cultivation there (Gulden et al. 2008), as reviewed and studied by Knispel and McLachlan (2010). They surveyed canola plants in Manitoba, along roadsides and on the edges of agricultural fields. Canola was most frequently found adjacent to canola fields, and was also abundant along highly traveled roads and near grain elevators. Some of these volunteer and feral plants produced as much seed per plant as their cultivated siblings, crossed with each other, survived over winters, and thus formed persistent feral populations (Knispel et al. 2008). Numbers of volunteer and feral plants in field-edge and roadside populations fluctuated substantially from year to year. Since canola is grown and transported each year in Manitoba, the volunteer populations are continually replenished. Transport is also the most likely way canola "escapes" in western Canada, where canola was found along railways as well as roads near ports (Yoshimura et al. 2006).

As discussed above, canola seeds move long distances via wind, as shown dramatically in Canada this summer when whole plants blew across the landscape. The Willamette Valley has had its share of high wind events, and can be expected to have high winds in the future (Oregon Parnership for Disaster Relief 2007).

* United States

Since the year 2000, 80-92% of U.S. canola has been cultivated in a single state, North Dakota, which borders two major canola-growing provinces of Canada, Manitoba and Saskatchewan. Canola acreage over this period has ranged from 0.78

to 1.46 million acres.[10] Though North Dakota grows the majority of the country's canola, it represents only 10% of the state's cropland, and ranks just fifth among crops in terms of acreage.

In the summer of 2010, researchers surveyed roadways throughout North Dakota for *B. napus* canola plants growing outside of cultivation, sampling at predetermined intervals (Schafer et al. 2011). They drove 5600 km (~3,500 mi), and sampled a total of 39 miles of that distance. Canola was found at 288 of the 634 roadside sites that were sampled (45%), at densities up to 30 plants per square meter.

As in Canada and other canola growing regions, populations of feral canola were found at higher densities along the major transportation routes and near cultivated canola fields, indicating that they arose from spillage of seeds during transport. But some canola plants were found growing on roadsides far away from known canola growing or transporting areas.

Shafer and colleagues also found dense feral canola populations in fill dirt at highway construction sites, perhaps because fill dirt provides excellent conditions for rapid canola germination and growth. Canola seeds could be deposited near cultivated fields or along transportation routes, grow to maturity and then contribute seeds to the soil seed bank. This fill dirt could then be moved to construction sites far away from the original location, carrying canola seeds with it.

There is evidence that the North Dakota roadside canola populations can persist from year to year. First, many plants had developing flowers and/or seeds, even though samples were taken well before canola in commercial fields had started to flower: "This striking difference in flowering phenology suggests that flowering canola in roadside habitats may have originated from the previous generation's seed bank rather than from seed spill during the current growing season." (Schafer et al. 2011). Also, it appears that feral plants have been interbreeding. Schafer and colleagues tested individual plants for herbicide resistance transgenes, either Liberty Link (LL) or Roundup Ready (RR) traits. At 2 of the sites, individual plants contained both traits, a combination that has not been commercialized, indicating that these plants were offspring of a cross between LL and RR parents, perhaps within the feral populations themselves.

While it is not surprising that feral canola is found in North Dakota since canola is cultivated there, it is remarkable that the distribution and characteristics of these populations are just now being studied, given the potential for negative impacts, as we discuss in these comments.

Volunteer canola is also an emerging weed in California after being planted in small field trials (Munier et al. 2012), as discussed further below.

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[10] Based on USDA National Agricultural Statistics Service data.

* Australia

Canola along roadways and in disturbed areas is common in Australia (OGTR Australia 2008), as elsewhere, but recent approval of GE canola has increased concerns for contamination of conventional and organic canola seed. As discussed above, flooding has emerged as a factor in spreading canola seeds away from intentionally planted fields (Heard 2011; de Souza 2011). A recent survey revealed that over 62% of fugitive canola plants tested along the edge of a highway in a GM-free region of Australia were GE glyphosate-resistant varieties (CCWA PR & Report 2012).

Farmers concerned about GE contamination of conventional canola and other crops in Australia have posted photos of canola seed and swathed plants blowing across the landscape in the wind, seeds being spread by machinery, volunteer plants growing in wheat and lupin, and other examples of rampant canola escape (Newman 2004). They are particularly skeptical of measures to prevent seeds from escaping during transport: "It is a common feeling amongst farmers, grain merchants and handlers that due to it's size, canola is like liquid to handle and if the equipment used is not waterproof, it will not be able to contain canola."

* Great Britain

Rapeseed, the *B. napus* oilseed progenitor of canola, has been grown in Great Britain for a few hundred years, although now canola is more commonly planted. Feral populations are found in a variety of habitats:

> Three hundred and twenty-one fields of winter-sown oilseed rape were found in the survey area. Many occurred in close proximity to one or more of the 100 `feral' populations identified. `Feral' populations ranged in size from isolated individuals to stands containing more than 1,000 plants. Fifty populations consisted of 10 or more individuals. The most commonly encountered habitat types were roadside verges, margins of agricultural fields and sites with disturbed soil (often associated with road or building construction). A number of more unusual sightings included individuals growing in domestic gardens, drainpipes and guttering. (Timmons et al. 1995)

Finding canola in "domestic gardens, drainpipes and guttering" points out the importance and the difficulty of surveying areas away from roadways to get a true picture of feral canola distribution and thus the likelihood that it will be in proximity to crossing partners such as vegetable seed plants.

* Europe

Again, since canola is grown in Europe, it is found in the wild. For example, feral canola populations were mapped in the French insect pollination study we discussed above (Chifflet et al. 2011).

Feral canola also originates from canola transported into Europe. The most striking example is Switzerland, the country with perhaps the most restrictive policies on GE crops in Europe and perhaps the world (see Schoenenberger and D'Andrea 2012 for following discussion). Switzerland has prohibited all cultivation of GE crops since 2005, and no GE feed has been imported since 2008. No GE rapeseed imports are allowed for human consumption; and the 11,000 tons of rapeseed that were imported in 2009 originated mainly from Hungary, Romania, Austria, Germany and Balkan countries where GE canola is not grown. "Switzerland does not import oilseed rape seeds from countries growing GE-oilseed rape on a large scale such as Canada or USA." Switzerland also has a law mandating "elimination of feral unauthorized GE populations."

Schoenenberger and D'Andrea scouted for canola populations at 79 railway stations and yards in Switzerland. Feral canola populations were found at 58 (73%) of the sites. Glyphosate-resistant feral canola plants were discovered at four sites, and formed the great majority of canola plants growing at three of the four sites. The authors concluded that: "GE oilseed rape may be capable of establishing self-perpetuating populations outside agricultural areas, for instance on herbicide-treated railway tracks, infrastructures for the transfer of goods from ship to train, and surrounding disturbed habitats in Switzerland." Monsanto's Roundup Ready canola has also been found growing around the port area in Basel (Frid 2012), possibly spilled en route to crushing facilities for biofuels.

The establishment of feral GE canola, albeit in small populations, in the country with perhaps the world's strictest regulations prohibiting GE crops, testifies to the extreme difficulty in controlling gene flow in canola. It also underscores the threat canola poses to Willamette Valley's vegetable seed growers.

* Japan

Japan uses large quantities of canola for oil, and currently little conventional canola and no GE canola is grown there. However, GE canola is imported into Japan for crushing into oil, mainly from Canada. Not surprisingly, GE canola plants of the types common in Canada are now found growing wild around ports, along roads, beside rivers (Aono et al. 2006); and around silos and conveyor belts near crushing facilities (Kawata et al. 2008). Some of these feral plants have multiple herbicide resistance traits, not found together in commercial varieties, and analyses suggest that they are a result of crossing within the feral canola populations in Japan (Aono et al. 2006). There is evidence that some feral plants persist over generations, and flower for most of the growing season, making it more likely that the flowering periods of feral canola will overlap with flowering of other Brassica family crops such as *B. rapa*, and Brassica family weeds in Japan (Kawata et al. 2008). Weedy *B. juncea* populations were found together with feral canola, particularly near riverbanks (Kawata et al. 2008). This proximity between compatible species and overlap in flowering increases the chances of cross-pollination between canola and crops or weeds.

Flowering overlap

We have established that pollen and seed from canola can move long distances, that weedy canola is prevalent wherever canola is grown, and that some vegetable seed crop species are capable of being cross-pollinated by canola. Other factors influence the likelihood that cross-pollination will occur.

Both canola and the vegetable seed crop have to be in flower at the same time in order for hybrid seeds to form. Trying to predict and thus control when the different Brassica family crops will be in bloom in the Willamette Valley, and able to cross, is impossible, though:

> In order to cross-pollinate, two crops would need to be in bloom at the same time. There is no way to predict flowering time of the various *Brassica* crops grown in the Willamette Valley as some are direct seeded (the only way canola is planted at this time) while many vegetable *Brassica*s are transplanted at varying times. There are also differences in flowering time within a species dependent on the cultivar being grown. Direct-seeded crops will typically be in bloom before transplanted crops. In addition, canola and many *Brassica* specialty seed crops flower over an extended period of time (indeterminate flowering) increasing the timeframe within which cross-pollination can occur (Karow 2010).

The flowering times of volunteer and feral canola are even more difficult to control, as discussed above. Mitigation schemes that attempt to control when intentionally planted crops will be in flower are thus not likely to be effective in preventing cross-pollination.

Effect of specific cultivars on likelihood of crosses

Another factor that makes it difficult to predict the success of cross-pollination is the specific cultivars involved. Many studies of crosses between canola and other species show that the likelihood that hybrids will form differs dramatically for particular cultivars of canola and vegetable crops (Fitzjohn et al. 2007; Quinn 2011) or accessions of weed species (e.g. Ammitzbøll and Bagger Jørgensen 2006). Crossing frequency can also depend on which parent is the pollen donor (Fitzjohn et al. 2007).

There are some characteristics of the vegetable seed cultivars grown in the Willamette Valley that may make them more vulnerable to cross-pollination by canola. For example, some of the inbred lines used to make hybrid vegetables are male sterile (Mallory-Smith et al. 2007), and thus rely completely on pollen from other plants. As we have seen in the studies of pollination distances, male sterile plants are more likely to be cross-pollinated since there is no competition from self-pollen.

Also, some of the vegetable cultivars are self-incompatible (Mallory-Smith et al. 2007), meaning that pollen has to come from a different, genetically distinct individual within the population. Self-incompatible cultivars, like those that are male-sterile, are more likely to be cross-pollinated, and so are more vulnerable to canola pollination (see, for example, Londo et al. 2011; also Zapiola and Mallory-Smith 2012).

For most cultivars and breeding lines, the differences in ability to cross are untested; and if tested, the reasons for differences are unknown. This means that growers have to assume that their vegetable breeding lines are able to cross with canola. No matter what *Brassica* seed crop cultivars are chosen, vegetable seed growers will be burdened with the extra tasks of monitoring the locations of canola populations, controlling volunteers and feral canola plants, and testing seed lots for unwanted canola hybrids and for transgenic contamination.

Ubiquitous volunteer and feral canola means regional measures are necessary to prevent cross-pollination with canola

If canola is grown for oil in the Willamette Valley it is highly likely that volunteer and persistent feral populations of canola will become widespread, as they have throughout the world wherever canola is grown or seeds are transported. Canola seedpods shatter easily, and seeds move away from fields via wind, floods, animals, and human actions. Given the large quantities of seeds that will be crushed for oil and thus will be moved from fields to refineries, and the inherent difficulties of containing such small seeds during transport, schemes for preventing spillage are doomed to fail.

These landscape-level processes of seed dispersal will override any measures taken by individual growers to prevent cross-pollination by controlling volunteers and feral canola around their own farms, as discussed here in relation to containing gene flow from genetically engineered canola:

> "To date, stewardship plans in North America (Beckie et al. 2006) and coexistence measures in Europe (Devos et al. 2009) have focused on farm-scale management practices. Though coexistence strategies emphasize geographic isolation of GM crops as an effective means of containing GM traits, these are likely to be inadequate where OSR [oilseed rape = canola]

> volunteers and escaped plants are not effectively controlled (Colbach 2009). Our results indicate that landscape-scale factors contribute substantially to the spread of escaped GMHT traits, which will further confound local management efforts and the reliance of coexistence strategies on localized approaches." (Knispel and McLachlan 2010)

The researchers support large control areas for maintaining coexistence without unwanted seed contamination:

> Consideration of the North American experience reveals that a decade of GM crop cultivation has resulted in the ubiquitous presence, long-term landscape scale persistence, and long-distance dispersal of escaped OSR volunteers. Distinct regional production areas for GM and non-GM crops may thus be necessary to ensure that cropping system choice is maintained in accordance with the objectives of coexistence. (Knispel and McLachlan 2010)

The current control area that excludes canola from the Willamette Valley is just such a landscape-level approach required for coexistence of canola and vegetable seed crops, with or without concerns about GE traits in canola, and should be maintained.

Contamination of vegetable seed crops via cross-pollination with canola and hybrid weeds containing herbicide resistance traits: a special case

Three types of HR canola – resistant to glyphosate, glufosinate, or imidazolinones – are grown, known respectively by the trade names Roundup Ready (Monsanto), LibertyLink (Bayer CropScience) and Clearfield (BASF). Glyphosate- and glufosinate-resistant canola are products of genetic engineering and comprise the majority, roughly 82% of canola grown in the U.S. in 2007 (GMO Compass 2010).[11] According to Monsanto, 42-75% of U.S. canola has been Roundup Ready from 2000-2009 (Monsanto 2009).[12] Many of the varieties of winter canola available in the Pacific Northwest and thus likely to be grown in the Willamette Valley are engineered with these herbicide-resistance traits as well (WSU 2012).

Is there any difference in the likelihood that HR canola – transgenic or not – will cross with vegetable seed crops compared with non-HR canola?

At the basic level of crossing compatibility, there is no reason to think that HR canola will behave differently, so ability to cross with Brassica family species and

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[11] USDA does not publish figures on the proportion of the U.S. canola crop that is genetically engineered, as it does for corn, cotton and soybeans.

[12] Monsanto figures are rounded off to the nearest 100,000. Total canola acres for the corresponding years from USDA NASS. Monsanto's figures suggest that roughly 51% of U.S. canola was Roundup Ready in 2007, which in combination with the GMO Compass figure of 82% cited above suggests that 31% of U.S. canola was glufosinate-resistant (LibertyLink) in 2007.

cultivars probably will not differ. Pollination distances based on insects and wind also should be the same.

In terms of volunteer and feral canola, there is no evidence to suggest that HR genes benefit or detract from canola survival in the wild in the absence of associated herbicide use. However, there is evidence that HR transgene flow from both cultivated and weedy HR canola is greater when the associated herbicide is used. Similarly, canola-weed hybrids that are HR are more likely to proliferate in herbicide-treated environments than plants without the HR transgenes (Schafer et al. 2011; Watrud et al. 2011), and presumably this would also be the case with non-transgenic HR as well. Such plants also may be more difficult to control with standard herbicides regimes (discussed in weed section below).

We expect that glyphosate selection of glyphosate-resistant (GR) volunteer and feral canola and weeds with GR traits will indeed occur in the Willamette Valley. Glyphosate is the most widely used herbicide in practically every sector of Oregon agriculture, and is commonly applied in the Willamette Valley to control vegetation along roadsides, for invasive plant management, in forests, in orchards, by homeowners, and in other non-agricultural situations, and for general weed control in a variety of crops (ODA 2009). Any canola plant or hybrid weed with a GR transgene that is over-sprayed or encounters glyphosate drift from these applications will be at an advantage relative to plants without GR transgenes. Their populations are more likely to increase and to persist (Watrud et al. 2011). If different HR traits are present in the feral populations – glyphosate resistance and glufosinate resistance, for example – mating between individuals will result in "stacking" so that some plants contain resistance to multiple herbicides (Schafer et al. 2011) and become more difficult to control.

Researchers at the EPA in Corvallis OR (Watrud et al. 2011) looked at the consequences of glyphosate drift exposure for plant communities that contained GR transgenes. They set up artificial ecosystems with mixes of plant species of the type that might be found along the edges of fields or roadsides. These constructed plant communities included *B. napus* with and without the GR transgene, weedy *B. rapa*, two common annual grass weeds and a widespread weed in the sunflower family. Glyphosate was applied at drift levels in years 2 and 3, and the numbers, sizes, and reproductive output of the different species were monitored and compared to unsprayed controls. Numbers of *Brassica* seeds with the GR transgene were also determined.

In unsprayed control communities, *Brassica* spp. lost out over time to more aggressive grasses. Although *Brassica* spp. decreased in number, the relative proportion of transgenic to non-transgenic individuals did not change, indicating that there were no advantages or disadvantages to carrying the GR trait in the absence of glyphosate.

As expected, glyphosate treatments changed the plant communities, favoring *B. napus* with the GR transgene and hybrids that formed between transgenic *B. napus* and *B. rapa*. Transgenic plants were larger, produced more seed, and became more abundant as the experiment proceeded. They conclude: "Our data suggest that under conditions of repeated exposures to glyphosate drift, feral *Brassica* that express the CP4 EPSPS transgene [which confers glyphosate resistance] may have an increased ability to compete and persist in weedy communities such as those found in roadsides…. Our results suggest that herbicide drift can facilitate the persistence of the CP4 EPSPS transgene in roadside habitats that provide corridors for movement of pollen and seeds into new areas and increase the potential for introgression of transgenes into plant communities." (Watrud et al. 2011).

The authors also conclude that glyphosate drift exposure can increase the weediness of plants that have the transgene:

> Transgene escape is typically considered an environmental issue when transgenic plants survive, compete, persist, and transfer genes. We observed an interacting process between transgenic glyphosate herbicide resistance and glyphosate drift that allowed greater persistence of *Brassica* in a weedy community in which it is not otherwise competitive. We conclude that glyphosate drift selection is sufficient to increase the competitive ability of transgenic *Brassica* in non-agronomic environments and should be considered in management plans for monitoring and mitigating unintended ecological consequences of dispersal and establishment of glyphosate-resistant transgenic plants in disturbed habitats. (Watrud et al. 2011)

The idea that GR transgenes are beneficial in situations where glyphosate is used has also been proposed based on the spread of GR creeping bentgrass in Oregon. In this case, GR creeping bentgrass from a field test has "escaped" and is proliferating in the wild where it has formed hybrids with wild relatives, including an unexpected hybrid with a grass in another genus (Snow 2012; Zapiola and Mallory-Smith 2012). The researchers note that the frequency of rare hybrids can be increased if the hybrid ends up with the GR transgene and finds itself in a glyphosate-positive environment:

> If a transgenic glyphosate-resistant intergeneric hybrid becomes established at a site where glyphosate is commonly used, the frequency of an otherwise infrequent event will increase, as happened with the frequency of transgenic GRCB [glyphosate resistant creeping bentgrass] found on irrigation canals in Central Oregon (Zapiola et al. 2008) and in Malheur County in Eastern Oregon in 2010 (Mallory-Smith 2011). Therefore, a species may or may not be invasive and may or may not pose an environmental risk, but it still could become a weed problem, indirectly affecting the ecosystem by requiring the use of less environmentally friendly alternative herbicides or because there are no effective alternative control options (Dale et al. 2002). (Zapiola and Mallory-Smith 2012)

In addition, as we discuss in relation to weeds below, glyphosate drift can facilitate hybridization by causing changes in flowering behavior of sensitive plants, making crosses between GR canola and compatible weeds more likely (Londo et al. 2010, 2011; Watrud et al. 2011).

Brassica family weeds can act as bridges for gene flow of herbicide resistance genes from canola to vegetable seed crops

It is also possible for weeds in the Brassica family that contain transgenes or other HR genes to act as "bridges" for HR gene flow between GE canola and vegetable seed crops if those weed species cross more easily because they are more compatible with the vegetables, are more widely dispersed in the environment, or maintain transgenes or other HR genes over a longer time period.

"Bridging" based on crossing compatibility is explained in some detail by Brown and Brown (1996) in their discussion of experiments on crossing canola with various weedy Brassicas in the greenhouse:

> A relatively high number of hybrid seeds were obtained after pollination between field mustard (*B. rapa*) and canola (*B. napus*). Hybridization rates were approximately one hybrid seed for every 25 pollinations. Most of the field mustard x canola hybrids were sterile, probably due to cytological defects and lack of chromosome pairing in meiosis, and would therefore pose little transgenic gene flow risks in the environment. However a small proportion (around 2% of all hybrids obtained) produced a small amount of fertile seed which remained self fertile. In addition, these fertile plants were found to cross pollinate with high frequency to either the weed or canola parent. This poses the question as to the possibility of back-crossing or bridge-crossing in crop x weed gene flow studies which has yet to be explored in transgenic risk assessment.
>
> In order to explain potential bridge-crosses, consider the hybrid combination field mustard x wild mustard (which produced small amounts of mature seed in this study). Field mustard [*B. rapa*] has 10 paired chromosomes (2n = 20) and wild mustard [*Sinapis arvensis*] has 9 paired chromosomes (2n = 18). A hybrid between the species would most likely be an allotetraploid with 19 paired chromosomes (2n=38) and hence will have the same chromosome number as canola (*B. napus*). Having the same chromosome number…may be an important factor in hybrid formation. A hybrid between these two weed species could therefore act as a bridging species with *B. napus* and could further add to the risk of transferring transgenic characters into weed species. (Brown and Brown 1996)

There are many other examples of potential crosses between canola and weedy species that could result in hybrids that then were able to cross more easily with particular vegetables.

Brassica rapa and *B. juncea* weeds

Perhaps the most likely weed-to-crop cross-pollination bridge for transgenes or other HR genes from canola is *B. rapa*. Weeds in this species are common throughout the world, throughout the Willamette Valley and elsewhere in the Pacific Northwest (WSU 2012; USDA NRCS Brassica rapa 2012), and *B. rapa* crosses easily with *B. napus*.

Recently, naturally occurring weedy *B. rapa* X *B. napus* canola hybrids carrying GR transgenes have been found in Québec, and these transgenes are persisting in the weedy *B. rapa* populations there (Warwick et al. 2008). Hybridization between HR canola and weedy *B. rapa* was first detected in two locations near commercial canola fields in 2001. Warwick and colleagues then followed the populations for 6 years, finding hybrids with various stages of transgene introgression via backcrossing. Chromosome numbers in backcrossed generations tend to shift towards the diploid *B. rapa* parent, and Warwick and colleagues did find one GR diploid *B. rapa* plant that was partially male fertile and produced almost 500 seeds. Such individuals can be expected to cross with *B. rapa* vegetable seed crops – e.g. Chinese cabbage, Chinese mustard, pai-tsai, broccoli raab, turnip, bok choy, mizuna – better than would the parent canola, thus acting as a bridge for transgene flow, as predicted by Brown and Brown (1996).

Warwick and colleagues conclude that the GR trait is likely to persist in nature, both because the transgene will be reintroduced into weedy *B. rapa* via crosses with canola crops and volunteers, and also because it is now stably introgressed into the weeds:

> We have described a case where a transgene from an HR crop, after being introduced by gene flow into a weedy relative, persisted over a 6-year period in the absence of herbicide selection pressure (with the exception of possible exposure to glyphosate in 2002), and in spite of the fitness cost associated with hybridization (Halfhill et al. 2005; Warwick 2007)…
> …
> Although, *B. rapa* has a limited distribution as an agricultural and/or ruderal weed in *B. napus*-growing areas in Québec, transgene escape into natural wild populations of *B. rapa* via the formation of first generation hybrids has and will continue to occur when the two species grow sympatrically (Simard et al. 2006). The persistence of the HR trait over time in *B. rapa* populations will likely result from either seed bank longevity and/or continued F1 hybrid production with *B. napus* volunteers. Volunteers can serve as a genetic bridge contributing to transgene persistence, as evidenced in *B. napus* (Hall et al. 2000) and *Helianthus annuus* (Reagon & Snow 2006). Introgression of the transgene into wild *B. rapa* plants should further

> contribute to the persistence and spread of the transgene, given that *B. rapa* is an obligate outcrossing species. (Warwick et al. 2008).

In other words, transgenic *B. rapa* populations will maintain the GR trait long after the original cultivated canola source is gone, increasing the likelihood of gene flow in both space and time.

Besides weedy *B. rapa*, other weedy species that can cross with canola and then potentially act as bridges for more likely gene flow to cultivated species are:

- *Brassica juncea*, wild mustard, that can form hybrids with cultivated *B. juncea*, brown mustard (Fitzjohn et al. 2007; Huangfu et al. 2011), (Fitzjohn et al. 2007; Huangfu et al. 2011), found occasionally in Willamette Valley counties (USDA NRCS Brassica juncea 2012)

- *Raphanus raphanistrum*, wild radish, and weedy *R. sativus*, that can form hybrids with cultivated *R. sativus,* radish (Ammitzbøll and Bagger Jørgensen 2006; Ridley and Ellstrand 2008; Snow et al. 2010)

***Raphanus* weeds**

Radishes are a particularly important example. *Raphanus raphanistrum*, wild radish, originating from the Mediterranean region, has been listed as one of the world's worst weeds, and is found in six of nine the Willamette Valley counties (USDA NRCS Raphanus raphanistrum 2012). It crosses easily with cultivated radish, *R. sativus* – a species that can also be weedy with wild populations throughout the Willamette Valley (USDA NRCS Raphanus sativus 2012)– forming hybrids that have reduced fertility but that can regain fertility in later generations (Snow and Campbell 2011; Snow et al. 2010). In fact, the invasive California wild radish is a recent *R. raphinstrum* x *R. sativus* hybrid with more aggressive characteristics that has driven its parents to extinction in California (Ridley and Ellstrand 2008). This California wild radish has been found as far north in Oregon as Coos Bay (Ridley 2008).

Brassica napus canola forms hybrids with both *R. raphanistrum* and *R. sativus* (Ammitzbøll and Bagger Jørgensen 2006). If transgenic canola crosses with either one of these weeds the transgene could persist in weedy populations. Snow and colleagues have demonstrated persistence of non-transgenic alleles of cultivated radish in wild radish hybrids for at least 10 years after a single hybridization event, and comment on implications of their work for transgene persistence:

> …many agricultural weeds have large populations, long-lived seed banks and extensive pollen- and seed-mediated gene flow, all of which can facilitate the spread and persistence of crop alleles (Ellstrand 2003). Although our study

> employed only three crop-specific markers, this was sufficient to document both long-term persistence following a single hybridization event and different degrees of introgression among loci. Our findings have implications for understanding the fates of transgenes in wild populations. Clearly, crop alleles can persist for many generations following a single hybridization event, and crop–wild hybrids may recover wild-type fitness in later generations. Thus, beneficial or neutral transgenes that recombine independently of deleterious crop alleles may spread and persist indefinitely. (Snow et al. 2010)

Herbicide resistance transgenes are neutral for fitness (Mallory-Smith and Zapiola 2008), unless the associated herbicide is present, in which case HR transgenes are very likely to be beneficial. So weedy *Raphanus* species that obtain the GR transgene from canola will provide a source of that transgene for generations, and can pass it to any vegetable crops that can form hybrids, including cultivated radish and presumably some vegetable *Brassica* spp. as well.

Glyphosate can also increase the likelihood of gene flow between canola and weedy relatives by changing flowering behavior

In addition to giving transgene-carrying *Brassica* plants a competitive advantage in plant communities, glyphosate can both "change the gene-flow dynamics between compatible transgenic crops and weeds" and at the same time result in "an increase in the transgenic seed bank." (Londo et al. 2010).

The researchers who studied plant community structure (Watrud et al. 2011, discussed above) also used similar experimental designs to look at the frequency of transgene flow with or without glyphosate (Londo et al. 2010; 2011). The experiments involved glyphosate-resistant *Brassica napus* canola growing in mixed-species plant communities that included non-transgenic *B. napus*, weedy *B. rapa*, as well as other experiments including non-compatible weedy species. Glyphosate was applied to simulate drift, and the movement and persistence of the GR transgene and population dynamics of the species were monitored over a two-year period.

Londo et al. (2010; 2011) found that glyphosate spray drift does increase the "persistence of glyphosate resistance transgene in weedy plant communities due to the effect of glyphosate on plant fitness", meaning that plants containing the transgene are immune to glyphosate injury, and thus, unsurprisingly, leave more offspring.

The surprise in their work has to do with the finding that glyphosate spray drift changes the flowering behavior of some *Brassica* spp. that do not have the transgene and are thus sensitive to the herbicide. With *B. rapa*, seed production is so severely impacted by glyphosate that few transgenic seeds are formed. However, with non-GR *B. napus* there are enough seeds produced to see an increase in transgene flow. Sensitive *B. napus* plants have fewer viable flowers for pollination because of delayed flowering after drift. Then, when flowers start to form again during recovery from glyphosate drift injury, they suffer temporary male sterility, and thus with little pollen of their own and little pollen from other sensitive individuals in the population, are more likely to be pollinated by the unaffected glyphosate-resistant plants in the population. This means that the glyphosate-resistance trait will spread more quickly if glyphosate is present:

> …glyphosate drift does not simply render flowers nonviable. Instead, it appears that it may contribute to a suppression of male reproductive function (self-fertility) following flower recovery in sensitive *B. napus* plants. As such, glyphosate drift could contribute to a greater number of transgenic feral *B. napus* that persist in weedy communities both by selecting for resistance on transgenic plants, and by increasing transgene flow to nontransgenic plants. Thus, glyphosate drift could contribute to the persistence of a transgene reservoir, allowing subsequent repeated opportunities for hybrid formation between *B. napus* and *B. rapa*. (Londo et al. 2011)

This glyphosate-enhanced reservoir of transgenes in feral *B. napus*, and then in weedy *B. rapa* could also increase the opportunities for transgenic contamination of Brassica family vegetable seeds, as noted by Londo and colleagues in their conclusions:

> This is the first evidence that suggests that glyphosate exposure may alter reproductive function and contribute to transgene flow potential associated with outcrossing in *Brassica*. The implication of a temporary change in self-fertility of *B. napus* is an increased window for interplant outcrossing and higher rates of gene flow to feral or volunteer *B. napus* from transgenic plants.
>
> ...In addition, transient male sterility resulting from glyphosate drift exposure could contribute to increased crop–crop gene flow and adventitious crop contamination under certain conditions. For example, in locations where nontransgenic conventionally bred and managed or organically grown canola plants exposed to glyphosate drift were within pollinator distances of feral transgenic glyphosate resistant plants. Further studies are underway to quantify the length and severity of glyphosate-drift-induced affects on reproduction and male-sterility in *B. napus*. (Londo et al. 2011)

Clearly, the impacts of general glyphosate use in the Willamette Valley need to be carefully considered in assessing likelihood of transgenic contamination from canola to vegetable seed crops.

“Transgenes are forever”

To recap, GR transgenes have been shown to persist in feral canola populations even without glyphosate selection, but there is reason to think that glyphosate exposure can increase transgenic GR gene frequency and persistence. This is likely to also be true for HR traits that are not transgenic.

Various scenarios for increased transgene flow from canola to vegetable seed crops are possible. For example, GR canola could successfully pollinate a *B. rapa* weed anywhere within a few miles of the canola field, given the compatibility between these species. Even a rare cross at some distance from the pollen source might be favored over other plants if the *B. rapa* x canola hybrid and subsequent generations were on a ditch bank or roadway that was being sprayed with glyphosate for general weed control, or if the hybrid was at the edge of the RR canola field itself and subjected to drift. These transgenic hybrids could establish a stable population where the GR trait would persist with or without further glyphosate exposure, and could act as a bridge for moving the transgene to other weedy *B. rapa* populations, or to compatible Brassica family vegetables.

Another scenario would involve canola volunteers and feral populations in proximity to weed species. Canola volunteers from seed spillage during transport; movement of seeds by wind, floods or animals; or within the field in subsequent years will have started with the genetic makeup of the original canola cultivars in the area. However, if some of these volunteers find themselves in an environment where they are exposed to glyphosate, those with GR transgenes will be able to make flowers and produce pollen normally, whereas canola without transgenes will be impaired. At drift levels, non-GR canola may become temporarily male sterile, and thus more likely to be pollinated by transgenic canola, increasing the proportion of GR canola in the wild population. Feral canola populations will then act as reservoirs for the transgene, and will be able to transfer it to weedy relatives and to *Brassica* crops that are close enough to cross.

Other more complex but perhaps just as likely scenarios for transgene flow are possible, as described in the various studies discussed above. GR creeping bentgrass provides an ongoing cautionary tale about how unexpected crosses can nevertheless move transgenes into wild species.

Once GR transgenes are established in wild populations, the resulting feral plants and weeds will contribute seeds to the soil seed bank; they will be moved around the landscape in unpredictable ways; and thus it is likely that the transgenes will persist indefinitely.

Contamination of specialty seeds via canola seed mixing

In addition to contamination of vegetable seed stocks via cross-pollination, canola seeds themselves can end up mixed in with seeds of other species. If the seeds are transgenic, even a small number can be detected during testing and result in market rejection and losses. There is no clear threshold for what degree of transgenic contamination triggers market losses, since different buyers have different purity standards in this respect.

Mustard seed

A case in point is the accidental mixing of GE canola seeds with brown mustard (*B. juncea*) shipped to Europe from Canada in 2003 (Demeke et al. 2006; MacArthur 2003). Seeds of canola are very similar in size, color and shape to brown mustard seeds, and up to 1% canola seeds are allowed in mustard for export. However, many markets are more sensitive to transgenic contamination, so shipments are routinely tested for adventitious presence of transgenes. In 2003, low levels of glyphosate resistance and glufosinate resistance transgenes were found in mustard seed destined for France, including events that had not been approved in parts of Europe (Demeke et al. 2006).

The chair of the Canadian Mustard Association, Walter Dyck, expressed concern because 80% of Canadian brown mustard is exported to Europe, but acknowledged that prevention would be difficult. He said: “There are several places the canola could have been mixed with the mustard: as a volunteer in the field; in the grain truck; in the country elevator; in a rail car; or at the export terminal.” (MacArthur 2003).

Seed growers in the Willamette Valley will have to examine their specific seed handling chain to see where canola seed might be able to enter.

Other Brassica family seed crops

Canola seed from volunteer and feral canola growing as weeds is a likely contributor to direct contamination of seed crops. A buyer of Willamette Valley radish seeds has already stated the likelihood of this happening: “As canola is closely related to radish and it will act as a weed, there will be no way to clean the fields and make them free of canola. Contamination of the radish seed with canola seed will be the consequence.” (Peter Konijn, Production Manager, Enza Zaden Seed Operations B.V., Netherlands; letter attached as Exhibit 1 to Second Declaration of Nicholas Tichinin in Support of Petitioners’ Motion, CA A A152202: Tichinin 2nd Declaration 2012)

Also, in some situations, canola seeds could be transported by wind from volunteer and feral plants, canola fields, or even from seed spilled in transport, ending up in vegetable seed fields as they are harvested. As discussed above, high winds at harvest time, can move canola seed large distances. Because canola harvesting involves cutting the crop and letting it dry in windrows or “swathes” for 10-14 days or more, there is ample time for high winds to move huge quantities of seed off the field, as seen this year throughout the Prairie provinces of Canada.

If Brassica family weeds acquire herbicide resistance transgenes from canola, as we discussed above, their seeds could also contribute transgenic contamination by mixing with seed crops in the Willamette Valley.

Clover and other legume seeds

Seeds of several legume species are grown in the Willamette Valley, such as red, crimson, arrowleaf and white clover; as well as some alfalfa and vetch. OSU reports that over 20,000 acres of the Willamette Valley were devoted to legume seed production in 2010, with $24 million dollars in gate sales (OSU 2012). These seeds are shipped worldwide.

Contamination of clover seed lots by canola can occur when volunteer or feral canola growing in clover seed fields flowers and goes to seed, and then those seeds are harvested with the clover. Canola seeds could also get mixed with clover seeds if they blow in from commercial canola fields, or from volunteer or feral canola populations, while clover is windrowed, as is the custom with crimson clover: "Crimson clover is harvested in late June and early July. As with the other clovers, it is swathed at night, when dew is on the plants, to reduce seed shatter. It's allowed to dry in the swath for about a week, then harvested with a combine using a belt pick-up header." (OSU 2012).

And, again, any weeds that end up with transgenes from hybridization with canola will be a potential source of transgenic seeds in legume seed crops, as they will be in Brassica family seed crops.

Herbicide-resistance exacerbates the weed threat posed by canola

The fact that the vast majority of canola grown in the U.S. and Canada is engineered to survive direct application of an herbicide makes the agronomic problems posed by volunteer/feral canola populations much worse. Herbicide-resistant varieties of canola were introduced in Canada and the U.S. in 1996 and 1997, respectively.[13] As described above, three types of HR canola – resistant to glyphosate, glufosinate, or imidazolinones – are grown, known respectively by the trade names Roundup

[13] The 1997 introduction of HR canola in the U.S. refers to Monsanto's Roundup Ready canola. It is possible that LibertyLink and/or Clearfield canola was introduced a year or two earlier, though in Canada all three varieties appear to have been introduced in 1996. USDA does not collect statistics on GE canola as it does for GE corn, cotton and canola.

Ready (Monsanto), LibertyLink (Bayer CropScience) and Clearfield (BASF). Glyphosate- and glufosinate-resistant canola are products of genetic engineering and comprise the majority.

Under the proposed rule, most of the canola grown in the Willamette Valley would likely be herbicide-resistant (HR). HR canola, and in particular glyphosate-resistant (GR) canola, is being actively bred for use in winter canola varieties (US Canola Assoc 2010), including many varieties already grown in the Pacific Northwest (WSU 2012). At the same time: "Non-GMO winter and spring canola varieties are available, but they are rapidly becoming difficult to find" (Ehrensing 2008). It is thus likely that many canola growers in the Willamette Valley would grow HR and especially GR canola varieties, whether from choice or lack of non-GE options.

Herbicide resistance exacerbates the canola weed threat in several ways. First, weedy HR canola would survive and be propagated wherever the corresponding herbicide is used for control. Increased prevalence of volunteer and feral HR canola means more opportunities for contamination of seed crops via cross-pollination or seed dispersal. Second, contamination thresholds for GM content are generally much lower than those for off-type seeds. Thus, contamination with HR canola would lead to market rejection at lower levels than contamination involving conventional canola. Third, HR canola weeds would increase the cost and toxicity of weed control wherever the corresponding herbicide is used for control purposes and alternative control options are more toxic. Fourth, increased use of the HR canola-associated herbicide would increase selection pressure for resistant weeds. Both of the latter effects can adversely impact non-HR canola growers, and are particularly serious if many farmers rely on the herbicide in question.

Herbicide-resistant canola has been grown longer and more widely in Canada than anywhere else in the world. Examination of the Canadian experience may offer insight into the potential consequences of canola cultivation in the Willamette Valley under the proposed rule. Another even more relevant context is the emergence of glyphosate-resistant canola volunteers as a new weed threat in California.

Herbicide-resistant canola weeds in California

In 2007, a small field trial of 4 different GE canola varieties was conducted in Butte County, California: 3 resistant to glyphosate and one to glufosinate (see Munier et al. 2012 for following discussion). The total planted area for this trial was just 0.04 hectare. In the following years, canola volunteers were counted and destroyed via shallow tillage and herbicide application in a 0.4 ha area including and surrounding the 0.04 ha plot. Canola volunteers continued to emerge in the fourth year (2011) after the 2007 trial – thousands of plants per hectare – despite no additional planting, demonstrating canola's pronounced secondary dormancy. In addition, glyphosate-resistant canola has been detected in great numbers along roadways in the area, fostered by use of glyphosate to control roadside weeds. The authors conclude:

> Canola's glyphosate resistance in combination with canola's seed dormancy makes it a challenging weed for roadsides, orchards, vineyards, fallow fields, and glyphosate resistant crop fields, or anywhere where glyphosate is an important herbicide.
>
> Glyphosate is the most common (California Department of Pesticide Regulation 2009) and valuable herbicide in California agriculture. Stephen Powles of the University of Western Australia has described glyphosate as "a once-in-a-century herbicide" (Powles and Preston 2006). Glyphosate is effective on many broadleaf and grassy weeds, both annual and perennial….. If glyphosate is a "once in a century herbicide," a replacement herbicide for glyphosate is likely decades into the future. Each time another weed, for example, ryegrass (Powles and Preston 2006), develops resistance to glyphosate, it makes weed control more complicated, more expensive, and decreases the value of glyphosate. If glyphosate-resistant canola spreads along roadsides and into orchards and fields, it will make glyphosate less valuable in those places. It will also result in the use of additional herbicides, adding both economic and environmental costs.

Oregon resembles California in a number of respects that make this report relevant. Both states have extremely varied agriculture, and depend heavily on glyphosate for control of weeds in numerous settings. In Oregon, glyphosate is the primary herbicide (as measured by pounds of annual use) in field crops, seed crops, fruits/nuts, nursery/Christmas trees, pasture/forage/hay, livestock/poultry, and in forestry (ODA 2009). As is happening in California, herbicide-resistant canola would seriously impair the efficacy of glyphosate in numerous use settings. The fact that a field trial just 0.04 ha in size is the source of a new and difficult weed in California should be carefully heeded by Oregon officials. If so little HR canola is the source of such problems, what would be the impacts of thousands, tens or hundreds of thousands of acres of HR canola in Oregon? The Canadian experience provides further context.

Volunteer herbicide-resistant canola weeds in Canada

The vast majority of Canadian canola is grown in the Prairie provinces of Saskatchewan, Alberta and Manitoba. Overall canola acreage has tripled over the past 25 years: from 6.5 million acres in 1986 to 18.5 million acres in 2011 (see Canadian Canola Acres). Herbicide-resistant canola was introduced in 1996 (10% of acres) and reached 51% adoption by 1998, 84% by 2002, and since 2008 has occupied 99% of Canadian canola acres (see Canadian HR Canola).

Canadian government agronomists have conducted periodic weed surveys since the mid 1970s. Major goals of this effort are to monitor shifts over time in dominant weed species in various regions and crops, explain these shifts with reference to farm management strategies and other factors, and use this knowledge to inform and improve weed control practices and policies.

All three major canola-growing provinces have seen sharp increases in the abundance of volunteer canola since the surveys were begun. The relative abundance[14] (Thomas 1985) of volunteer canola versus other weeds over time, expressed as a rank, is indicated below:

1) Saskatchewan: 26th in mid-1970s to 22nd in the mid-1980s to 12th in the mid-1990s (Gulden et al. 2003).
2) Alberta: 20th in the late 1980s to 21st in 1997, 17th in 2001, and 6th in 2010 (Leeson et al. 2010, pp. 237-238);
3) Manitoba: 31st in 1978-81 to 28th in 1986 to 19th in 1997 (Van Acker et al. 2000) to 10th in 2002 (Van Acker et al. 2002)

Agronomists attribute the rapid rise in volunteer canola's abundance to two major factors: 1) Increasing canola acreage; and 2) Increasing proportion of canola that is herbicide-resistant, particularly glyphosate-resistant, making it more difficult to control. With reference to Manitoba, Canadian agronomists Van Acker and colleagues observed that:

> Volunteer canola (*Brassica napus* L.) has increased in rank from 31st in 1978-81 to 28th in 1986, to 19th in 1997 and 10th in 2002, based on relative abundance (Table 1). This rapid and steady increase was due, in part to the increase in canola acreage in the province, but between the years of 1997 and 2002 canola acreage has not increased and so ***the most recent rise in relative abundance of this species must be due to other factors***. Controlling glyphosate resistant volunteer canola requires the addition of 2,4-D or MCPA to pre-seeding glyphosate treatments and this may not always be entirely effective (Simard et al. 2003). In addition, glyphosate tolerant volunteer canola has been found to contaminate pedigreed certified canola seedlots and this can lead to unexpected control problems for producers who choose to grow non-glyphosate tolerant canola in direct-seeded cropping systems (Friesen et al. 2003). (Van Acker et al. 2002, emphasis added)

Chief among the "other factors" responsible for increased abundance of weedy volunteer canola in Manitoba from 1997-2002 is the steep rise in HR canola cultivation over this period: from just 26% to 84% of Canadian canola acres (see Canadian HR Canola).[15] This clearly suggests that volunteer canola has flourished in

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[14] As explained in more detail in Thomas (1985), "relative abundance" is a synthetic parameter based on frequency, uniformity and density of weed populations. Frequency = proportion of fields that harbor the weed; uniformity = proportion of quadrats (20 per field) in which the weed is present; and density = number of weeds per square meter where it occurs.

[15] As Van Acker states, canola acreage in Manitoba stagnated from 1997 to 2002 (from 2.35 to 2.15 million acres, see Canadian Canola Acreage).

part because its herbicide-resistant trait makes it more difficult to control. Van Acker singles out glyphosate-resistant canola volunteers as especially problematic because glyphosate-resistant canola was the most commonly planted HR canola over this period, and glyphosate is by far the most agriculturally important of the three herbicides, and its inability to control volunteer canola has greater adverse agronomic impacts.

The situation is similar in Alberta, where volunteer canola has risen from obscurity in the late 1980s to become the 6th most prevalent weed of cereal and oilseed crops in 2010 (Leeson et al. 2010). Volunteer canola's weed ranking remained virtually unchanged as canola acreage rose 30% from the late 1980s to 1997. Then it rose in relative abundance rank (21st to 17th) during the period of rapid HR canola adoption (1997-2001), which is all the more striking given the sharp decline in Alberta canola acreage over this period (3.95 to 2.67 million acres). Canola's rise from 17th (2001) to 6th most abundant weed (2010) coincides with a doubling of canola acreage as well as a rise in HR canola's share of it: from 81% to 99%. As in Manitoba, it is clear that the herbicide-resistance of volunteer canola has contributed to its increased prevalence as a weed in the canola-growing provinces of Canada.

In both provinces, volunteer canola is still more abundant in small grains such as wheat. In Manitoba, a recent survey found canola to be a "subdominant weed species" in winter wheat, ranking 5th in relative abundance (Gulden & Lewis 2009). In Alberta in 2010, canola was the 3rd, 5th and 6th most abundant weeds in spring wheat, barley and oats, respectively (Leeson et al. 2010, p. 273).

Today, nearly all of these volunteers must be herbicide-resistant, mirroring the reported 99% adoption rate of HR canola in Canada since 2008, with glyphosate-resistant varieties accounting for 45-51% (Canada HR Canola). Indeed, whenever researchers look, they find volunteer canola plants resistant to one or more herbicides. Multiple herbicide-resistant canola plants were detected as early as 1998 in Alberta, Canada, where researchers responded to farmer complaints about volunteer canola un-amenable to control (Hall et al. 2000). The farmer had grown varieties resistant to glyphosate, glufosinate and imidazolinones in proximity. A sizeable number of the resultant volunteer canola plants were dual-resistant (glyphosate + glufosinate or imidazolinone + glyphosate), while several (2 seedlings) had triple resistance to all three herbicides. Knispel et al. (2008) collected seed from 16 escaped canola populations along the edges of fields and roadways in southern Manitoba. Of the 16 populations, glyphosate resistant individuals were found in 14 (88%), glufosinate resistance in 13 (81%), imidazolinone resistance in 5 (31%), and multiple herbicide resistance in 10 (62%) of the populations. Beckie et al. (2003) had similar results (in the following passage, "gene stacking" refers to multiple herbicide resistance):

> The results of this study suggest that gene stacking in *B. napus* canola volunteers in western Canada may be common, and reflects pollen flow between different herbicide-resistant canola, presence of double herbicide-

> resistant off-types in seedlots, and/or agronomic practices typically employed by Canadian growers.

Other studies have revealed rampant contamination of certified conventional canola planting stock with herbicide-resistance traits in Canada. Friesen et al. (2003) found that 14 of 27 unique seedlots had HR gene contamination levels exceeding the 0.25% purity standard for certified seeds in Canada: nine due to glyphosate-resistance and five due to glufosinate resistance, with one seedlot failing due to contamination with both traits. Three of the 27 seedlots had glyphosate-resistant seed at levels exceeding 2%. Downey & Beckie (2002) likewise found extensive canola seedlot contamination with HR traits. Such extensive contamination is particularly surprising in light of the fact that buffer zones and other precautions are supposed to be taken to ensure the genetic purity of certified seeds for planting stock.

The upshot is that Canadian farmers must now reckon on the possibility, even the probability, that the canola seeds they purchase and the volunteer canola in their field harbor seeds and plants resistant to one and often several herbicides.

Herbicide-resistant canola weeds, no-till, and increased use of toxic herbicides

From an agronomic perspective, glyphosate-resistant canola weeds are far more threatening than volunteer canola resistant to other herbicides. Adverse impacts include: 1) Increased use of more toxic herbicides; 2) Increased use of tillage; 3) Higher weed control costs; 4) Impacts on farmers who do not utilize glyphosate-resistant canola. No-till growers are particularly impacted.

It is estimated that in 2001, approximately 25-30% of the annually cropped land in the three major canola-growing provinces of Canada was under no-till production (often called "direct-seeding" in Canada), or 16 to 20 million acres (Van Acker et al. 2003). And these no-till fields tend to have a much higher density of volunteer canola than conventionally tilled fields (Lawson et al. 2006). In lieu of traditional moldboard plowing to kill and bury weeds prior to planting, no-till farmers utilize glyphosate, as "there are no suitable substitutes for glyphosate as a spring burn-off herbicide considering spectrum of activity, efficacy, absence of soil residue, and cost" (Friesen et al. 2003), which in 2002 was estimated to be $4.50/acre (Van Acker et al. 2003).

Over a decade ago, Van Acker et al. (2003) reported that no-till growers in western Canada were rapidly shifting from the standard pre-emergence use of glyphosate alone, to a two-herbicide treatment involving both glyphosate and a chlorophenoxy herbicide such as 2,4-D or MCPA, in order to kill glyphosate-resistant, volunteer canola. 2,4-D, as a broadleaf herbicide, cannot replace glyphosate, which kills a broader spectrum of grassy as well as broadleaf weeds, so the two are used together. At a typical 2,4-D use rate of 0.5 lb./acre, GR volunteer canola would thus be responsible for application of 4.5 to 9 million lbs. of 2,4-D, assuming use on half (9 million acres) to all (18 million acres) of no-till land in western Canada. Although 2,4-D is inexpensive, weed control costs would climb 40%, by 1.50 to $2.00 Canadian dollars per acre (Smyth et al. 2002).

There is an interesting parallel in the U.S., where the overall use of 2,4-D in soybeans rose by over 2.5-fold from 2005 to 2006,[16] the most likely explanation for which is the epidemic of glyphosate-resistant weeds that at this time was spreading from the East and South to become a major problem in the soybean fields of the Midwest. Dow AgroSciences is poised to introduce 2,4-D-resistant corn and soybeans, explicitly marketing the crops to farmers who have glyphosate-resistant weeds.

However, chlorophenoxy herbicides like 2,4-D do not always do the job. Farmers report that they sometimes fail to control volunteer canola (Gulden 2008). Weed scientists have likewise had mixed results in experiments. Beckie et al. (2003) reported that pre-emergence use of 2,4-D gave poor control, and post-emergence application of a dichlorprop + 2,4-D mixture only fair control, of volunteer canola. Beckie et al. (2004) present several reasons for such control failures. First, volunteer canola seedlings become two times more tolerant to 2,4-D as they grow from the 2-4-leaf to the still early 5-6-leaf stage; hence: "Efficacy of 2,4-D was markedly lower when plants were older and would result in poor control of volunteers under field conditions." Second, cool temperatures that are common early in the season – when volunteer canola plants are small enough to control – "can impair growth and herbicide uptake and present another challenge for controlling volunteers."

The fact that most volunteer canola emerges early in the spring (Lawson et al. 2006) exacerbates these control problems. The plants can rapidly become "large, hardy and robust at the time of spring burn-off [i.e. pre-emergence herbicide treatment]; therefore, complete control may be difficult with alternative herbicides such as 2,4-D, MCPA and thifensulfuron/tribenuron…" (Friesen et al. 2003).

Volunteer glyphosate-resistant canola is an even greater problem in broadleaf crops such as field pea, field bean, lentils, chickpeas and sunflower (Gulden et al. 2008, Van Acker et al. 2003). This is because such crops are very sensitive to chlorophenoxy herbicides, which eliminates them as late pre-emergence[17] and post-emergence control options; and because volunteer canola is abundant in such crops, for instance ranking as the 5th most abundant weed in field pea in Alberta (Leeson et al. 2010, p. 273).

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[16] Based on Agricultural Chemical Usage reports from USDA's National Agricultural Statistics Service for the respective years.

[17] Because 2,4-D has some residual activity, application to soybean fields, for instance, must take place one to four weeks before crop emergence (depending on rate and type of 2,4-D) to prevent crop injury from residual 2,4-D. Similar waiting periods would be necessary for other leguminous and broadleaf crops, which would make use of 2,4-D impossible or impractical in many circumstances. In contrast, cereal crops like wheat have some natural tolerance to 2,4-D.

North Dakota State University tested various herbicides for use in controlling volunteer canola in corn, soybeans, flax, dry pea and sunflower (Jenks et al. 2005). As in Canada, chlorophenoxy herbicides like 2,4-D and MCPA generally provided poor to fair control; and control with most herbicides worsened as the canola seedling advanced from 3-leaf to 6-leaf stage. The only herbicides to provide good control at either growth stage in dry peas and sunflower were ALS inhibitors (Raptor = imazamox in dry peas; Express = tribenuron-methyl or Assert = imazamethabenz-methyl in sunflower). Clearfield canola is resistant to the imidazolinone class of ALS inhibitor herbicides. Shirtliffe (2003) states unequivocally that: "…in some circumstances such as Clearfield® volunteer canola growing in peas, there will be no herbicide options." Friesen et al. (2003) add that tribenuron (an ALS inhibitor of the sulfonylurea class) will also not control "IR" [imidazolinone-resistant = Clearfield] canola volunteers.

Rainbolt et al. (2004) conducted a study designed explicitly to identify herbicides that effectively control volunteer herbicide-resistant canola and wheat before planting in PNW [Pacific Northwest] conservation tillage systems. Their concerns are almost precisely the same as those expressed by the Canadian agronomists, discussed above, and are worth quoting at some length (emphasis added):

> Traditionally, PNW growers have relied on tillage in conventionally tilled cropping systems and glyphosate in conservation tillage systems to control volunteer crops and weeds before planting the next crop (Thill 1996). Glyphosate is the herbicide of choice for control of volunteer crops and weeds because it is effective, relatively fast acting, dependable, economical, and has no soil activity (Bayliss 2000; Ogg and Isakson 2001). ***Volunteer glyphosate-resistant wheat and canola plants will pose a problem for growers who rely solely on glyphosate for total vegetation control before planting in conservation tillage systems.*** In addition, non–acetolactate synthase-inhibiting herbicides will be required to control imidazolinone-resistant volunteer crop plants in subsequently planted imidazolinone-resistant crops.
>
> Control of herbicide-resistant volunteer wheat and canola plants must be addressed before these crops are widely adopted in the PNW (Mallory-Smith and Hyslop 1999). …
>
> ***Growers using conservation tillage systems must have herbicides that adequately control glyphosate-resistant volunteer plants or they will have to resort to tillage,*** which could increase soil erosion, reduce water infiltration into the soil, decrease soil organic matter, and increase production costs (Schillinger et al. 1999; Young et al. 1994). ***No-till growers recently were surveyed regarding the use of glyphosate-resistant wheat, and they overwhelmingly responded that they would not use this technology unless an inexpensive and effective alternative to glyphosate for volunteer wheat control was available*** (Ogg and Isakson 2001).

Rainbolt et al. tested many different herbicides, and found that most did not provide adequate control of HR volunteer canola. Like other researchers, they found that 2,4-D (applied in a mixture with glyphosate) was not as efficacious as desired: "In this study, glyphosate/2,4-D only controlled volunteer RRC [Roundup Ready canola] 81% 21 DAT [days after treatment]. Other research has shown that auxinic herbicides do not always effectively control volunteer canola in spring cereals and that efficacy decreases as plants get larger (Simard and Legere 2002)." Rainbolt and colleagues found that a mixture of paraquat + diuron was "the best alternative to glyphosate for control of volunteer herbicide-resistant canola."

Exposure to 2,4-D and other herbicides of its class (phenoxyacetic acids) has been strongly linked to increased rates of the often fatal immune system cancer non-Hodgkin's lymphoma in farmers in numerous epidemiological studies by epidemiologists at the National Cancer Institute and elsewhere (Blair & Zahm 1995). Other studies report abnormally high incidence of birth anomalies in wheat-growing counties of Minnesota where 2,4-D is heavily used (Garry et al. 2002). Depressed sperm counts have been found in 2,4-D-exposed men, among other adverse health effects attributable to this herbicide (Beyond Pesticides 2004).

Imazethapyr, one of the most widely used imidazolinone herbicides, has been strongly linked to higher rates of colon and especially bladder cancer in pesticide applicators (Kourtros et al. 2009). The latter findings are strengthened by a century-long history of research that attribute bladder cancer to aromatic amines, the class of chemicals to which imidazolinones belong.[18]

Paraquat is one of the most hazardous pesticides in use. Acutely toxic, it is associated with thousands of deaths – accidental and suicides – via ingestion. Paraquat is known to be highly neurotoxic, and an increasing body of evidence links paraquat exposure to Parkinson's disease (PANAP 2012).

The above discussion demonstrates clearly that volunteer canola is a significant weed wherever canola is grown, and becomes more abundant and difficult to control when bearing one or more herbicide-resistance traits. HR volunteer canola leads to greater use of more toxic herbicides, such as 2,4-D, MCPA, imidazolinones, paraquat and diuron; leads or could lead to greater use of tillage, abandonment of no-till methods, and the adverse impacts of conventional tillage (e.g. soil erosion); and triggers increased weed control costs.

Farmers' views on herbicide-resistant canola weeds

An interesting study of farmer experiences with and attitudes to HR canola, conducted in 2002 and 2003 by Mauro and McLachlan (2008), offers empirical

[18] Steingraber, S. (2010). Living Downstream, Da Capo Press, 2nd edition, 2010.p. xxv.

confirmation of these impacts. The authors' surveyed 370 farmers in Manitoba and across Canada, the large majority of whom (298) grew HR canola. HR canola farmers were asked about the risks associated with growing the crop. The top four risks were economic and political in nature, and in descending order of importance were: loss of markets (e.g. in Europe), loss of right to save seeds, increased seed costs, and being sued by biotechnology companies. The most important operational risk (5th overall) was herbicide-resistant canola volunteers. Thirty-eight percent (38%) of the HR canola farmers had experienced them on their land.[19] Most of the HR volunteers (72%) were glyphosate-resistant, and emerged on average 2 to 3 years after planting Roundup Ready canola, though emergence was noted by some farmers up to six years after planting. Fully 20% of the volunteers were resistant to multiple herbicides, versus just 6% resistant to imidazolinones (CF) alone and 2% resistant to just glufosinate (LL). Each of these farmer findings are in line with scientific studies discussed above concerning canola's pronounced secondary dormancy and the proliferation of multiple herbicide resistance in weedy canola.

Farmers responded to HR canola volunteers in various ways, but the top responses for single tactics were "glyphosate and additional herbicide" (17.5%) and tilling (17.5%), followed by sweeps on the air seeder (9%), chemicals or letting the volunteers grow (7%), glyphosate (5%), and hand pulling (1%). Forty-three percent (43%) used a combination of these techniques. Many (9%) of the no-till farmers in the study even reverted to tillage to control Roundup Ready canola volunteers. This survey provides direct empirical confirmation that HR canola volunteers do in fact trigger greater use of more toxic herbicides and more soil-eroding tillage, and that HR canola may in fact be incompatible with no-till cropping systems. This should not be surprising. Roundup Ready crop systems have triggered outbreaks of glyphosate-resistant weeds in Tennessee, Arkansas, Mississippi, Missouri and likely other states that have in turn led to significant reductions in conservation tillage, as farmers turn back to the plow to fight them (Laws 2006).

Mauro and McLachlan (2008) also found that farmers' perceptions of risk increased the longer they grew HR crops, which might suggest cumulative adverse impacts on their own fields from growing it. Interestingly, however, it might involve impacts over which the farmer has no control. Many farmers reported that HR canola volunteers emerged in fields where the corresponding HR crop had never been planted. This is empirical confirmation that HR canola can and does spread (as discussed above) to create problems for growers who have never used or benefited from the crops. Several of these reports are quoted below:

> I had volunteer Roundup resistant canola in a sunflower field before I had ever used it, and, I could not remove it with Roundup [herbicide] or other means. We are finding resistant canola everywhere, even if it has never

[19] The survey was conducted a decade ago, and the percentage is likely much higher today.

> been seeded on that field. I like using Roundup as pre-emergent burn-off and its not working great anymore.
>
> These volunteers are showing up in fields that have never been planted to these crops. Farmers that have never seeded genetically modified crops are finding volunteers on their farm and that the volunteer picture is much broader than we had expected to see. (Manitoba farmer, interview)
>
> I don't think enough attention has been paid to the fact that we have these crops growing volunteer, not just the year after we grow them. In fact, I've found with my own experience with a zero-till system that my volunteers are two years after I produce a crop. (Manitoba farmer, interview)
>
> Our biggest concern is Roundup Ready canola polluting our fields by being blown off neighbors fields and infesting our fields with voluntary plants. Is Monsanto going to compensate farmers in this situation? (Survey 206)

The case of Australian farmer Bob Mackley, described above, suggests that the answer to this question is no (see statements of Monsanto officer Keryn McLean in Heard 2012).

Glyphosate-resistant canola would also lead to increased selection pressure for glyphosate-resistant weeds, which up until now have not been a major problem in Oregon. Consider that glyphosate is already by far the most heavily used herbicide in Oregon agriculture, with 1.56 million lbs. applied in 2008 (ODA 2009). Widespread introduction of Roundup Ready canola would sharply increase its use, and thus selection pressure for glyphosate-resistant weeds. Interestingly, California has recently experienced an upsurge in glyphosate-resistant weeds, as recorded by the Weed Science Society of America.[20] Oregon's similarly diverse agriculture, climate, and dependence on glyphosate could easily lead to similar GR weed problems (in addition to GR canola volunteers) if a major field crop were to become predominantly Roundup Ready.

Disease and Pest Issues

Large scale and low value of canola would foster pests and disease

Cultivation of canola would likely introduce new *Brassica* diseases and pests into the Willamette Valley, and exacerbate existing disease and pest problems that are currently well-controlled by producers of *Brassica* crops and seeds. The operative factors are scale and value of production. Canola growers would not have the labor resources, time or economic incentive to control insect pests and diseases as thoroughly as vegetable crop and seed growers do. Under the proposed rule, canola

[20] See California reports at: http://www.weedscience.org/Summary/UspeciesMOA.asp?lstMOAID=12&FmHRACGroup=Go.

fields would be hundreds to thousands of acres, with roughly 100,000 acres possible each year in the Willamette Valley as a whole.[21] In contrast, as noted above, the average Oregon vegetable seed farm is just 57 acres, while vegetable seeds are planted to 7,850 acres in the state (3,150 acres in the Willamette Valley); Brassica seeds represent some unknown fraction of these acreages. The average Brassica crop farm is still smaller, just 15 acres, with 4,193 acres planted to non-canola Brassicas in the state (Census 2007, Table 34[22]). Total non-canola Brassica acreage is thus less than 12,000 acres in the state, and less than 7,300 acres in the Willamette Valley.[23] And even this acreage is widely distributed: 139 vegetable seed farms (76 in the Willamette Valley) and 285 non-canola Brassica crop farms. As detailed above, vegetable seeds and Brassica vegetable crops have a much higher per acre value, making thorough control measures more economically feasible than with canola.

Russ Karow expressed this well in the ODA report with respect to insects, but the same reasoning applies to disease control as well:

> "The concern with insects is that large fields of canola grown for oilseed would serve as reservoirs of insects that would infest nearby *Brassica* specialty seed and root vegetable crops. This concern is greatest for cabbage maggot but aphids and other insects capable of movement among fields are of concern. Insects are already a problem in specialty seed crops and intensive monitoring and spraying are done to control insect pests. Monitoring and pesticide control are possible in specialty seeds as the potential value of the crop is high enough to allow these management practices. Specialty seed growers suggest that because of the lower value of canola … growers may not monitor their crops as closely or be able to afford to make the repeated pesticide treatments that may become necessary to achieve high levels of insect control. Potential canola growers counter that a single prophylactic insecticide treatment may be adequate to control insect problems given the low level of insects observed in experimental fields.
>
> In our OSU studies, insects were monitored in both small, experimental field trials (several acres of test plots on Hyslop Farm north of Corvallis) and in large, grower field trials (@ 25 acres each) scattered throughout the Valley" (Karow 2010).

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[21] As noted elsewhere, ODA's provision for granting *ad hoc* "variances" to the putative 2,500 acre cap renders that cap essentially meaningless when projecting potential canola acreage in the Willamette Valley under the proposed rule.

[22] Based on figures for all Brassica crops listed in Table 34: broccoli, Brussels sprouts, cabbage (Chinese & head), cauliflower, collards, kale, mustard greens and turnips.

[23] Brassica seed crop acreage is some fraction of vegetable seed acreage for the state (7,850) and the Willamette Valley (3,150). Brassica crop acreage for the state totals 4,193 acres, with some unknown fraction in the WV.

It should be noted that what Mr. Karow refers to as "large" field trials (25 acres) are in fact far smaller than canola plantings that would be expected under the proposed rule.

Pests and pathogens build up quickly over time in canola

Karow observes that the generally low level of insect pests and pathogens found in three years of field trials was attributable to the lack of canola/Brassica crop history in those fields, meaning pest and pathogen populations had not had time to build up to significant levels. As Karow (2010) puts it: "grower fields were 'virgin' fields. *Brassica* crops had not been grown previously in these fields nor were other *Brassica* crops growing nearby." The low pest levels were "not surprising as most fields were first canola crop fields surrounded by predominantly grass and grain fields."

Interestingly, some evidence of pathogen buildup was noted in the OSU field trails, despite their extremely small size and brief duration. In the third year (2009), a field "had exploded with white mold," with nearly 20% of plants infected. This heavily infested field was planted adjacent to a 2008 canola field that they suspect provided the white mold inoculums for the 2009 infestation. This finding led Karow to ask: "What would be the effect on sclerotinia levels from growing 5-10,000 acres of canola in the Valley?" It would be more relevant to ask about the effect of 50,000 to 100,000 acres of canola.

Some likely answers to this question may be found by examining the experience in North Dakota, where most of the country's canola is grown. Among other diseases to which canola is prone, North Dakota State University (NDSU) researchers have singled out sclerotinia stem rot (SSR) and blackleg for special attention.

Sclerotinia stem rot and blackleg

Sclerotinia (aka white mold, white rot, stem rot) is caused by the fungal pathogen *Sclerotinia sclerotiorum*, and is one of the most common and serious diseases of canola in North Dakota (for following discussion, see NDSU 2009). It infests more than 400 plant species, including many crops grown in the Willamette Valley: canola and other Brassicas; green beans, peas, dry beans, soybeans, lentils, chickpeas, clovers and other legumes, including cover crops; sunflowers and flax. Other susceptible hosts include lettuces and relatives (e.g. endives & chicory), parsley family plants (e.g. cilantro, fennel), peppers, tomatoes, and many flowers, including calendula and chrysanthemum (Morton 1st Declaration: par. 8).

Sclerotinia infections cause stem rot, lodging and yield loss. The disease affects North Dakota canola nearly every year, with statewide yield losses reaching up to 13%, and losses as high as 50% in some fields (NDSU 2009). Infected stems produce hard reproductive structures called sclerotia, which can persist in the soil for 6-8 years to infest future crops grown in the same field (Karow 2010).

Crop rotation is the key strategy to suppress sclerotinia. Susceptible crops like canola should be followed by at least two years of non-susceptible crops (e.g. cereals). Collectively, tens of thousands of acres of sclerotinia-prone plants are already grown in the Willamette Valley (Karow 2010). Adding tens of thousands of canola acres to the mix would make acceptable rotations extremely difficult, leading to overly frequent planting of host plants, and a worsening of the disease for all growers of sclerotinia-prone crops in the Willamette Valley, including vegetable seed and crop farmers.

The risk of sclerotinia is not confined to fields where it emerges. Sclerotia form spore-generating structures that send millions of spores on the wind to neighboring and sometimes distant fields. In some cases, "spore clouds" infest fields several kilometers away from source fields (Karow 2010).

Blackleg is one of the most destructive diseases of canola, and is caused by the fungus *Leptosphaeria maculans* (see NDSU 2008). When North Dakota agronomists first surveyed canola for diseases in 1991, blackleg was found in all fields surveyed, with an average of 28% of plants infected with the disease. Blackleg can reduce yields by more than 50% in severely infected fields. Like sclerotinia, blackleg infections can lead to stem rot and lodging; and the pathogen is spread by spores which can be dispersed for several miles. Blackleg has apparently not been found in the Pacific Northwest (Ehrensing 2008), but it is likely to emerge with large-scale canola cultivation. Ehrensing (2008) maintains that fungicidal seed treatments are very effective in controlling this disease, but as discussed below, this has not been the case in North Dakota. Fungicide spraying is generally less effective in controlling blackleg than sclerotinia (NDSU 2008).

Additional evidence comes from Limagrain, a major vegetable seed producer. According to Peter Garland of Limagrain UK Limited, the widespread cultivation of canola in the UK has triggered "an explosion of diseases and pests associated with the crop" (Limagrain UK 2009, p. 2). Among diseases, he singles out stem canker (aka blackleg), stem rot (sclerotinia), dark leaf and pod spot (alternaria) and grey mold (botrytis). "Growers are now spending thousands of pounds per year on seed treatments and field sprays in order to combat these conditions, and protect seed yields." Garland points out that oilseeds (mainly canola) are planted on over 600,000 hectares in the UK, or 10% of the total UK croppable area. Canola would likely soon come to occupy a similar proportion of Willamette Valley's arable land, and have similarly disease-promoting effects, in the Willamette Valley.

Under the proposed rule, many large fields of canola would become infested with sclerotinia, blackleg and/or similar diseases such as alternaria and club root, and each would serve as source fields for spread of these diseases throughout the Willamette Valley. Since even fields with moderate infestations of sclerotinia can produce acceptable yields (Karow 2010, p. 7), and canola has a low per-acre value relative to vegetable seeds/crops, canola growers would have little financial incentive to control any but the most severe infestations. The result will be steadily worsening disease problems throughout the Willamette Valley and a large increase in toxic fungicide use, as has been seen in North Dakota.

Increased fungicide use and impacts on human health

Fungicide use has increased sharply in North Dakota canola as fungal diseases become more prevalent (e.g. see disease incidence map in NDSU 2008). First, seed treatments have long been common on canola seed, with 76% to 88% of planted seed in North Dakota treated with one or more fungicides and/or insecticides since 1996 (ND Pesticide Use 2009-1, p. 5). In 2008, at least 30% of canola seed was treated with two or three of the fungicides mefenoxam, fludioxonil and/or difenoconazole, while another, up to 32% of seed was treated with one or more unidentified fungicides (ND Pesticide Use 2009-2, p. 11). Despite this heavy use of fungicidal seed treatments, blackleg has become more prevalent in recent years (NDSU 2008), contradicting reports of their efficacy (Ehrensing 2008). Another sign of the declining efficacy of seed treatments is the dramatic rise in the percentage of canola acres ***sprayed*** with fungicides, which has increased from 0.6% in 1996, to 1.4% in 2000, 4.6% in 2004 and 18.9% in 2008 (ND Pesticide Use 1996, ND Pesticide Use 2002, ND Pesticide Use 2006, p. 21, ND Pesticide Use 2009-3, p. 23).

NDSU data list two fungicides, prothioconazole and vinclozolin, sprayed on 5.0% and 7.2% of canola acres, respectively, in 2008. Another 6.7% of canola was sprayed with unknown fungicide(s) (ND Pesticide Use 2009-3, Table 20, p. 23). Vinclozolin and its metabolite, 3,5-dichloroaniline (3,5-DCA), are reproductive/developmental toxins by virtue of their endocrine-disrupting activity. They are anti-androgenic; that is, they interfere with the action of male hormones (EPA 2000). Rat embryos (F1 generation) that were transiently exposed to vinclozolin via administration to the mother (F0 generation) developed a number of disease states or tissue abnormalities, including prostate disease, kidney disease, immune system abnormalities, testis abnormalities, tumor (e.g. breast) development and hypercholesterolemia. Subsequent generations of rats (F2-F4) also developed these conditions, suggesting that vinclozolin has epigenetic effects on the male germ line giving rise to “transgenerational” disease (Anway et al 2006). Vinclozolin is also genotoxic, and a possible human carcinogen. Due to this fungicide’s toxicity, EPA cancelled all uses of vinclozolin in 2004, except for application to canola and turf (EPA 2000, p. v). (EPA regularly registers hazardous pesticides if the putative economic benefits of their use on specific crops are deemed to outweigh the adverse health impacts on farmers, other pesticide applicators and the environment.) Finland has banned all uses, and vinclozolin has also been withdrawn in Australia due especially to occupational hazards from its use (NRA 1997).

Prothioconazole is also a toxic fungicide. In animal tests, liver and kidney function are impacted at fairly low levels; and a major metabolite (prothioconazole-desthio) has developmental toxicity (fetal abnormalities) that occur at doses much lower (3 mg/kg/day) than maternally toxic doses (100 mg/kg/day) when fed to pregnant rats via gavage (FAO-WHO 2008, pp. 267, 270-271).

Under the proposed rule, large-scale canola plantings would lead to rapid spread of fungal disease and much increased toxic fungicide use, as has occurred in North Dakota. Ehrensing (2008) states that "no fungicides are currently available for use on canola," which is certainly not true, unless Oregon restricts the use of those available in other states. Oregon State University plant pathologist Cindy Ocamb has said that fungicide would need to be used regularly, every year, if canola were introduced to the Willamette Valley (Karow 2010, p. 7).

Increased fungicide use under the proposed rule would likely include vinclozolin. Vinclozolin's metabolite 3,5-DCA is mobile and persistent, and according to EPA can contaminate surface and ground water, presenting a risk of cancer (EPA 2000, p. 39). Surface water can be contaminated by spray drift from aerial or ground applications (EPA 2000, p. 34), and in North Dakota aerial applications were made to 45% (2004) and 14% (2008) of vinclozolin-treated canola acres (ND Pesticide Use 2006, p. 21; ND Pesticide Use 2009-3, p. 23). The only other registered use of vinclozolin, besides canola, is turf. Turf is widely grown in the Willamette Valley; hence use of vinclozolin may already be widespread and intense. If so, additional heavy use on canola would certainly increase the likelihood and incidence of adverse human health impacts from this toxic fungicide.

Insect pests

Karow (2010) found multiple canola insect pests in the 2007-2009 canola field trials, including cabbage maggot, cabbage seed pod weevil, various aphids, flea beetles, pollen beetles, cucumber beetles and lygus bugs, though as discussed above none were very severe because there has been no history of Brassica crop production on those fields to foster buildup of pest populations (Karow 2010, pp. 5-6).

Karow (2010) singles out cabbage maggots and pollen beetles as having particular potential to expand with canola cultivation and harm other Brassicas. Cabbage maggot was a major problem for vegetable crop growers in 2007 (Karow 2010, p. 5), and is developing resistance to chlorpyrifos (Lorsban), making it a very serious and potentially difficult to control pest if populations expand with canola cultivation (personal communication, Ted Hake, Universal Seed Co., 1/23/13).

Willamette Valley producers regard the pollen beetle as perhaps the most serious insect threat that canola cultivation poses to their vegetable crops (Ted Hake, personal communication). Nick Tichinin of Universal Seeds projects losses in radish production of $2 million/year when the pollen beetle becomes established with widespread canola cultivation in the Willamette Valley (Tichinin 1st Declaration: par. 8). The pollen beetle does not always damage canola, but upon canola harvest it migrates to other crops. In France, widespread canola cultivation has fostered increased pollen beetle populations, which in turn have devastated hybrid radish production there, forcing producers Enza Zaden and Rijk Zwaan to leave France. These same producers – now in Oregon – dread the possibility of canola in the Willamette Valley triggering the same outcome (Ted Hake, personal communication). Limagrain UK also singles out pollen and flea beetles as major pests of vegetable seeds that have been greatly exacerbated by canola production (Limagrain UK 2009, p. 2).

Karow (2010) downplays the pollen beetle threat on the assumption that "[t]he pollen beetle observed in Western Oregon is not the same species as found in Europe, the latter causing extensive damage." However, several authorities regard them as of the same species. The European pollen beetle (aka "rape beetle") has long been known as *Meligethes aeneus.* Easton (1959) regarded the North American pollen beetle as a distinct species, *M. dauricus*, but later taxonomists have differed. Kirejtschuk (1992) classifies *dauricus* as a subspecies of *aeneus*; Audisio (1993) reports the range of *M. aeneus* as encompassing the whole of Europe as well as western North America, among other regions, indicating that he also regards the European and North American pollen beetles as belonging to one species (CABI 2011). Whatever the correct taxonomic classification, vegetable seed production experts are unanimous in believing the pollen beetle would rapidly emerge as a serious threat to Brassica/radish production in the Willamette Valley under the proposed rule.

Flea beetles are barely mentioned by Karow (2010), but are the major insect pest featured in North Dakota canola extension publications (NDSU 2007), and are likewise regarded as serious threats by Willamette Valley vegetable seed producers, especially in hot weather when plants are young (Ted Hake, personal communication).

Canola seed, neonicotinoid seed treatments and pollinators

Most canola seed is treated with insecticides and/or fungicides. In North Dakota, the seed planted on at least 48.3% of canola acres in 2008 had one of three neonicotinoid seed treatments: clothianidin, imidacloprid or thiamethoxam (ND Pesticide Use 2009-2, p. 11). Up to an additional 32.1% of canola acres, planted to seed with "unknown or other seed treatment," may also be treated (Id.), giving anywhere from half to four-fifths of canola seeds in North Dakota treated with neonicotinoids. Seed of corn, sunflower, canola and dry bean generally is treated by the seed company (ND Pesticide Use 2009-1, p. 5), and many varieties may not be available in untreated versions. Thus there may be little or no choice of desired seed varieties that are not treated with neonicotinoids.

Under the proposed rule, similarly high proportions of canola seed planted in the Willamette Valley would likely be treated with neonicotinoid insecticides. Canola flowers are extremely attractive to bees, which are the major pollination vectors. Neonicotinoid insecticides are taken up systemically by the growing plant, and bees are exposed to them in the nectar, pollen, and guttation drops (Girolami et al 2009) of plants grown from treated seed. Another route of exposure is neonicotinoid-bearing dust produced when sowing treated seeds (Krupke et al 2012). There is abundant and growing evidence that exposure of honeybees and other pollinators to neonicotinoids is responsible for lethal and sublethal impacts, and is a significant factor in colony collapse disorder, a view recently supported in an analysis by the European Food Safety Authority (EFSA 2013).

Thus, canola cultivation in the Willamette Valley would likely greatly increase exposure of pollinators to neonicotinoid insecticides. Adverse pesticidal impacts on pollinators is particularly undesirable in the Willamette Valley, where so many crops depend on pollinator services, particularly in seed production.

Future Prospects: Vegetable Brassicas vs. Canola

In terms of future prospects, the vegetable seed sector will continue to grow with consumption of vegetables. Brassicas have enjoyed particularly strong growth over the past decades. UN Food and Agriculture Organization data show that world production of "cabbages and other Brassicas" rose 274% from the mid-1960s to the first decade of the 21st century; per capita production rose by a still considerable 92%.[24] Since production must reflect consumption, the world's people are eating twice as much Brassicas as they did half a century ago. A correspondingly sharp increase in Brassica seed production is needed to meet this still growing demand, and Willamette Valley growers are uniquely well positioned to capitalize on this development.

Canola's future prospects are far less certain. Reality has fallen far short of expert projections from two to three decades ago.

> "Early expectations were that canola would take the United States by storm as this new, improved, and renamed version of rapeseed had done in Canada in the previous decade. Many experts projected three to four million hectares [7.5 to 10 million acres] in the U.S. by the turn of the century with broad scale adoption in the Midwest and Southeast." (Raymer 2002).

National canola acreage did grow rapidly from 1991 to reach 1 million acres by 1998. But canola has stagnated since that time, at just 15% of the projected 7.5 to

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[24] Based on data downloaded from FAOSTAT database on October 27-28, 2012. http://faostat3.fao.org/home/index.html#VISUALIZE_BY_DOMAIN. Country production figures for "cabbages and other brassicas" aggregated. World population from World Bank used for per capita figures.

10 million acres, with no evident trend. While it is true that two of the five top-acreage years for canola occurred in 2010 and 2012, the three others were recorded over a decade ago, from 2000 to 2002. Likewise, the two lowest-acreage years since 1998 occurred fairly recently, in 2004 and 2009.

Canola is heavily concentrated in a single state, North Dakota, which has had 80% to 92% of national canola acreage since the turn of the century. Once anticipated growth in other states has been stymied by dearth of infrastructure, markets, research funds, locally adapted varieties and registered pesticides, among other constraints (Raymer 2002). Canola has achieved a foothold in North Dakota mainly because of its proximity to Canada:

> One could view virtually all of the US canola production simply as an extension of Canadian production since it is largely supported by Canadian infrastructure, Canadian varieties, and Canadian markets (Raymer 2002).

Experts are once again predicting growth in canola, but there are several good reasons to remain skeptical. First, federal and state subsidies and mandates are responsible for canola's current attractiveness as a biodiesel crop (Jaeger 2008), and what government grants it can just as easily take away. This is especially likely in an era of budget cutting, in which legislators have shown great interest in trimming fat from agricultural budgets. In addition, public opinion is shifting strongly away from using food crops to fuel vehicles, as awareness grows that diversion of food to fuels shrinks supplies, and raises commodity prices. Higher priced foodstuffs contribute significantly to world hunger and political instability (Runge & Senauer 2007). It also drives conversion of virgin land for crop production, which releases huge quantities of global-warming gases that in turn more than negate the supposed environmental benefits of energy crops (Searchinger et al 2008). While public ire has focused on corn, as America's predominant energy crop, biodiesel food crops like canola will be similarly disfavored if and as they are more used for energy production.

What's at stake: Oregon's agricultural diversity

Oregon has perhaps the most diverse agriculture of any state in the nation. It is difficult to name a crop or commodity group that Oregon farmers do not produce. Large-scale commodity crops and forages like wheat and hay figure prominently, but do not begin to dominate the state's agriculture the way that corn and soybeans do in Iowa and Illinois. Oregon is rich in fruits, vegetables and tree nuts (ranking 3rd to 5th in state agricultural export value), a leading producer of the nation's berries, pears, onions, snap beans and hazelnuts. Livestock is also present, with production of cattle & calves and milk valued at $609 and $530 million per year (the 3rd and 4th most valuable agricultural products), respectively. Perhaps no other state can claim greenhouse and nursery products as their top-valued agricultural commodity group. Oregon also supplies a host of crops that, while perhaps obscure, add bite and beauty to life, including a third of the country's peppermint, 12% of hops, and 59% of potted florist azaleas. Christmas would be unthinkable without Oregon, which tops the nation by supplying 31% of all Christmas trees.

This agricultural diversity is a great blessing on Oregon, a source of tremendous strength. Agronomists without exception (though some agricultural economists have yet to get the word) value diversity of cropping and agricultural practices as the key foundational management principle to accomplish numerous objectives, for instance:

1) To suppress insect pests, diseases and weeds;
2) To preserve and restore soil fertility;
3) To forestall evolution of pesticide-resistant pests; and
4) To protect and stabilize producer economic returns through risk reduction.

These many benefits make agricultural diversity the most hallowed of agronomic principles, though in practice it is among the least followed, and less so as time goes on.

One force that has substantially lessened agricultural diversity is the near-unlimited demand for biofuels, a product of perverse subsidies and mandates enacted by federal and state governments. Demand for biofuels leads to vastly increased acreage of certain favored energy crops, such as corn, canola and soybeans, at the expense of many others, such as wheat and hay.[25] U.S. acreage planted to corn has reached near historic highs, increasing a massive 31% since 1990, largely to produce ethanol, which now consumes an astounding 35-40% of the U.S. corn harvest. One consequence of expanding corn acreage is reduced populations of insect pest predators and hence free and non-toxic pest control services.[26] Another consequence is more fields where corn is planted continuously over years, rather than rotated with soybeans and other crops. "Corn on corn" has been the major factor driving corn rootworm, corn's billion dollar pest, to evolve resistance to the Bt toxins in Bt corn; and as resistant rootworm expands in range, corn yields will decline, use of toxic organophosphate insecticides will increase, and insect control costs skyrocket. These and many other adverse impacts of expanded corn cultivation[27] would not have occurred without artificial stoking of demand for corn through wrongheaded biofuels' policies.

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[25] Land converted to corn also includes cropland that was formerly idle and land enrolled in the Conservation Reserve Program.
[26] Landis et al. (2008) show that soybean aphid populations rise, and predator (e.g. ladybird beetle) populations fall, with increasing regional presence of corn.
[27] Increased corn cultivation and shunting of 35-40% of America's corn to ethanol production have numerous other adverse impacts as well which are beyond the scope of these comments, but which include increasing world hunger, expanding dead zones in the Gulf of Mexico and other bays, and declining soil fertility.

The proposed change allowing canola in the Willamette Valley, together with Oregon state and federal subsidies for biodiesel and other factors, will likewise spur vast increases in canola acreage, which would ultimately lead to declining crop diversity in the Willamette Valley, and associated adverse impacts. Specific adverse impacts of the proposal have been discussed above. Oregon officials should carefully consider whether or not to open the door even to limited canola production in the Willamette Valley.

Ample cropland is available outside the Willamette Valley for canola cultivation. Canola grows well and profitably even under dryland conditions with as little rainfall as 11" per year. It has been suggested that 100,000 acres of canola could be grown outside of the Willamette Valley in the drier central and eastern portions of the state (Chastain undated, slide 9).

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