House Committee on Agriculture and Natural Resources,

Thank you for hearing this bill in committee.

I was born and raised in Corvallis, Oregon. I went to Oregon State University and earned a B.S. in Horticulture. I am a young vegetable seed farmer. At my farm I currently grow specialty vegetable seeds on contract for Wild Garden Seeds. I intend to be part of the specialty seed industry in the Willamette Valley for the rest of my professional life. With so many aging farmers in America, and so few young farmers stepping up to fill their place, I represent the future of farming in Oregon. Right now I can't afford hundreds of acres and the equipment to manage it to grow a low value commodity crop, but I can afford a few acres and small equipment to grow high value specialty seed crops. I oppose canola because wherever it grown, it stays, spreads, and contaminates other crops. Canola will irreversibly limit future agricultural opportunity for beginning farmers in the Willamette Valley.

For the past ten years, the Specialty Seed industry has enjoyed support and protection from canola by the Oregon Department of Agriculture (ODA). The ODA broke from this relationship in August of 2012 with the sudden reversal of their position despite a lack of supporting evidence and a large dissenting population. Since then, the ODA has spent a considerable amount of time and money on defending itself in court. Note the Emergency Board request for over $446,000 to address a long list of unanswered questions. Furthermore, the ODA has not adequately defined enforcement of the rules or the inevitable rule violations. Funding of enforcement is on "a cost recovery basis". This money would be better spent researching and marketing alternative non-Brassica rotational crops like camelina or flax for grass seed farmers. In summary, many of the unseen costs of isolating, managing volunteer plants, mitigating rule violations, and testing seedlots for contamination of canola will not be handled by the ODA and will be externalized to other industries and agencies, resulting in a negative effect on Oregon's economy. Oregon cannot afford canola.

Please support HB 2427 to continue the restriction on canola in the Willamette Valley.

Thank you for your service,

Hank Keogh
Avoca Farm
Corvallis, Oregon

Rep. Witt and the House Committee on Agriculture and Natural Resources,

Regarding the hearing on HB 2427 this morning in which many of us were unable to make our statements heard, I wish to submit these additional comments:

1. I urge the legislature to act on this bill. The ODA has done its best to handle this, but with all due respect for their work, the question of canola in the Willamette Valley has implications and complications that extend beyond the purview of the ODA and require the legislature to make a decision on behalf of the citizens of Oregon.
2. Rep. Witt asked Dr. Mallory-Smith for peer-reviewed, scientific papers that might help you come to a decision. Here are several papers that represent pieces of the black and white puzzle:
    a. "Seed bank persistence of genetically modified canola in California." Munier et. all, 2011 A study on how long canola seeds persist in the seed bank
    b. "Outcrossing Potential for *Brassica* Species" – Dr. Meyers, OSU.
    c. "ODA Oilseed Synopsis Report 2010." Prepared by Dr. Russ Karow after three years of ODA and OSU collaborative research on the effects of canola in the Willamette Valley.
    d. "Canola, Pushed by Genetics, Moves Into Uncharted Territories" http://www.nytimes.com/2010/08/10/science/10canola.html?_r=0 - Describes a study in North Dakota on the escape of GE canola on roadsides.
3. There is no co-existence. Any amount of canola in the Willamette Valley will spread and eventually contaminate the quality of our seed. As the gentleman from Japan said, our seed is not the cheapest, but it is the highest quality in the world. And his company is willing to pay for it. Canola has pushed out vegetable seed production in several other parts of the world including France, Australia, and others. Now they buy their seed from us. If canola comes into the Willamette Valley, they will take their business elsewhere. As another foreign seed company representative said, "You there in Oregon have yourselves a jewel. Don't blow it."
4. The sunset clause is a bad idea. Six years from now will only kick this can down the road. Science, biology, and economics will not change. We will be back at the same table with the same people talking about the same things. Meanwhile, uncertainty will cripple growth.
5. The grass seed growers need help. The half a billion dollars requested by the ODA for additional research on canola would be put to better use researching alternative non-canola crops that would fit these farmers rotational needs. This type of proactive solution is exactly what the ODA and OSU scientists are good at.
6. Lastly, as a young farmer just coming into the realm of Oregon agriculture, I urge you to think of the future. If I'm lucky I will have 50 good years ahead of me to farm in this valley, and I wish to provide the nation and world with high quality vegetable seed. Canola would severely limit my agricultural opportunity. Please protect the Willamette Valley for the future.

Thank you,

Hank Keogh
Avoca Farm
Corvallis, Oregon

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RESEARCH ARTICLE

Seed bank persistence of genetically modified canola in California

Douglas J. Munier · Kent L. Brittan · W. Thomas Lanini

Received: 8 June 2011 / Accepted: 29 December 2011

Abstract
Introduction Canola, which is genetically modified (GM) for tolerance to glyphosate, has the potential to become established as a new glyphosate resistant weed, thus reducing the effectiveness of glyphosate.
Methods Volunteer from dormant canola seeds produced thousands of plants per hectare in the fourth year (2011) following a 2007 crop harvest. This occurred with no additional canola seed production since the 2007 harvest.
Results Volunteer plants following harvests of annual crops are typically only a problem for the first year after harvest. In California, glyphosate is the core herbicide on over a million hectares of high value row, tree, and vine crops and new glyphosate resistant weeds reduce the effectiveness of glyphosate.
Conclusions The combination of dormant seed and herbicide resistance makes GM glyphosate-resistant canola a new and difficult California weed which was first observed in the winter of 2009.

Keywords Genetically modified · Canola · Glyphosate · *Brassica napus* · Resistance · Seed dormancy · Volunteer

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1 Introduction

Canola is known for shattering large amounts of seed before and during harvest (Mallory-Smith and Zapiola 2008). When shattered canola seed is buried, seed can enter a "secondary dormancy" (Lutman et al. 2003; Gruber et al. 2004). Even if all volunteer canola is controlled before it produces seed in the first year following canola, seedlings will continue to emerge for many years from dormant seed (Squire et al. 2011; Knispel and McLachlan 2010; Pessel et al. 2001; Begg et al. 2008). Most of this dormant seed emerges in the first 4 years (Crawley and Brown 2004; Lutman et al. 2003), but in Sweden some canola emerged 10 years after burial in the soil following harvest (D'Hertefeldt et al. 2008). In the UK, the seedbank of GM tolerant canola was studied for 4 years, and models predicted 95% seed loss after approximately 9 years (Lutman et al. 2005). Within an oilseed rape field, seed rain was found to deposit several thousand seed per square meter, but after just 3 years, average seed density had declined to about 200 seeds m^{-2} (Begg et al. 2008). Most annual crops only produce volunteer crop plants during the year following production.

Vehicle movement has been implicated as a main source of canola seed transport and the infestation of new sites along roadways. In Manitoba, Canada, 93–100% of the escaped canola along roadsides and field edges was observed to be herbicide-tolerant (Knispel and McLachlan 2010), similar to the proportion of herbicide tolerant canola produced in the region. They observed these populations were relatively distinct, indicating very little propagule exchange among populations. Canola has limited natural seed dispersal, and thus seed transport has been observed to be the main mechanism for dispersal along roadsides (Knispel and McLachlan 2010; Crawley and Brown 2004; von der Lippe and Kowarik 2007). Paved road surfaces and areas close to grain elevators were more likely to contain populations of herbicide tolerant canola, than were dirt roads or areas further from grain elevators (Knispel and McLachlan 2010). In Germany, feral canola seed was collected between June and October, with no seed found the remainder of the year (von der Lippe and Kowarik 2007). Since seed production from canola plants occurred much later than June in that area, they theorized that spillage during seed transport was the mechanism of seed deposition.

Glyphosate-resistant canola is a weed because of its ability to produce a significant percentage of secondary dormant seed when seed is buried after harvest (Lutman and Lopez-Granados 1998). There are no studies of glyphosate resistant dormant seed in California with its Mediterranean climate.

Canola is used to produce high-quality oil. Canola varieties are selections from several mustard species, but most varieties produced in the United States originated from *Brassica napus*, commonly called rapeseed mustard. Rapeseed mustard and other mustard species, to which canola is related, are present in California as wild weeds (Hickman 1993).

Canola is the most important oilseed crop in Canada (Harker et al. 2000), planted on millions of hectares of farmland and more recently has become an important crop in the northern United States. In these areas, canola is commonly grown in rotation with wheat where several phenoxy herbicides can be widely used to control volunteer canola. In California, with the presence of cotton, grapes, and other phenoxy sensitive crops, the use of phenoxy herbicides is restricted. This limits the available herbicides for controlling glyphosate resistant canola. California's diverse agriculture and restrictions on phenoxy herbicide use makes "weedy" glyphosate-resistant canola control much more difficult than in Canada and the northern cereal growing areas of the United States.

2 Materials and methods

In 2007, a variety trial was done on a Butte County farm (−121°49′E, 39°41′ N) with four GM canola varieties. This was the second year canola, or any other oil seed rape crop, had been planted on this farm. The first oil seed rape planting was on 6 ha in the 1980's. Ten years of detailed GPS weed mapping through 2010 found no oil seed rape from the 1980's or any wild *B. napus* or *B. rapa* on the 325-ha farm, and thus canola volunteers in the 0.4-ha area were assumed to be from the 2007 variety trial.

Three of the varieties in the 2007 variety trial were tolerant to glyphosate and one to glufosinate. Each variety was planted in 2.4×10.7 m plots with four replications. The total planted area was 0.04 ha.

The crop history of the area from 2006 to 2011 is shown in Table 1. The area was left fallow from June 2007 through October 2008 to allow for the destruction of volunteer canola seedlings before any seed was produced. Canola germinated with fall and winter rainfall and was destroyed several times each year with shallow (10–15 cm) tillage.

Table 1 Crop history of 0.04 ha 2007 GM canola trial area and the surrounding 0.4 ha

Date	Crop
December 2006–June 2007	Canola (surrounding 0.4 ha fallow)
July 2007–November 2008	Fallow
December 2008–March 2009	Wheat
April 2009–May 2011	Fallow

Assuming all volunteer canola was germinated and destroyed, wheat was planted in November 2008. Following planting, hundreds of canola plants germinated in the wheat. To prevent canola seed production, the wheat and canola were destroyed before the canola produced seed.

Since late winter 2009, the area has been kept fallow and weeds controlled with a combination of tillage and herbicides, mostly glyphosate. The clean fallow 0.4-ha area made counting canola volunteers very simple and effective. Because of the control of all volunteer canola before any seed production, all canola volunteers are from the seed produced in the spring of 2007.

Each year since canola harvest, volunteer canola seedlings have been visually estimated or counted several times and then destroyed in a 0.4-ha area including and surrounding the initial trial area. Canola volunteers were counted and destroyed as seedlings. The counted canola plants were pulled and counted in groups of ten and then the number of groups of ten counted at the end, plus any remaining less than ten.

In addition to the plot area, GM glyphosate-resistant canola populations along county roads leading to the farm were identified by applications of glyphosate or by Enviro-Logic test strips for the presence of the CP4 EPSPS protein.

3 Results

The numbers of canola seedlings from the initial 0.04-ha planting were initially visually estimated as shown in Table 2

Table 2 GM canola volunteer counts in the 0.04 ha 2007 trial planting and in the surrounding 0.4 ha area

Date	Canola (no. estimated or counted)	Canola (no. per ha)
July 2007–June 2008	Thousands	Ten thousands
July 2008–June 2009	Hundreds	Thousands
July 2009–June 2010	Hundreds	Thousands
July 2010–June 2011	372	9,193

and later were counted as the numbers decreased to lower numbers. The fallow area surrounding the original 0.04 ha planted area is ten times larger allowing for good estimations of the scattered emerging canola seedlings. The number of canola per hectare in Table 2 is calculated based on the original 0.04-ha planted area since this was the source of all germinating seed. During the fourth year of volunteer emergence, a total of 372 seedlings emerged, which was 9,193 per hectare.

Only a few GM canola plants were found on this farm outside of the 0.4-ha plot area. These were found in the combine loading area and along roadsides where the combine was hauled. These plants were not included in the counts in Table 2.

4 Discussion

Weedy glyphosate-resistant canola is an unintentional consequence of producing a glyphosate-tolerant crop, not glyphosate resistance occurring from repeated use of glyphosate for weed control in the field.

In addition to the plot area, the transportation of farm equipment to and from this 2007 trial scattered some GM canola along county roads and state highways. This scattering of seed along the roadside is typical in field crop production. However, unexpected reproducing roadside populations of canola were found during the winter of 2009 as shown in Figs. 1 and 2.

Mowing and herbicide application have both been observed to increase herbicide-tolerant canola frequency (Knispel and McLachlan 2010). The timing of these operations could influence feral canola. Mowing during flowering would be expected to reduce seed set and future populations. Likewise, treating with an effective herbicide would also reduce feral canola, but mowing or herbicide treatments performed too early in the season may remove competing vegetation. Soil disturbance resulted in a reduction in the feral canola population in the sampling year (Knispel and McLachlan 2010). However, Crawley and Brown (2004) observed an increased frequency in feral canola the year following soil disturbance. They hypothesized that feral canola benefited by the removal of competing vegetation, which might also explain the observation by Knispel and McLachlan (2010) that canola increased following mowing or herbicide treatment, which would also reduce competition.

Roadside GM canola is established in Japan along roads leading from 13 harbors to inland canola processing plants (Kawata et al. 2009). Other glyphosate resistant crops, corn and cotton, have been widely planted over the past 10 years in California, but have not become established along roadsides as reproducing weeds.

Aggressive control with effective herbicides and hand pulling of escapees along some of the county roads has resulted in control, if not eradication. Some state highways with more limited control efforts have canola populations along their roadsides. Disturbance of roadside soil may promote secondary dormant seed through shallow burial.

Wild types of rapeseed mustard are not common weeds in California's agricultural fields or on roadsides. Currently these wild types are well controlled by glyphosate.

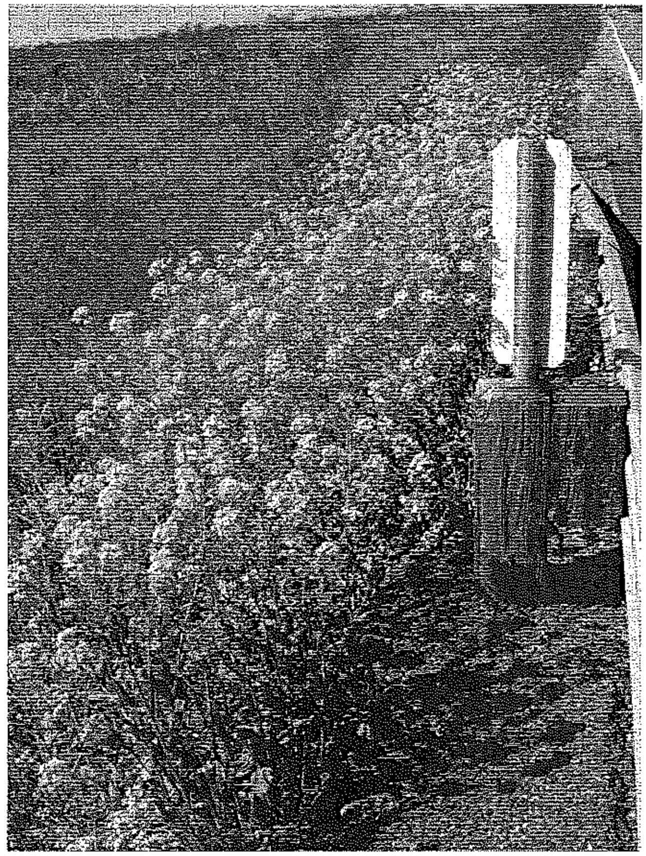

Fig. 1 Roadside glyphosate resistant canola growing with competition from other weeds removed by roadside glyphosate applications

Fig. 2 Glyphosate resistant canola surviving a recently applied roadside glyphosate application

The seed dormancy of canola makes it a difficult weed to control, persisting in a field where it was once planted for years. Shattered rape seeds have almost no dormancy, but when buried, particularly under dry conditions, rape seeds can enter a secondary dormancy which can persist for many years (Lutman et al. 2003; Gruber et al. 2004). Even if all volunteer canola is controlled before it produces seed in the first year following canola, seedlings will continue to emerge for many years from dormant seed (Squire et al. 2011; Knispel and McLachlan 2010; Pessel et al. 2001; Begg et al. 2008). 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, with extensively proven animal and environmental safety. 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.

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Outcrossing Potential for *Brassica* Species

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James R. Myers
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Outcrossing Potential for *Brassica* Species
and Implications for Vegetable Crucifer Seed Crops of Growing Oilseed *Brassicas* in the Willamette Valley

James R. Myers

Summary

The oilseed mustards known as canola or rapeseed (*Brassica napus* and *B. rapa*) are the same species as some vegetable crucifers and are so closely related to others that interspecific and intergeneric crossing can occur.

Intraspecific crosses (within the same species) readily occur among the following:

- *B. napus* canola with rutabaga and Siberian kale
- *B. rapa* canola with Chinese cabbage, Chinese mustard, pai-tsai, broccoli raab, and turnip

Interspecific crosses (between different species) can occur among the following:

- **Occur readily**: *B. napus* canola with Chinese cabbage, Chinese mustard, pai-tsai, broccoli raab, and turnip
- **Occur more rarely**: *B. napus* or *B. rapa* canola with the *B. oleracea* cole crops (cabbage, kohlrabi, Brussels sprouts, broccoli, cauliflower, collards, and kale)

Intergeneric crosses (between species of different genera) are possible with varying degrees of probability:

- *B. napus* or *B. rapa* canola with wild and cultivated radish (*Raphanus raphanistrum* and *R. sativus*)

Many factors affect the probability of an interspecific cross, but the most important is proximity of the two species. Many interspecific crosses need to occur for a few to succeed. Thus, hybrid seeds rarely are detected more than 50 meters (165 feet) from the pollen-supplying parent. Because both wind and insects transfer pollen, very rare outcrosses can be detected up to 4 kilometers (2.4 miles) away under special circumstances. However, a distance of 2 kilometers (1.2 miles) should be sufficient for stock seed production.

Although it is relatively easy to maintain adequate distance between fields with pinning maps, other sources of canola seed present a greater threat to vegetable seed growers. The two greatest threats are canola seed blown from vehicles onto road shoulders and volunteers in fields previously planted to canola. Detecting and eliminating volunteers from a 2-kilometer radius around a seed field would be onerous and perhaps impossible.

The introduction of genetically modified, herbicide-tolerant canola also constitutes a threat to vegetable seed production. Herbicide resistance is unlikely to become established in weedy species or seed crops. However, transgenes can be detected at very low frequency and would make a seed crop unsuitable for some markets.

The best solution for introduction of canola into the Willamette Valley would be to maintain zones free of canola plantings and from traffic carrying canola seeds to crushing plants.

Introduction

The proposal to introduce substantial canola (*Brassica napus*) acreage into the Willamette Valley for biodiesel production has caused concern among *Brassica* and *Raphanus* vegetable seed growers. The vegetable species of the family Brassicaceae readily outcross, with pollen transferred by insects. Seed growers are concerned about the potential for canola pollen to contaminate their seed crops.

In this paper, I describe species relationships, discuss the literature on interspecific hybridization, and describe potential impact on vegetable seed production.

Identification of Brassicaceae species

The family Brassicaceae has more than 3,000 species in 370 genera, a number of which have been brought into cultivation. Most rapeseed and canola are of the species *B. napus,* although some cultivars are *B. rapa.*

The vegetable Brassicaceae include the following:

- *B. napus* (rutabaga, Siberian kale)
- *B. rapa* (Chinese cabbage, pai-tsai, mizuna, Chinese mustard, broccoli raab, and turnip)
- *B. oleracea* (cabbage, broccoli, cauliflower, Brussels sprouts, kohlrabi, collards, kale)
- *Raphanus sativus* (radish)

Condiment crops include *B. nigra* (black mustard), *B. carinata* (Ethiopian mustard), *B. juncea* (brown or Indian mustard), *Armoracea rusticana* (horseradish), and a number of minor potherbs and salad vegetables.

In the Willamette Valley, weedy crucifers of economic significance include black mustard (*B. nigra*), birdsrape mustard (*B. rapa*), wild mustard (*Sinapsis arvensis*; synonyms *B. arvensis*, *B. kaber*, *S. kaber*), wild radish (*R. raphanistrum*), sheperdspurse (*Capsella bursa-pastoris*), and bittercress (*Cardamine hirsute*) (E. Peachey, Oregon State University, personal communication).

Brassica species relationships

Brassica species relationships are complicated by the fact that new species have arisen through the fusion of two progenitor species. The relationships among species were described in the classic work by U in 1935, in what is now termed the Triangle of U (Figure 1).

At the tips of the triangle are the species with the fewest chromosomes—*B. nigra* (N=8), *B. oleracea* (N=9), and *B. rapa* (N=10). These species are diploid, meaning they have two sets of chromosomes. N is the number of chromosomes found in either the pollen or egg, thus one-half the number found in the adult plant.

At some time in the past, the diploid species spontaneously hybridized to produce the allotetraploids. These species have four sets of chromosomes, two from each parent

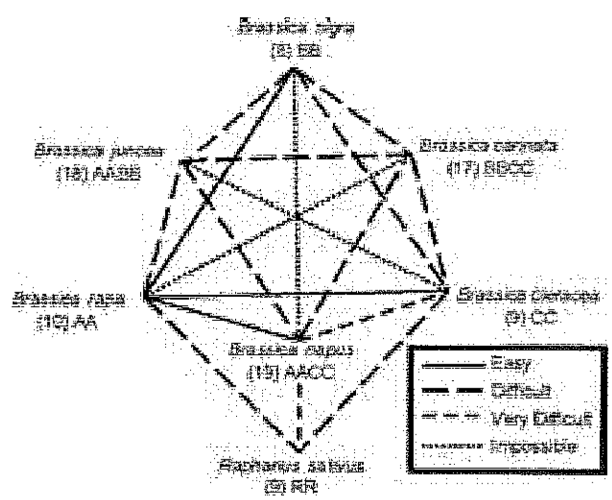

Figure 1. Triangle of U (1935) (modified to include radish) showing genome relationships among cultivated *Brassica* species. Genomes are represented by letters (A, B, C, or R), and haploid chromosome numbers are enclosed in (). Lines represent ease with which species can be crossed. Diagram was modified to include more recent data on crossing among species, including with *Raphanus*.

species. They include *B. carinata* (N=17), *B. juncea* (N=18), and *B. napus* (N=19).

There are two ways in which fertile allotetraploids can occur. In one case, unreduced gametes join. (Unreduced gametes are pollen or eggs having the full parental number of chromosomes rather than half the number.) In the other, normal fertilization occurs, followed by doubling of the chromosomes in the hybrid plant.

Because allotetraploid *Brassica* species share a genome with their diploid parents, gene flow can continue in both directions. Of particular relevance to the potential for outcrossing between vegetable and oilseed *Brassicas* is the fact that *B. napus* was derived when *B. rapa* hybridized with *B. oleracea* (Figure 1).

Although rare, allopolyploids have occurred repeatedly in nature and have been resynthesized by plant geneticists.

Pollen dispersion in *Brassicas*

Most *Brassica* pollen disperses to within 10 meters (33 feet) of its source (Nieuwhof, 1963; Anonymous, 2002), although transfer has been detected up to 3 or 4 km (1.8 to 2.4 miles) away (Rieger et al., 2002; Anonymous, 2002). Pollen may be moved by wind as well as by insects. Wind-transferred pollen has been detected up to 1.5 km (0.9 mile) from the source plant (Timmons et al., 1995).

Pollen can live up to 4 or 5 days when temperatures are low and humidity is high. With warm temperatures and low humidity, survival time may drop to 1 or 2 days.

Probability of intraspecific crosses

Rutabaga and Siberian kale are the same species as *B. napus* oilseed cultivars and will cross readily with *B. napus* canola. Turnip, Chinese cabbage, and related Asian vegetables are the same species as *B. rapa* oilseed cultivars and cross readily with them.

With outcrossing rates of 10 to 50 percent in canola (Anonymous, 2002), it is very likely that gene flow would occur between canola and rutabaga or Siberian kale. The amount of gene flow would depend on many factors: number of acres planted to canola, field distance, factors affecting pollen viability, and types of pollinators present.

Probability of interspecific hybridization

Many *Brassica* species show a high degree of relatedness, which allows crossing to occur across species and even genera (for example, wild radish with canola). Intercrossing occurs with varying degrees of difficulty.

Information about interspecific hybridization comes from two sources: (1) crosses attempted by plant breeders and geneticists and (2) natural hybrids found in the field.

Data from artificial hybridization are difficult to use in predicting potential for natural crossing because special techniques such as embryo rescue may be used to obtain viable offspring. However, plant breeders normally report the number of successful crosses compared to the number of attempts, as well as whether artificial measures were used. Thus, these data do provide a measure of the relative ease of hybridization.

In Figure 1, the different types of lines drawn between the species indicate the relative ease of interspecific hybridization based on available data (Anonymous, 2002; Bothmer et al., 1995; Davey, 1939; Honma and Summers, 1976; Yarnell, 1956).

Canola with *B. rapa* and *B. napus* vegetables

Pollen movement from canola to related species has been detected under field conditions. *B. rapa* shares the A genome with

Table 1. Potential for gene flow between canola (*B. napus*) and selected Brassicaceae species[1]

Category	High	Moderate	Low
Artificial hybrids	Yes	Yes	Yes
Field hybrids	Yes	Yes	Not reported
Gene introgression	Yes/Likely[2]	Yes	Yes
Weeds	*B. rapa*	*R. raphanistrum*	—
Cultivated species	*B. napus* and *B. rapa* vegetables	—	*B. nigra* *B. oleracea* *R. sativus*

[1] Modifed from Table 2 in Anonymous, 2002.

[2] Considered likely to happen over a period of time if the species are in physical proximity and have flowering synchrony.

B. napus (Figure 1). Several researchers have documented gene flow between these species in both directions (Bing et al., 1996; Jorgensen et al., 1996; Ellstrand et al., 1999; Wilkinson et al., 2000). Anonymous (2002) considers potential for gene flow between *B. napus* and *B. rapa* to be high (Table 1).

Canola with *B. rapa* weedy mustards

Hybridization frequencies were low (0.4 to 1.5 percent) between canola and weedy mustard plants growing just outside a field (Scott and Wilkinson, 1998). Seeds tended to be small, seedling survival was low, and fitness and fertility were reduced. With backcrosses between the hybrids and either parent, both fitness and fertility improved.

In a large-scale (15,000 km^2) survey of gene flow from canola into weedy *B. rapa* in Great Britain, one hybrid was identified (Wilkinson et al., 2000). The scarcity of hybrids was due in part to the lack of overlap between cultivated canola fields and the riparian habitat preferred by *B. rapa*.

Canola with *R. raphanistrum* (wild radish) and *R. sativum* (cultivated radish)

Wild radish (*R. raphanistrum*) hybridizes spontaneously with *B. napus* to produce viable hybrids (Baranger et al., 1995). Hybrid seeds generally were smaller than normal seeds, allowing seed size to be used as a way to identify hybrids. Backcrosses to *B. napus* as the pollen parent did show a low level of fertility. Wild radish seems to cross more readily with *B. napus* than does cultivated radish (*R. sativum*) (Anonymous, 2002).

Canola with *B. oleracea* vegetables (cabbage, broccoli, cauliflower, Brussels sprouts, kohlrabi, collards, kale)

Very little information exists on potential for natural hybridization between *B. napus* and *B. oleracea*. Hybrids have been made using controlled crosses and embryo rescue (Chèvre et al., 1996; Honma and Summers, 1976; Kerlan et al., 1992 and 1993). No researcher has obtained seed from natural crossing studies or without the assistance of embryo rescue.

However, not many research programs have attempted to hybridize these two species. As such, only a limited number of different parental combinations have been tried, and it may be possible that with the right combination, natural hybridization would produce viable offspring.

Of the hybrids made through controlled crosses, two kinds of hybrids have been observed from crosses of *B. napus* and *B. oleracea*: triploids (ACC) and amphidiploids (AACCCC). These hybrids probably resulted from union of an unreduced gamete from *B. oleracea* with a reduced (normal) gamete from *B. napus*.

Chèvre et al. (1996) examined the potential for natural gene flow over two generations of backcrossing. They found increased fertility in each successive generation, particularly when *B. napus* was the maternal parent. It appears that once the F_1 interspecies hybrid has been made, backcrossing to either parent can produce viable and partially fertile offspring.

Wilkinson et al. (2000) also examined wild *B. oleracea* populations for proximity to canola fields and for the formation of natural hybrids. *B. oleracea* is restricted to maritime cliff habitats in Great Britain, so only one population was found to be within 50 meters (165 feet) of canola production. None of the nine new seedlings found in that population was hybrid.

There is a need for additional research to address the question of the potential for natural interspecific hybridization between *B. napus* and *B. oleracea*.

Concerns about genetically modified canola

Genetically modified canola presents the greatest risk to vegetable crucifer seed crops. Although it is very unlikely that transgenes would persist once transferred to the seed crop, the presence of the gene would make the seed crop unsuitable for markets that have strict tolerances on GMO contamination.

Transgenes are relatively easy to detect at very low levels, so it is likely that their presence could be detected even if only a few interspecific hybrids were found in a vegetable seed lot. Contamination could still be detected even if interspecific seeds were nonviable.

Minimizing the risk of outcrossing

Most hybrids that have been detected were from plants within the same field or closely adjacent areas. Thus, distance is a key to preventing pollen contamination of vegetable crucifer seed crops. Based on the literature, an absolute minimum distance of 2 km (1.2 miles) between canola crops and seed fields would minimize chance crossing. With pinning maps, it is relatively easy to maintain these distances.

These distances, however, do not take into account spread of canola seed along roadways after harvest. Additional measures would be needed to make sure that seed does not blow out of harvest vehicles, and seed growers would need to police roadways near their fields for volunteer canola plants.

Volunteer plants in fields previously planted to canola might be another source of contamination if a grower unknowingly plants a seed crop near a former canola field.

Conclusions

There has been little study of gene flow between *B. napus* and *B. oleracea* or *R. sativum* under natural conditions. Further research is warranted to determine the overall risk in the Willamette Valley. Based on studies elsewhere of gene flow into weed species, we can assume interspecific hybridization will occur in certain species combinations, although probably at a low level.

Because of the dollar value per unit area and the small size of seed production fields, seed companies and growers will seek to minimize the risk of contamination. Thus, they may move their seed crops out of the valley if canola production becomes widespread. The best solution at present is to maintain canola-free zones for vegetable seed production. These zones should not allow canola production or traffic bearing seeds.

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