Canadian Food Inspection Agency

The Biology of *Linum usitatissimum* L. (Flax)

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Biology Document BIO1994-10: A companion document to the 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

Since 1988, Agriculture and Agri-Food Canada has been regulating the field testing in Canada of agricultural and horticultural crop plants with novel traits (PNT's). "Plants with novel traits" 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 PNT's can either be derived from recombinant DNA technologies, or from traditional plant breeding. Regulated field testing is necessary when the PNT's 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 of the same species already in use, and regarded as safe.

Before PNT's may be authorized for unconfined release, they must be assessed for environmental safety. The **Directive 94-08** (Dir94-08), entitled "*Assessment Criteria for Determining Environmental Safety of Plants with Novel Traits*", has 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 is a companion document to **Dir94-08**. It is intended to provide background information on the biology of *Linum usitatissimum* L., its centres of origin, its related species, and the potential for gene introgression from *L. usitatissimum* 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 Dir94-08. Specifically, it will be used to determine whether there are significantly different/altered interactions with other life forms, resulting from the PNT's 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 *L. usitatissimum* 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 *L. usitatissimum*

B1. General Description, Cultivation and Use as a Crop Plant

L. usitatissimum L. is a species of the family *Linaceae* (Flax family). It is an erect, herbaceous annual which branches corymbosely above the main stem (Fernald, 1950). Two types of *L. usitatissimum* are cultivated: the linseed type, grown for oil extracted from the seed, is a relatively short plant which produces many secondary branches compared to the flax type, grown for the fibre extracted from the stem, which is taller and is less branched (Gill, 1987). *L. usitatissimum* has a short tap root with fibrous branches which may extend 90 - 120 cm in light soils. Leaves are simple, sessile, linear-lanceolate with entire margins, and are borne on stems and branches. The inflorescence is a loose terminal raceme or cyme. Flowers are borne on long erect pedicels, are hermaphrodite, hypogynous and are composed of five sepals, five petals (blue), five stamens, and a compound pistil of five carpels each separated by a false septum. The fruit is a capsule, composed of 5 carpels and may contain up to 10 seeds. The seed is oval, lenticular, 4-6 mm long with a smooth, shiny surface, brown to light-brown in colour. Seeds contain 35-45% oil and 20-25% protein (Gill, 1987; Fernald, 1950).

Canada is a major producing country along with Argentina, India, the USA and Russia; most Canadian flaxseed is exported as linseed. Traditionally, the oil pressed from the seed (linseed oil) has been used for a variety of industrial purposes and the oil-free meal could be fed to livestock (boiling with water is advised to counteract the effect of the cyanogenetic glycoside linamarin). There is no commercial production of fibre flax in Canada. Recently, plant breeders have been successful in developing a low linolenic-acid edible oil flax for human consumption. In addition to usage of seed for industrial purposes, whole flaxseed is used extensively in baked goods in Europe (Daun, 1993).

Flax is grown primarily in the three prairie provinces of western Canada, specifically in southern Manitoba, Saskatchewan and Alberta. It grows best on heavy loam soils that retain moisture well. Because of its limited root system, flax does not grow well on sandy, moisture-limited soils. Flax is moderately tolerant to salinity provided that soil nutrients are present at adequate levels and that moisture is not limiting at germination. Good weed control is essential as flax is a poor competitor.

Flax may be grown in rotation with cereals or corn but not following potatoes or sugar beets (because of problems with root diseases) or following a previous flax crop. A three-year period is recommended between flax crops to avoid fusarium wilt. Flax may grow poorly after canola or mustard; control of volunteers may minimize the detrimental effects.

Shallow tillage prior to seeding is recommended; this provides a firm seedbed and reduces the number of weed seeds brought to the surface. No or minimum till practices are also beneficial because of better soil organic matter content, moisture retention, and reduced crusting problems that can impair seedling emergence (Daun, 1993).

Seeding is usually done when soil temperatures are warm (mid-May on the prairies), at a rate of 30 to 40 kg/ha and no deeper than 2.5 to 4 cm. If the seed coat has been damaged at harvest, soil-borne fungi may infect the seed; therefore, seed treatment with a fungicide will increase seedling emergence and vigour. Flax does not require as much fertilizer as cereals but will benefit if nitrogen or phosphorus is limiting.

Most varieties of flax are resistant to wilt (*Fusarium oxysporum* f. sp. *lini*) and rust (*Melampspora lini*). Rhizoctonia root rot may be a problem under certain conditions. Weeds must be controlled in the flax crop to minimize losses due to competition.

Flax is usually swathed when 74% of the seed bolls (capsules) have matured and turned brown and, when dry, it can be threshed with a combine. If both plant and seeds are sufficiently dry, straight combining can be done. The combine must be adjusted carefully when threshing flax to prevent seed coat damage and loss of seeds to the ground (Daun, 1993).

B2. The Centres of Origin of the Species

The origins of *L. usitatissimum* L. (n = 15), one of the oldest of cultivated plants is uncertain (Lay and Dybing, 1989). Remains of flax, possibly *L. angustifolium* Huds. (n = 15), have been found associated with archaeological remains of early civilizations. The most likely progenitor is *L. angustifolium* but other species such as *L. bienne* Mill. may have contributed some germplasm (Lay and Dybing, 1989). It is generally accepted that, because of the very diverse forms of flax found in an area east of the Mediterranean Sea towards India, flax originated in this area (Zeven and Zhukovsky, 1975). Seed-type flax grown for expressible oil was grown in southwestern Asia, while the fibre types were developed primarily in the Mediterranean. Lay and Dybing (1989) suggest that selection for annual plants with indehiscent or partially dehiscent seed-bearing capsules has resulted in genotypes suitable for modern agriculture.

B3. The Reproductive Biology of *L. usitatissimum*

Cultivated flax is an annual reproducing by means of seed. Because of its flower structure and because its "sticky pollen" is rarely transferred by insects (Beard and Comstock, 1980), flax is a highly self-pollinated species. The pollen is viable for only a few hours, from the time of anther dehiscence until about the time the petals dehisce - between 4 and 7 hours (Lay and Dybing, 1989; Dillman, 1938). As the flower opens, the anthers come together and form a cap over the stigma. Dillman (1938) in studying natural crossing in flax reported the range of natural crossing from 0-5%, there being variation among genotypes. In over 8,000 observations in the flax variety "Bison" no natural crossing was observed.

B4. Cultivated *L. usitatissimum* 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 the 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. 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.

B5. Summary of Ecology of *L. usitatissimum* and its Progenitors

L. usitatissimum and its progenitors are plants of "disturbed land" habitats. In un-managed ecosystems these species may be considered as "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, open sites where soil is light or sandy and windblown, 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 crop production systems, poor management practices or other circumstances may result in large numbers of seed of *L. usitatissimum* not being harvested and thus finding their way back to the soil. These seed may cause volunteer "weed" problems in succeeding crops, especially if they occur at high density.

Part C - *L. usitatissimum*: Related Species

C1. Inter Species/Genus Hybridization

Important in considering the potential environmental impact following the unconfined release of genetically modified *L. usitatissimum* is an understanding of the possible development of hybrids through interspecific and intergeneric crosses between the crop and related species. Development of hybrids could result in the introgression of the novel traits into these related species and resulting in:

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

The genus *Linum*, to which *L. usitatissimum* belongs, contains more than 100 species differing in chromosome number from 2n = 16, 18, 30, 36 and 60 (Seetharam, 1972). Among nine *Linum* species with chromosome 2n = 30, Gill and Yermanos (1967a) reported the following successful hybridization events with *L. usitatissimum* as one of the parents:

- *L. usitatissimum* x *L. angustifolium*
- *L. usitatissimum* x *L. africanum*
- *L. corymbiferum* x *L. usitatissimum*
- *L. usitatissimum* x *L. decumbens*
- *L. nervosum* x *L. usitatissimum*
- *L. pallescens* x *L. usitatissimum*

Seetharam (1972) reported the following successful crosses among *Linum* species with 2n = 30:

- *L. angustifolium* x *L. usitatissimum*
- *L. hirsutum* x *L. usitatissimum*
- *L. floccosum* x *L. usitatissimum*

- *L. tenue* x *L. usitatissimum*
- *L. africanum* x *L. usitatissimum*
- *L. pallescens* x *L. usitatissimum*

and, Bari and Godward (1970) the following:

- *L. africanum* x *L. usitatissimum*
- *L. pallescens* x *L. usitatissimum*

Seetharam (1972) attempted crosses between different species having different chromosome numbers, but without any success. Gill and Yermanos (1976b) reported similar results.

C2. Potential for Introgression of Genes from *L. usitatissimum* into Relatives

None of the species listed in section C1. above are reported in the Canadian flora. The commonest wild *Linum* species reported is *L. lewisii* Pursh, a perennial with a chromosome number 2n = 18. Moss (1983) reports that *L. rigidum* Pursh, a large, yellow-flowered annual, is present on open slopes and grasslands of southern Alberta; it has also been reported on dry open soil in Manitoba (Fernald, 1950). Budd (1987) reports that *L. rigidum* is common locally on sandhills and on very light sandy soils. It is not generally common, but plentiful where found. Scoggan (1978) reports a similar distribution for *L. rigidum*. There are no reports of hybridization between *L. usitatissimum* and *L. rigidum*. There appear to be no relatives in Canada with which *L. usitatissimum* can outcross to form hybrids.

C3. Occurrence of *L. usitatissimum* in Canada

Other than in cultivation, *L. usitatissimum* is reported found as an escape in waste places and along roadsides.

Part D - Potential Interactions of *L. usitatissimum* 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 *L. usitatissimum* with other life forms during its life cycle

Other life forms	Interaction with *L. usitatissimum* (Pathogen; Symbiont or Beneficial Organism; Consumer; Gene transfer)
Melampsora lini	Pathogen
Fusarium oxysporum f. sp. *lini*	Pathogen
Septoria linicola	Pathogen
Rhizoctonia solani	Pathogen
Polyspora lini	Pathogen
Colletotrichum lini	Pathogen
Seedling blight (specify)	Pathogen
Other diseases (specify)	Pathogen
Aster yellows	Pathogen

mycoplasma	
Flax bollworm	Consumer
Aphid	Consumer
Beneficial insects	Symbiont or Beneficial Organism
Mychorrhizal fungi	Symbiont or Beneficial Organism
Soil insects	Consumer
Earthworms	Consumer
Soil microorganisms	Symbiont or Beneficial Organism; Consumer
Birds	Consumer
Animal browsers	Consumer
Other *L. usitatissimum* plants	Gene transfer

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Date modified: 2012-03-05