The Biology of *Brassica napus* L. (Canola/Rapeseed)

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Biology Document BIO1994-09: A companion document to Directive 94-08 (Dir94-08), Assessment Criteria for Determining Environmental Safety of Plant with Novel Traits

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Part A - General Information

A1. Background

The Canadian Food Inspection Agency (CFIA) is regulating the field testing of crop plants with novel traits (PNTs) in Canada. PNTs are defined as a plant variety/genotype possessing characteristics that demonstrate neither familiarity nor substantial equivalence to those present in a distinct, stable population of a cultivated species of seed in Canada and that have been intentionally selected, created or introduced into a population of that species through a specific genetic change. "Familiarity" is defined as the knowledge of the characteristics of a plant species and experience with the use of that plant species in Canada. "Substantial equivalence" is defined as the equivalence of a novel trait within a particular plant species, in terms of its specific use and safety to the environment and human health, to those in that same species, that are in use and generally considered as safe in Canada, based on valid scientific rationale.

The PNTs can either be derived from recombinant DNA technologies or from traditional plant breeding. Regulated field testing is necessary when the PNTs have traits of concern, i.e., the traits themselves, their presence in a particular plant species or their use are: (1) considered unfamiliar when compared with products already in the market; (2) not considered substantially equivalent to similar, familiar plant types already in use, and regarded as safe.

Before PNTs may be authorized for unconfined release, they must be assessed for environmental safety. Regulatory guidelines entitled: ***Directive 94-08 (Dir94-08) Assessment Criteria for Determining Environmental Safety of Plants with Novel Traits*** have been developed to define criteria and information requirements that must be considered in the environmental assessment of PNTs to ensure environmental safety, in the absence of confinement conditions.

A2. Scope

The present document represents a companion document to the Directive 94-08 (Dir94-08), entitled "***Directive 94-08 (Dir94-08) Assessment Criteria for Determining Environmental Safety of Plants with Novel Traits***". It is intended to provide background information on the biology of *Brassica napus* (L.), its centres of origin, its related species and the potential for gene introgression from *B. napus* into relatives, and details of the life forms with which it interacts.

Such species-specific information will serve as a guide for addressing some information requirements of Part D of Dir 94-08. Specifically, it will be used to determine whether there are significantly different/altered interactions with other life forms, resulting from the PNTs novel gene products, which could potentially cause the PNT to become a weed of agriculture, become invasive of natural habitats, or be otherwise harmful to the environment. The conclusions drawn in this document about the biology of *B. napus* only relate to plants of this species with no novel traits. Novel traits of concern might confer new characteristics to the plant, that could impact on the environment pursuant to their unconfined release.

Part B - The Biology of *Brassica napus*

B1. General Description, Use as a Crop Plant and Origin of Species

B. napus L., an ancient crop plant, belongs to the Cruciferae (Brassicaceae) family, also known as the mustard family. The name crucifer comes from the shape of flowers, with four diagonally opposite petals in the form of a cross. *B. napus* has dark bluish green foliage, glaucous, smooth, or with a few scattered hairs near the margins, and partially clasping. The stems are well branched, although the degree of branching depends on variety and environmental conditions; branches originate in the axils of the highest leaves on the stem, and each terminates in an inflorescence. The inflorescence is an elongated raceme, the flowers are yellow, clustered at the top but not higher than the terminal buds, and open upwards from the base of the raceme (Musil, 1950).

There are two types, the oil-yielding oleiferous rape, often referred to in Canada as Argentine Rape, of which canola is a type having specific quality characteristics, and the tuber-bearing swede or rutabaga. The oleiferous type can also be subdivided into spring and winter forms. Indian Sanskrit writings of 2000 to 1500 BC directly refer to oilseed rape and mustard, as do Greek, Roman and Chinese writings of 500 to 200 BC (Downey and Röbbelen, 1989). In Europe, domestication is believed to have occurred in the early middle ages and commercial plantings of rapeseed were recorded in the Low Countries as early as the 16th century. At that time rapeseed oil was used primarily as an oil for lamps. Later it became used as a lubricant for steam engines. Although used widely as an edible oil in Asia, only through breeding for improved oil quality, and through the development of improved processing techniques, has rapeseed oil become important in western nations. Since the Second World War, as a result of improved oil and meal quality, rapeseed production in Europe and Canada has increased dramatically. China, India, Europe and Canada are now the top producers, although there is potential for the crop to be successfully grown in Australia, the United States and South America.

Within Canada, the primary production areas are the prairie provinces of Manitoba, Saskatchewan, Alberta and the Peace River area of both Alberta and British Columbia, although there is also some production in Ontario and Quebec. Today, two species of *Brassica* have varieties of canola quality: *B. napus*, the species considered in these guidelines, and *B. rapa*. The former species requires more frost-free days than the latter to mature. Whereas *B. napus* varieties may require on average 105 days from seeding to harvest, *B. rapa* varieties require on average only 88 days. Consequently, *B. napus* varieties tend to be grown south of the areas in which *B. rapa* is grown: the central parts of Alberta and Saskatchewan, and the southern part of Manitoba.

B2. Brief Outlook of Agronomic Practices for the Oleiferous *B. napus* (based on the Canola Growers Manual of the Canola Council of Canada, 1994 edition)

The oleiferous *B. napus*, a cool-season crop, is not as drought-tolerant as the cereals. It is widely adapted, and performs well in a range of soil conditions, providing that moisture and fertility levels are adequate. Air and soil temperatures influence canola plant growth and productivity. The optimum temperature for maximal growth and development is just over 20°C, and it is best grown between 12°C and 30°C. After emergence, seedlings prefer relatively cool temperatures up to flowering; high temperatures at flowering will hasten the plant's development, reducing the time from flowering to maturity.

Due to an increased awareness of soil conservation issues, minimal or no till canola production is advised, where most of the crop residue and stubble are left on the soil surface to trap snow, reduce snow melt run-off, stop erosion and increase soil water storage. Reduced tilllage techniques, however, are only effective when they are combined with a good systematic weed control program.

Weeds can be one of the most limiting parameters in rapeseed production. The closely related cruciferous weeds (wild mustard (*Sinapus arvensis* a.k.a. *Brassica kaber*), stinkweed (*Thlapsia arvense*), shepherd's purse (*Capsella bursa-pastoris*), ball mustard (*Neslia paniculata*), flixweed (*Discurainia sophia*), wormseed mustard (*Erysimum cheiranthoides*), hare's-ear mustard (*Conringia orientalis*) and common peppergrass (*Lepidium densiflorum*)) are often problematic. Oilseed rape does not compete with weeds in the early growth stages, because it is slow growing and slow to cover the ground. Weeds must be controlled early to avoid yield loss due to competition. Although rapeseed crops can be attacked by a number of insect pests, insect control must be carefully designed to reduce unnecessary and costly pesticide applications, chances of resistance buildup in insects, and damage to honeybees and native pollinating insects. Flea beetles and root maggots are the most important pests of oilseed rape. Diseases can be severe in large production areas, and are greatly influenced by cultivation practices and environmental factors, so that disease management programs are advisable.

When the first pods begin to shatter, *B. napus* is usually cut just below the level of seed pods and swathed. The use of dessicants allows a reduction of shattering, thus allowing direct combining.

Oilseed rape should not be grown on the same field more often than once every four years, to prevent the buildup of diseases, insects, and weeds. Volunteer growth from previous crops (buckwheat for example), and chemical residues from herbicides, are also important factors to consider when selecting sites.

B3. The Reproductive Biology of *B. napus*

Most *B. napus* cultivars grown in Canada are of the annual type, the species showing poor survival at temperatures lower than -6°C, although there is some production of fall-sown winter hardy types in the warmest part of southern Ontario. Fertilization of ovules usually result from self pollination, although outcrossing rates of 20 - 30% have been reported (Rakow and Woods, 1987). The pollen, which is heavy and sticky, is moved from plant to plant primarily through insect transmission. Cross pollination of neighbours can also result from physical contact of the flowering racemes. Successive generations of *B. napus* arise from seed from previous generations. There are no reports of vegetative reproduction under field conditions in Canada. However, reproduction via parthenogenesis (seed production without fertilization) has been reported in the *Brassica genus*. In some circumstances foreign pollen landing on the stigma surface is enough to induce the production of parthenogenic seed (Reiger *et al.*, 1999).

B4. The Centres of Origin of the Species[1]

The origins of *B. napus* (an amphidiploid with chromosome n=19) are obscure but were initially proposed to involve natural interspecific hybridization between the two diploid species *B. oleracea* (n = 9) and *B. rapa* (syn. campestris)2 (n = 10), (U 1935). Recent evidence (Song and Osborn, 1992) through analyses of chloroplast and mitochondrial DNA suggests that *B. montana* (n = 9) might be closely related to the prototype that gave rise to both cytoplasms of *B. rapa* and *B. oleracea*. It also suggests that *B. napus* has multiple origins, and that most cultivated forms of *B. napus* were derived from a cross in which a closely related ancestral species of *B. rapa* and *B. oleracea* was the maternal donor.

B4.1. Geographic Origin and Habitat of *B. oleracea*

First collected as a food in neolithic times (Prakash and Hinata, 1980), it is believed that all cultivated forms of the cabbage group originated from the wild species through mutation, human selection and adaptation. Although the origin of the various cultivar types is not fully understood, the conclusion that could be arrived at is that wild kale was the ancestral progenitor.

Chromosome structural changes do not seem to have played an important part in the development of the many different cultivar types because they are similar in genetic architecture to the wild type (Harberd, 1972).

The wild forms of *B. oleracea*, a suffrutescent (low, shrubby plant with woody lower parts of stems and herbaceous upper parts) perennial, grow along the coast of the Mediterranean from Greece through to the Atlantic coasts of Spain and France, around the coast of England and to a limited extent in Helgoland (Snogerup *et al.*, 1990). Typically, the wild type is found on limestone and chalk cliffs in situations protected from grazing. Individuals are often found below cliffs in scree where they grow among other shrubs, and some populations are found on steep grassy slopes. In Helgoland, populations are found on open rocky ground.

In Europe and North America, domesticated types have been reported as escapes, but do not form self sustaining populations outside of cultivation. *B. oleracea* is a recent introduction into North America.

B4.2. Geographic Origin and Habitat of *B. rapa*

Wild *B. rapa* (subspecies *sylvestris* L.) is regarded as the species from which the subspecies *rapa* (cultivated turnip) and *oleifera* (turnip-rape) originated. It is native throughout Europe, Russia, Central Asia and the Near East (Prakash and Hinata, 1980), with Europe proposed as one centre of origin. There is some debate as to whether the Asian and Near Eastern type arose from an independent centre of origin in Afghanistan which then moved eastward as it became domesticated. Prakash and Hinata (1980) suggest that oleiferous *B. rapa* subspecies developed in two places giving rise to two different races, one European and the other Asian.

Typically, *B. rapa* is found in coastal lowlands, high montane (the slopes of high valleys of mountain ranges) and in alpine and high sierras. In Canada, where it is a recent introduction, it is found in disturbed land, typically in crops, fields, gardens, roadsides and waste places (Warwick and Francis, 1994).

B4.3. Geographic Origin and Habitat of *B. montana*

B. montana, possibly a progenitor species of *B. napus*. (see above), also a suffrutescent perennial, originates from the Mediterranean coastal area between Spain and Northern Italy (Snogerup *et al.*, 1990).

It is found typically in or below limestone cliffs and rocks, walls, etc., often in disturbed ground. It is usually found in coastal areas and on rocky islets, but has been recorded at 1000m somewhat inland of the coast.

B4.4. Geographic Origin and Habitat of *B. napus*

B. napus is thought to have multiple origins resulting from independent natural hybridization events between *B. oleracea* x *B. rapa*. In Europe, predominantly the winter form has become a common yellow crucifer of roadsides, waste and cultivated ground, docks, cities and towns, tips, arable fields and riverbanks. In the British Isles, for instance, it has been naturalized wherever oil-seed rape is grown. It is a relatively recent introduction into Canada and the United States, and is described as an occasional weed, escape or volunteer in cultivated fields (Munz, 1968; Muenscher 1980). It is found typically in crops, fields, gardens, roadsides and waste places.

B5. Cultivated *B. napus* as a Volunteer Weed

As with all crops cultivated and harvested at the field scale, some seed may escape harvest and remain in the soil until the following season when it germinates either before or following seeding of the succeeding crop. In some instances the volunteers may give considerable competition to the seeded crop and warrant chemical and/or mechanical control.

Seed bank dynamics and seedling establishment may be important for the potential persistance of escaped transgenes. In particular, seed-oil modification genes are likely to affect seedling performance. For many angiosperms, seed oils are important to dormant seeds and to establishing seedlings prior to initiation of photosynthesis because no other energy or carbon sources are available (Levin, 1974). In addition, modified seed oil content may change mobilization and metabolization, thereby changing the proportion of seedlings surviving in the soil, the proportion of seeds emerging following germination, the timing of emergence, and seedling vigour (Linder and Schmitt, 1995). In many cases, maintenance of dormancy and cuing of germination in wild species is determined by the seed coat, which is maternal tissue. Hence the direction of pollen flow (gene transfer) between crops and their wild relatives may be very important (Linder, 1998).

If a transgene construction 1) increases crop-seed survivorship in the soil, 2) increases the probability that seeds will become dormant in the soil, and/or 3) alters germination cuing mechanisms so they correlate more closely with favourable environments for growth and reproduction, it will increase the the probability of transgene persistance (Linder and Schmit, 1995) and may alter the population dynamics of escaped crop seeds to effect community- and ecosystem-level dynamics (Linder, 1998).

The problem of volunteer plants in succeeding crops is common to most field crop species. Much depends on the management practices used in the production of the crop, e.g., whether the plants have disbursed seed at the time of harvest, the setting of the harvesting equipment, and speed of the harvesting operation which will determine whether more or less seed is lost by the harvester. With crops of the Brassica family, because of the small seed size and large number of seeds produced by the crop, poor management practices can result in severe volunteer problems in succeeding crops. Similar problems may be encountered with cultivated *B. juncea* and *B. rapa* varieties.

B6. Summary of Ecology of *B. napus* and its Progenitors

B. napus and its progenitors are plants of "disturbed land" habitats. In un-managed ecosystems these species may be considered "primary colonizers," i.e., plant species that are the first to take advantage of disturbed land where they would compete against plants of similar types for space. Unless the habitats are disturbed on a regular basis, such as on cliff edges, river edges and the edges of pathways made by animals, populations of these types of plants will become displaced by intermediaries and finally by plants that will form climax ecologies such as perennial grasses on prairies and tree species and perennial shrubs in forests.

In managed ecosystems, including roadsides, industrial sites and waste places, as well as crop lands, there is potential, because of their "primary colonizing" nature, for these species to maintain ever present populations, and it is in these habitat types that these species are recorded in the various flora of Canada and North America. Their success will be dependent on their ability to compete for space with other primary colonizers, in particular with successful weedy types. This, in turn, will depend on how well suited they are to the particular climate, soil conditions, etc. of individual sites.

In crop production systems, poor management practices may result in large numbers of seed of *B. napus* not being harvested, that may cause volunteer "weed" problems in succeeding crops, especially at high density.

B. napus is not listed as a noxious weed in the Weed Seed Order (1986). It is not reported as a pest or weed in managed ecosystems in Canada, nor is it recorded as being invasive of natural ecosystems. In summary, there is no evidence that in Canada *B. napus* has weed or pest characteristics.

Part C - The Close Relatives of *B. napus*

C1. Inter-species/genus Hybridization

Important in considering the potential environmental impact following the unconfined release of genetically modified *B. napus* is an understanding of the possible development of hybrids through interspecific and intergeneric crosses with the crop and related species. The development of hybrids could allow the introgression of the novel traits into these related species and result in:

- the related species becoming more weedy
- the introduction of a novel trait with potential for ecosystem disruption into the related species.

This section will be subject to updating, as more data become available. Based on background information provided in the present document, applicants will need to consider the environmental impacts of potential gene flow.

While many interspecific and intergeneric crosses have been made between *B. napus* and its relatives (Warwick and Black, 1993), many have necessitated intervention in the forms of ovary culture, ovule culture, embryo rescue and protoplast fusion. Reported here from the extensive review by Warwick and Black (1993) and Rieger *et al.* (1999) are *B. napus* and related species interspecific and intergeneric identified hybrids obtained sexually.

The following hybridizations were observed in field outcrossing studies reported by Bing *et al.* (1991).

- *B. napus* x *B. juncea* (Alam *et al.* 1992, Bing *et al.* 1991)
- *B. juncea* x *B. napus* (Alam *et al.* 1992, Bing *et al.* 1991)
- *B. napus* x *B. rapa* (Bing *et al.* 1991, Rieger *et al.* 1999)
- *B. rapa* x *B. napus* (Bing *et al.* 1991, Brown and Brown, 1996)

The following hybridizations were achieved through hand pollination (usually through emasculation of the female plant followed by transfer of pollen from the male plant using a paint brush).

- *B. napus* x *B. carinata* (Alam *et al.* 1992)
- *B. napus* x *B. nigra* (Bing *et al.* 1991)
- *B. nigra* x *B. napus* (Bing *et al.* 1991)
- *Diplotaxis erucoides* x *B. napus* (Ringdahl *et al.* 1987)
- *D. muralis* x *B. napus* (Ringdahl *et al.* 1987)
- *B. napus* x *Hirschfeldia incana* (*Brassica adpressa*) (Lefol *et al.* 1991)
- *H. incana* x *B. napus* (Lefol *et al.* 1991)
- *B. napus* x *Raphanus raphanistrum* (Lefol, E., R. K. Downey and G. Séguin-Swartz 1993 personal communication, Rieger *et al.* 1999)
- *B. napus* x *Sinapis arvensis* (Rieger *et al.* 1999)
  B. napus x *Sinapis alba* (Brown *et al.* 1997)

- *B. napus* x *Erucastrum gallicum* (Lefol, E., R. K. Downey and G. Séguin-Swartz 1993 personal communication)

Sexual hybrids derived through crosses between the various relatives of *B. napus* listed above, are as follows:

- *B. carinata* x *B. juncea* (Alam *et al.* 1992)
- *B. juncea* x *B. carinata* (Alam *et al.* 1992)
- *B. carinata* x *Sinapis arvensis* (Bing *et al.* 1991)
- *B. juncea* x *B. nigra* (Bing *et al.* 1991)
- *B. nigra* x *B. juncea* (Bing *et al.* 1991)
- *B. juncea* x *Sinapis arvensis* (Bing *et al.* 1991)
- *B. juncea* x *S. arvensis* (Bing *et al.* 1991)
- *B. oleracea* x *B. rapa* (Wojciechowski 1985)
- *B. rapa* x *B. oleracea* (Wojciechowski 1985)
- *B. rapa* x *B. nigra* (Bing *et al.* 1991)
- *D. muralis* x *B. rapa* (Salisbury 1989)
- *B. rapa* x *Raphanus sativus* (Ellerström 1978)
- *R. sativus* x *B. rapa* (Ellerström 1978)
- *H. incana* x *B. nigra* (Mattson 1988)
- *B. nigra* x *H. incana* (Mattson 1988)
- *R. sativus* x *B. oleracea* (Harberd and McArthur 1980)

For a trait to become incorporated into a species genome, recurrent backcrossing of plants of that species by the hybrid intermediaries, and survival and fertility of the resulting offspring, is necessary.

C2. Potential for Introgression of Genetic Information from *B. napus* into Relatives

Sinapis arvensis (wild mustard) is perhaps the most common of the weedy *Brassica* relatives, especially in the major canola growing areas of Manitoba, Saskatchewan and Alberta. A plant reported from the cross between *B. juncea* x *S. arvensis* was backcrossed into *B. juncea*, and into *S. arvensis* (Bing *et al.* 1991). The resulting plants were weak or sterile and produced no seed on open pollination suggesting that this cross would not result in the natural transfer of traits from either species being stably inserted into the other species.

Two other weedy species, *Raphanus raphanistrum* (wild radish) recorded to be more abundant in eastern Canada than in the prairie region, and *Erucastrum gallicum* (dog mustard) which may be locally quite abundant in croplands in the prairie provinces, formed hybrids with *B. napus* as the female parent. Field studies involving *B. napus* x *R. raphanistrum* have shown that not only are F_1 hybrids formed, but that these crosses had fertile pollen (0-65.4%), and resulted in a low number of F_2 or BC progeny (Rieger *et al.*, 1999).

Hybrids resulting from the *D. muralis* x *B. napus* and *D. erucoides* x *B. napus* crosses were male sterile (Ringdahl *et al.* 1987).

The same outcome was reported for backcrosses resulting from the hybrids produced from the *B. nigra* x *B. napus* cross.

Hybrid combinations that are successfully created using *B. napus* as a female parent might still be relevant to gene flow considerations, because their hybrid offspring can potentially act as genetic bridges.

C3. Occurrence of *B. napus* and Related Species in Canada

Of the above listed crosses, *B. carinata* and Hirschfeldia incana are not reported as present in Canada (Warwick, 1993), and *Diplotaxis erucoides* is reported as being rare in the Gaspé peninsula of Quebec. *B. oleracea*, apart from the wild types in their original habitats in Europe, is rarely found outside of cultivation. Of the other species:

- *B. napus* is recorded in the Northwest Territories, District of Mackenzie (NT-M), Labrador (LB), Newfoundland (NF), Prince Edward Island (PEI), Nova Scotia (NS), New Brunswick (NB), Québec (PQ), Ontario, (ON), Manitoba (MB), Saskatchewan (SK) Alberta (AB) and British Columbia (BC). *B. napus* is not listed in *Weeds of Canada* nor in *Weeds of Ontario*.
- *B. juncea* is recorded in NT-M, NF, NS, PEI, NB, PQ, ON, MB, SK, AB and BC. *Weeds of Canada* reports that it occurs in every province and reaches its greatest abundance in the western provinces. *Weeds of Ontario* indicates its distribution is similar to that of *S. arvensis* although it is generally less common;
- *B. nigra* is recorded in NF, NS, PEI, NB, PQ, ON, SK, AB and BC. *Weeds of Canada* suggests that it is not very common in western Canada. In Weeds of Ontario it is listed as occurring in a few localities in the south of the province especially in fields and waste areas bordering river valleys, and along railways;
- *B. rapa* is recorded in NT-M, YT (Yukon Territory), LB, NF, NS, PEI, NB, PQ, ON, MB, SK, AB and BC. *Weeds of Canada* suggests it is sometimes abundant and that in some parts of the East, bird rape, the wild form, supplants *S. arvensis* over large areas. Weeds of Ontario indicates it occurs in a few grainfields and waste areas in southern Ontario;
- *Diplotaxis muralis* is recorded in NS, PEI, NB, PQ, ON, MB, SK, AB, and BC. *Weeds of Canada* does not list this species. *Weeds of Ontario* indicates it usually occurs in coarse soils along roads, railways, beaches and around buildings and waste places in southern Ontario;
- *Erucastrum gallicum* is recorded in NF, NS, PEI, NB, PQ, ON, MB, SK, AB and BC. *Weeds of Canada* states that it reaches its greatest abundance in Manitoba and Saskatchewan where it inhabits fields, waste places, along railways, gardens, and orchards. It is very common on roadsides, and is an abundant field weed in many localities in Western Canada. In Ontario, it occurs throughout the province but is more common in southern Ontario where it is frequently found around railway yards, waste places, orchards, gardens, roadsides and occasionally in grainfields;
- *Raphanus raphanistrum* is recorded in LB, NF, NS, PEI, NB, PQ, ON, MB, SK, AB and BC. *Weeds of Canada* states that this species is very abundant in all provinces on the Atlantic seaboard. In Quebec and Ontario, it is of less importance and is reported to occur in the moister parts of Manitoba and Saskatchewan. *Weeds of Ontario* indicates that it is present in only a few scattered localities in Ontario where it infests cultivated fields and waste places;
- *Raphanus sativus* is recorded in NF, NS, PEI, NB, PQ, ON, MB, and BC. *Weeds of Canada* indicates that this species is occasionally persistent in gardens (as a result of cultivation);
- *S. arvensis* is recorded in NT-M, YT, LB, NF, NS, PEI, NB, PQ, ON, MB, SK, AB and BC. *Weeds of Canada* lists it as one of the most common annual weeds. It occurs in all provinces where the most serious infestations are probably in the rich river valleys of the West. Its habitats include grainfields, cultivated fields, waste places, fence rows and roadsides. *Weeds of Ontario* indicates that it occurs throughout Ontario being most frequent in cultivated fields and gardens but occasionally appearing in fence lines, along roadsides and in waste areas.

C4. The Agro-ecology of Weedy Relatives of *B. napus*

Of the relatives discussed, *S. arvensis*, *R. raphanistrum* are listed as primary noxious weeds in the *Weed Seeds Order, 1986* and *E. gallicum* is listed as a secondary noxious weed. These three species are potentially the weediest in agricultural crop lands. All are relatively easily controlled in crops of species other than *Brassica* by the use of selective herbicides.

The abundance of these three species in agricultural croplands is partly determined by the cropping practices. Weed species prominence can be dramatically affected by cropping systems and cultivation practices. The recent adoption of minimum and no till crop production systems, and the abandonment of cultivated summerfallow practices as a means of soil conservation, have caused a shift in the prominence of different weed species.

The above listed species are all plants of "disturbed land" habitats. Their success will be dependent on their ability to compete for space with other primary colonizers, in particular with other successful weedy plant types. This in turn will depend on how well suited they are to the particular climate, soil conditions, seed sensitivity etc. of individual sites.

Part D - Potential Interactions of *B. napus* with Other Life Forms

Table 1 is intended to guide applicants in their considerations of potential impacts the release of the PNT in question may have on non-target organisms, but should not be considered as exhaustive. Where the impact of the PNT on another life form (target or non-target organism) is significant, secondary effects may also need to be considered.

Table 1. Potential interactions of *B. napus* with other life forms during its life cycle

Other life forms	Interaction with *B. napus* (Pathogen; Symbiont or Beneficial Organism; Consumer; Gene transfer)
Albugo candida	Pathogen
Alternaria spp.	Pathogen
Botrytis cinerea	Pathogen
Erysiphe spp.	Pathogen
Leptosphaeria maculans	Pathogen
Peronospora parasitica	Pathogen
Plasmodiophora brassicae	Pathogen
Pythium debaryanum	Pathogen
Rhizoctonia solani	Pathogen
Sclerotinia sclerotiorum	Pathogen
Xanthomonas spp.	Pathogen
Turnip mosaic virus	Pathogen
Aster yellows mycoplasma	Pathogen
Flea beetle	Consumer
Mychorrhizal fungi	Symbiont or Beneficial Organism
Birds	Consumer
Animal browsers	Consumer
Soil microbes	Symbiont or Beneficial Organism
Earthworms	Symbiont or Beneficial Organism
Soil insects	Consumer
other *B. napus*	Gene transfer
B. rapa	Gene transfer
B. juncea	Gene transfer

B. nigra	Gene transfer
Raphanus raphanistrum	Gene transfer
Erucastrum gallicum	Gene transfer

Part E - Bibliography

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[1] Effectiveness of crossing, pollen tube growth, embryogenesis. Genetica Polonica 26: 423-436.

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