THE ECOLOGY OF WILD TOMATO (*SOLANUM TRIFLORUM* NUTT.)

IN

WHEAT AND LENTIL PRODUCTION SYSTEMS

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ABSTRACT

Studies were conducted to determine the potential of wild tomato (*Solanum triflorum* Nutt.) to cause yield and biomass losses in lentil (*Lens culinaris* Medik.) and wheat (*Triticum aestivum* L.), a potential clean-up crop. Wild tomato emergence patterns, survival, seed production and soil seedbank dynamics were also examined. The study sites were located near Delisle, Laird, and Vonda, SK., from the spring of 1991 to mid-summer of 1993. Seed yield of wheat was reduced at one of four sites, and seed yield of lentil was reduced at three of six sites. In general, wild tomato seedlings emerged from early May to mid-July. Peak emergence occurred around 1 June, varied from 2 to 3 weeks among locations. More than 4,000 and 50,000 wild tomato seeds m^{-2} were produced in wheat and lentil, respectively. Wild tomato seed bank estimates ranged from about 600 seeds m^{-2} to greater than 40,000 seeds m^{-2}. Approximately 0.5% to 20% of the seed bank emerged throughout the season. Wild tomato can cause severe difficulties during the harvest of lentil crops. Wild tomato seed is spread by harvest equipment during the harvesting of lentil crops. Farm managers should manage wild tomato patches separately from the rest of the field, practice pre-seeding tillage, grow competitive clean-up crops, and encourage Colorado potato beetles which can have a large impact on the duration, competitive ability and seed production of wild tomato plants.

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INTRODUCTION

Lentil (*Lens culinaris* Medikus) production in Saskatchewan began in 1970 when 600 hectares were grown at Eatonia, SK. (Slinkard and Holm 1993). Since that time, Saskatchewan lentil production has increased to 300,000 hectares (Saskatchewan Agriculture and Food 1992).

Lentil is a poor competitor and yield can be reduced severely without effective weed control (Saxena and Wassimi 1980). Yield loss in a lentil crop depends on the relative weediness of the land, the weed species involved, soil fertility, and soil moisture (Basler 1981, Salkini and Nygaard 1983).

Volunteer cereals establish quickly and can overgrow a lentil crop (Basler 1981). Lentil yield is reduced greatly as the number of wild oat plants is increased from 0 to 150 plants per square meter (Slinkard and Holm 1993).

Broadleaf species, such as Russian thistle (*Salsola pestifer* A. Nels.) and kochia (*Kochia scoparia* L. Schrad.), can severely decrease lentil podding, interfere with swathing, increase dockage and increase the moisture levels of the harvested lentil seed (Slinkard and Holm 1993). Wild tomato (*Solanum triflorum* Nutt.) can interfere with the harvest operation and may cause a yield reduction in lentil (personal observation).

In Saskatchewan, metribuzin and ethalfluralin are the two herbicides most commonly used for broadleaf weed control in lentil. Metribuzin has very limited activity on wild tomato (Holm and Clayton 1991a,b and 1992a,b). Ethalfluralin has good to excellent activity on most nightshades (*Solanum* spp.) (Ogg and Rogers 1989) and is registered for nightshade suppression (Saskatchewan Agriculture and Food 1993). However, nightshade species vary in their response to herbicides (Vandeventer *et al.* 1982, Quakenbush and Andersen 1985, Ogg 1986, Ogg and Rogers 1989). In newly planted spearmint (*Mentha piperita*), ethalfluralin controlled between 55 and 95% of the hairy nightshade (*S. sarrachoides* Sendt.), but only 26 and 35% of the wild tomato (Esau and Kruger 1992a).

Lentil is a poor competitor (Saxena and Wassimi 1980), and the application of herbicides which control other weeds but not wild tomato, allows wild tomatoes to compete vigorously with the lentil crop (Holm and Slinkard, personal communication). Lentil is sensitive to herbicides, and most herbicides will cause some crop injury (Slinkard and Holm 1993), resulting in further loss of competitiveness.

Many herbicides used in wheat (*Triticum aestivum* L.) will control wild tomato, if the herbicide is applied at the proper growth stage of wild tomato (Holm and Clayton 1991c,d and 1992c,d). Wheat is much taller than lentil and forms a dense canopy sooner. Therefore, wheat provides strong competition and may be effective in limiting recharge of the wild tomato seed bank.

Wild tomato reproduces via seeds. In the absence of competition, a single wild tomato plant may grow up to 1.5 m in diameter and produce more than 1000 berries (personal observation). Each berry may have between 75 and 90 seeds (Ogg and Rogers 1989). The seeds may lie dormant in cultivated soil, allowing seed germination over several years (Chepil 1946, Ogg and Dawson 1984). Therefore, data on seed longevity, germination, and seedling emergence are required before control practices are formulated (Ogg and Rogers 1989).

Nightshade berries and field pea (*Pisum sativum* L.) seeds are about the same size (Waller 1944). Wild tomato berries are difficult to remove from processing peas (Norman 1988), and the berries contain solasodine glycosides (Schulz *et al.* 1992), which makes them toxic and unfit for human consumption (Waller 1944, Majek 1981, Norman 1988 and Schulz *et al.* 1992). As a result, wild tomato can be a serious contaminant in processing peas (Waller 1944, Norman 1988).

Nightshade berries can cause problems during harvest of dry edible beans when the berry juice glues seed, soil and other material together and clog combine augers, sieves, rotors, and concaves (Majek 1981). Juice from the wild tomato berries mixes with dust and debris during lentil harvest, resulting in stained lentil seeds and reduced lentil quality (personal observations).

The objectives of this study were to determine: 1) the agronomic importance of wild tomato as a competitor in lentil and wheat production systems, 2) the emergence and survival patterns of wild tomato, 3) the extent and importance of the wild tomato seed bank, and 4) to recommend wild tomato control strategies.

LITERATURE REVIEW

2.1. Lentil

Lentil originated in the Fertile Crescent of the Near East, and is one of the oldest food crops known to man (Webb and Hawtin 1981). Human consumption of lentil began about 8000 years ago in the eastern Mediterranean region. Lentil is consumed primarily for its protein content and is often referred to as "poor man's meat" (Abu-Shakra and Tannous 1981).

Canadian lentil production began in 1970 when 600 ha were sown near Eatonia in West Central Saskatchewan (Slinkard and Holm, 1993). Since 1982, Saskatchewan lentil producers have seeded an average of 99,000 hectares annually and produced an average of 114,000 mt of lentil each year (Canada Grains Council 1992). In 1991/92, a record 203,800 mt of lentil was exported. Most of the 1991/92 lentil crop was exported to South America (Saskatchewan Agriculture and Food 1992).

2.1.1. Description

Lentil is a cool season food legume crop which is moderately resistant to high temperatures and drought (Slinkard and Holm 1993). The lentil plant is a light green, herbaceous plant with a slender stem and branches. The plants are relatively short (15 to 75 cm), and do not normally form a dense canopy except in excessively cool, wet seasons (Basler 1981, Saxena and Hawtin 1981, Salkini and Nygaard 1983, Slinkard and Holm 1993). Generally, lentil is shallow rooted and may suffer moisture stress sooner than deeper-rooted species (Basler 1981).

Lentil has an indeterminate growth habit and some stress is required during flowering to stimulate heavy pod set (University of Saskatchewan 1987). Under optimum growing conditions, lentil plants grow rapidly and can complete their life cycle in three to four months (Saxena and Hawtin 1981).

The cultivar, Laird, is adapted to the Brown and Dark Brown Soil zones of Western Canada, but can be grown in the southern part of the Black soil zone if sown early (Slinkard and Holm 1993). Laird lentil requires an average of 101 days to mature and reaches an average height of 43 cm. However, under cool moist growing conditions, Laird lentil produces excess vegetative growth, which leads to disease development, delayed maturity, and reduced seed yield (Alberta Pulse Growers Association 1993).

In Saskatchewan, lentil should be sown before May 15. Early seeding produces taller plants and increased podding, resulting in higher yield (Slinkard and Holm 1993).

2.1.2. Lentil Seed Size

Lentil types may be separated by seed coat colour, cotyledon colour and growth habit. However, the most commonly used characteristic is seed size (Alberta Pulse Growers Association 1993).

The Persian-type, or small-seeded lentil, has rounded seeds, about 2 to 6 mm in diameter; with yellow or red cotyledons. The seeds weigh approximately 25 to 35 g 1000 $seeds^{-1}$ (Slinkard and Holm 1993). Eston is the main Persian-type lentil grown in Saskatchewan and occupies about 7% of the total lentil acreage (Slinkard and Holm 1993, Saskatchewan Agriculture and Food 1992).

Chilean lentil seeds weigh about 50 to 70 g 1000 $seeds^{-1}$, and have yellow cotyledons. The testa is pale green and may be speckled (Webb and Hawtin 1981, Slinkard and Holm 1993). Laird is the main cultivar of Chilean lentil grown in Saskatchewan, and occupies about 93% of the total lentil acreage (Slinkard and Holm 1993, Saskatchewan Agriculture and Food 1992).

2.1.3. Acreage and Distribution

Canadian producers grow approximately 121,500 hectares of lentil, and produce approximately 141,700 mt annually. In the 1991/92 crop year, Canadian lentil producers produced 342,800 mt; of this amount, a record 203,800 mt were exported; mostly to South America (Saskatchewan Agriculture and Food 1992). Eighty percent of the total Canadian lentil crop is produced in Saskatchewan, while Manitoba and Alberta produce about 17% and 3%, respectively (Canada Grains Council 1992).

2.1.4. Weed Competition in Lentil

The main problem in lentil production in Saskatchewan is weed control (University of Saskatchewan 1987). Yield loss may range from zero to nearly 100% depending on the number and kind of weeds present (Basler 1981). In Saskatchewan, stinkweed (*Thlaspi arvense* L.), wild oat (*Avena fatua* L.), Russian thistle (*Salsola pestifer* L.), green foxtail (*Setaria viridis* L.), wheat (*Triticum aestivum* L.), and wild mustard (*Sinapis arvensis* L.) were the six most common weeds found in lentil fields in 1985 (Douglas and Thomas 1985). Wild tomato was the twelfth most common weed in lentil crops.

Weeds will often comprise a large proportion of the total crop canopy and in a lentil field will reduce lentil yield by more than 20% (Salkini and Nygaard 1983). Broadleaf weeds are usually more prominent than grassy weeds and often make up more than 80% of the total weed population (Saxena and Wassimi 1980, Hernando *et al.* 1987).

The duration of weed competition plays a major role in determining lentil yield. In Syria, weeds present throughout the growing season caused a 60% reduction in lentil yield and about a 36% reduction in straw yield. However, yield increased 15 to 18%, if weeds were controlled between 60 and 90 days after planting (Saxena and Wassimi 1980). In Pantnagar, India, lentil is a popular winter crop. In this area the critical period for weed control in lentil was within the first 30 to 60 days (Saxena and Yadav 1976). In Pullman, WA, the critical lentil stage for wild oat interference occurred during the vegetative and early reproductive stages (between 5 and 7 weeks after crop emergence) (Curran *et al.* 1987).

Competition studies were conducted in 1984 and 1985 near Pullman, WA, using 'Chilean' lentil (Curran *et al.* 1987). The crop was sown at 56 kg ha^{-1} and the wild oat stand was established at 32 and 65 wild oat plants m^{-2}. By the 7th week of competition, lentil yield was reduced by 33 and 30% in 1984 and 1985, respectively, when the wild oat density was 32 wild oat plants m^{-2} (Table 2.1.). When the wild oat plants were allowed to compete all season, lentil yield was reduced a further 9 and 26%, respectively. At a wild oat density of 65 plants m^{-2}, lentil yield was reduced by 59% and 25% in 1984 and 1985, respectively, if the wild oat plants were allowed to compete to the seventh week. If the wild oat plants were left until harvest, lentil yield decreased a further 8 and 30%, respectively (Table 2.1).

Oat (*Avena sativa* L.) and yellow mustard (*Sanapsis alba* L.) are much stronger competitors than Laird lentil (Hornford 1987). When Laird lentil was sown at 80 kg ha^{-1}, 10 yellow

Table 2.1. The effect of wild oat density and duration on lentil seed yield with 32 and 65 wild oat plants m^{-2}.

Wild oat duration	32 wild oat plants/m^2 1984	32 wild oat plants/m^2 1985	65 wild oat plants/m^2 1984	65 wild oat plants/m^2 1985
(weeks)		(kg/ha)		
0	1422	1042	2580	1726
1	.....	985	.....	1789
3	1508	1033	2497	1695
5	1589	885	2561	1702
7	945	731	1062	1288
11	826	463	855	783
LSD(0.05)	290	225	506	260

From Curran et al. (1987)

mustard plants m^{-2} reduced lentil yield from 1451 kg ha^{-1} to 971 kg ha^{-1}. Similarly, 10 oat plants m^{-2}, reduced lentil yield to 884 kg ha^{-1}. At the same time, a lentil seeding rate of 40 kg ha^{-1} resulted in a lentil yield of 799 kg ha^{-1}. At ten yellow mustard or oat plants m^{-2}, the lentil yield was reduced by 11 and 20%, respectively. However, the seed yield of yellow mustard and oat increased by 172 and 53%, respectively.

When large-seeded Chilean lentil was sown at 120 seeds m^{-2}, increasing the yellow mustard density from 10 to 125 seeds m^{-2}, reduced lentil seed yield (Slinkard 1978). At the same time, yellow mustard seed yield increased dramatically.

Increasing the seeding rate of lentil from 30 to 120 seeds m^{-2}, did not reduce the negative impact of yellow mustard. At Morden, MB, increasing the seeding rate of Eston lentil from 40 to 120 kg ha^{-1} did not reduce the negative impact of weeds on lentil yield (Wall 1991).

2.1.5. Seeding Date

Unlike cereals, lentil has an indeterminate flowering habit and continues to set seed until growth is terminated by some environmental factor such as frost (Slinkard and Holm 1993). Therefore, in general, the earlier the seeding date, the greater the yield. In Saskatchewan, maximum lentil yield is achieved if lentil is sown before 15 May (Canada Grains Council 1978). Maximum yields were obtained in Manitoba by seeding lentil between May 8 and 23, with 15 cm row spacing and at a seeding rate that results in 100 plants m^{-2} (Ali-Khan and Kiehn 1989).

In Pradesh, India, lentil yield increased as the length of the growing season increased. The maximum yield was achieved when the lentil crop had 145 days to mature (Singh and Ram 1986).

Lentil seeds will germinate at temperatures as low as 3 to 4°C, and the seedlings will tolerate overnight frosts of -2 to -4°C (Muehlbauer and Slinkard 1983, Alberta Pulse Growers Association 1993). Seeding the lentil crop early provides the crop with a longer growing period and adequate heat units for normal growth and development, resulting in a higher yield (Singh and Ram 1986, Ali-Khan and Kiehn 1989). The increased yield is mainly due to increased branching, pods and seeds plant^{-1}, and 1000-seed weight (Singh *et al.* 1990). In addition, early seeding reduces the risk of early fall frosts which severely damage immature seeds (University of Saskatchewan 1987).

2.1.6. Seeding Rate and Row Spacing

Reports on the optimum sowing density for lentil are inconsistent. Each lentil cultivar has a specific optimum seeding rate, largely dependent on the seed size (Wilson and Teare 1972, Slinkard 1976). However, two lentil cultivars, differing in seed size and plant structure, also differed in optimum plant density when grown under similar environments (Tosun and Eser 1979). Each cultivar varied in its optimum between and within row spacing. Therefore, lentil seeding rates must be based on seeds per unit area (Slinkard 1976).

In Saskatchewan, the optimum seeding rate is about 100 seeds m^{-2}, or about 30 kg ha^{-1} for small-seeded Persian-types and about 50 kg ha^{-1} for the larger-seeded Chilean (Slinkard 1976). The extra large Laird lentil is often seeded at 90 kg ha^{-1} (Slinkard, personal communication).

In the absence of weeds, a 15 cm row spacing is optimum for both large-seeded and small-seeded lentil (Wilson and Teare 1972, Tosun and Eser 1979). However, Tosun and Eser

(1979) obtained the highest yield for small-seeded lentil at 15 cm row spacing and a 3 cm within row spacing. In addition, large-seeded lentil obtained the highest yield when sown in 15 cm row spacings and 3 cm within row spacing (Tosun and Eser 1979).

Wilson and Teare (1972) report that with a 30 cm row spacing and a 1.5 cm within row spacing, lentil plants which closed their canopies, intercepted about 90% of the incident light. However, very few large or small-seeded lentil types closed their canopy at the 30 cm row spacing. This resulted in decreased yield due to increased weed competition, decreased interception of incident light, and increased soil moisture loss (Wilson and Teare 1972).

Lentil yield per unit area is determined by the number of seeds pod^{-1}, pods peduncle^{-1}, peduncles plant^{-1}, and plants unit area^{-1} (Wilson and Teare 1972). The number of branches and peduncles plant^{-1} are inversely related to plant density (Singh and Ram 1986; Wilson and Teare 1972).

2.2. Wheat

Wheat is grown in 102 countries around the world (FAO 1989). Evidence suggests that wheat evolved from wild wheat-like grass plants in the Near East about 9000 years B.P. It is believed to be the first plant cultivated by man. Today, wheat is the most widely cultivated plant in the world and the chief cereal used for making bread (Hartmann *et al.*

1981). Today, Canada produces about 30,000,000 mt of wheat annually, 54% of which is produced in Saskatchewan (Canada Grains Council 1992).

2.2.1. Description

The major wheat-producing regions of the world are in the areas which lie between latitudes 30 and 60°N and 27 and 40°S (Percival 1921). The two main types of wheat grown are the durum wheats (*T. durum* L.), used for making macaroni, spaghetti and noodles, and common winter and spring wheat used in breads and pastries (Hartmann *et al.* 1981).

The hard red spring wheats are best adapted to the cooler temperate zones where the winters are normally too cold for winter types. These zones mainly correspond to the northern prairies of the United States, Canada, and the former Soviet Union. The soils are often deep, well drained, dark-coloured, fertile, and high in organic matter (Hartmann *et al.* 1981).

Wheat has a determinate growth habit. This means that after a certain period of vegetative growth, the reproductive phase begins, starting with a short anthesis phase, after which all photosynthate is diverted to seed formation and maturation. Then the plant dies.

Wheat yield depends on the number of spikes per unit area, and the number and weight of the kernels produced in each (Percival 1921). The actual number and weight of the kernels per spike, or unit area, depends on the environmental conditions during tillering, spike formation, anthesis, and during seed formation and maturation. Therefore, actual yield is influenced by the environment.

2.2.2. Acreage and Distribution

Canada grows about 13,000,000 hectares of wheat a year. Of this total, about 80% is spring wheat. Saskatchewan produces about 12,000,000 mt of spring wheat per year, Manitoba produces about 18% and Alberta produces about 25% of the Canadian spring wheat crop (Canada Grains Council 1992).

2.2.3. Weed Competition in Wheat

Weeds reduce the commercial value of grain, increase transportation costs, increase tillage cost, and above all they reduce crop yield (Godel 1935-36). Yield loss in cereal crops due to weeds is primarily the result of reduced size of heads, decreased tillering and reduced kernel weight.

Annual weeds are the most troublesome weeds because they mature early and produce a large amount of seed which shatters in the field before harvest (Godel 1938-39). Of the six most abundant weeds in cereal and oilseed crops in Saskatchewan, all but one were annuals (Thomas and Wise 1987).

Pavlychenko and Harrington (1934) showed that crop and weed species differ greatly in competitive ability and practically all weeds suffer greatly from competition with crop plants. They classified cereal crops in the order of competitive ability as: barley (*Hordeum vulgare* L.) > rye (*Secale cereale* L.) > wheat >< oat > flax (*Linum usitatissimum* L.). Wild mustard and wild oat were the most competitive weeds, followed by redroot pigweed (*Amaranthus retroflexus* L.) > lamb's-quarters (*Chenopodium album* L.) > cow cockle (*Vaccaria pyramidata* L.) > tumbling mustard (*Sisymbrium altissimum* L.) > hare's-ear mustard (*Conringia orientalis* L.) > wild buckwheat (*Polygonum convolvulus* L.) > Russian thistle > Russian pigweed (*Axyris amaranthoides* L.).

There is an interaction between weed density and crop density, and duration of competition. For example, as wild mustard density increased, wheat tillering decreased, which resulted in reduced straw and grain yield (Burrows and Olson 1955). However, if wild mustard was removed 18 days after emergence, wheat tillering was not reduced. In addition, at each level of mustard density, the number of wheat tillers increased as crop density increased. Carlson and Hill (1985) reported similar results in competition trials between wild oat and wheat. Wheat yields declined much faster in response to wild oat density at low wheat densities than at high wheat densities.

Interspecific competition between other weeds plays a major role in reduced crop yield. As shown by Alex (1970), wild mustard did not reduce the yield of wheat when cow cockle was also present. However, if cow cockle was not present, the yield of wheat decreased as the density of wild mustard increased. At a wild mustard density of 190 plants m^{-2} wheat yield was reduced by 38%. It took 314 cow cockle plants m^{-2} to produce a similar effect. When wild mustard and cow cockle were in mixtures, they compete with the crop as well as with each other. Consequently, their competitive effects were not additive, and their combined effect is similar to that of their individual effects.

Herbicides play a major role in reducing economic losses due to weeds. However, the consistent use of the same herbicide may cause a shift in the weed community. A density of 190 wild mustard plants m^{-2} reduced seed production of cow cockle by 50% (Alex 1970). At the same time, 314 cow cockle plants m^{-2} had very little effect on wild mustard seed production. When wild mustard was removed from the population by the application of 2,4-D, cow cockle seed production was no longer suppressed. As a result, cow cockle populations began to increase when 2,4-D came into general use (Alex 1970).

Similar results were reported by Hume (1989). When green foxtail was removed, wild buckwheat and other minor weeds such as lamb's quarters increased in importance as competitors. Hume (1989) concluded that removal of the dominant weedy species changed the nature of the weed community. As a result, different species became the major cause of yield loss.

Wheat cultivars differ in their response to competition with similar weeds. Green foxtail consistently reduced the tillering, leaf area, and dry weight of the semi-dwarf wheat (C.V. Norquay) more than normal-height wheat (C.V. Napayo or Sinton) (Blackshaw *et al.* 1981b). The magnitude of yield reduction was determined by the environment at the time of seeding. Germination and emergence of green foxtail are very dependent on soil temperature and moisture conditions at the time of seeding (Blackshaw *et al.* 1981a). Carlson and Hill (1985) suggest wild oat was more competitive in the short wheat cultivar used in their experiments than in tall wheat cultivars used by other researchers.

2.2.3.1. Seeding Date

In Saskatchewan, Godel (1938-39) found that, early sowing of wheat resulted in increased grain yield when compared to late sowing, and reduced the loss from weed competition. Seeding wheat in early May with phosphate fertilizer placed with the seed reduced the weed seeds in the harvested sample by 50%. Similarly, Williams (1969) found that in Harpenden, Hertfordshire, England, quackgrass (*Agropyron repens* L.) decreased tillering and number of ears produced by wheat to a lesser degree when spring wheat was sown early. Godel (1935-36) recommended early seeding which allows the cereal crop to get a head start on weeds, shallow seeding which results in quick crop emergence, and the application of fertilizers which encourage rapid crop development and reduce the incidence of browning root rot.

Wheat has a competitive advantage over green foxtail if sown when the soil temperature and available soil moisture are low. At a soil temperature of 12°C, green foxtail required 53 hours to reach 50% germination, while wheat required 12 hours. If the water potential was -6.5 bars, green foxtail germination was reduced to zero. However, wheat germination remained unchanged from a water potential of 0 to -15.3 bars (Blackshaw *et al.* 1981a). Wild oat (Carlson and Hill 1985), wild mustard (Burrows and Olson 1955, Alex 1970), and green foxtail (Blackshaw *et al.* 1981b, Hume 1989) competition varies in intensity with environment.

2.2.3.2. Seeding Rate

The optimal seeding rate of any crop depends on the length of the growing season, weediness of the land, temperature extremes, available moisture, heat units and location. Wheat grain yield is directly related to heads per unit area, kernels per head, and weight per kernel (Percival 1921, Burrows and Olson 1955, Bauder 1990). Variations in the size and shape of individual plants, as a consequence of intraspecific competition, can affect their competitive ability with other species (Godel 1935-36, Burrows and Olson

1955, Hume 1985). When wheat was sown at 67 kg ha^{-1}, 62 wild mustard plants m^{-2} reduced wheat yield (Burrows and Olson 1955). However, when wheat was sown at 135 and 202 kg ha^{-1}, between 247 and 494 wild mustard plants m^{-2} were required before wheat yield was reduced. The effect of wild oat competition on the yield of wheat decreased as the seeding rate of wheat was increased. On the other hand, as the density of wild oat plants increased, the yield of wheat decreased (O'Donovan *et al.* 1985). Therefore, seeding wheat at higher rates on weedy land, results in increased grain yield.

The result of increasing the seeding rate depends on the level of intra- and inter-specific competition. Wheat sown at approximately 67 kg ha^{-1} on clean land had larger spikes, stronger straw, increased kernel weight, and more tillers than wheat sown at 135 kg ha^{-1}. Wheat grain yield was similar at both seeding rates (Burrows and Olson 1955). Seeding at 202 kg ha^{-1} in plots free of wild mustard, resulted in a lower yield than seeding wheat at either 67 or 135 kg ha^{-1}. However, if weeds were present, seeding wheat between 135 and 202 kg ha^{-1}, resulted in the best overall yield (Godel 1938-39; Burrows and Olson 1955). A higher seeding rate in the absence of weeds resulted in increased intraspecific competition. In the presence of weeds, intraspecific competition was reduced, and interspecific competition increased as the seeding rate increased.

Seeding rates also affect the seed and biomass yield of weeds. As the seeding rate of wheat increased from 67 to 202 kg ha^{-1}, the dry weight of wild mustard decreased (Burrows and Olson 1955; Alex 1970). Godel (1938-39) found that increasing the seeding rate in combination with phosphate fertilizer placed with the seed, reduced wild oat seed production by 92% and wild mustard seed production by 58%.

2.2.3.3. Row Spacing

Higher seeding rates per unit area generally resulted in increased yield, and reduced the number of days to maturity for Glenlea, Pitic 62 and Neepawa wheat (Briggs 1975). Each time row spacing was increased and seeding rate held constant, yield decreased (Siemens 1963). Yield in the wider row spacings decreased because available moisture and nitrogen were not utilized. As the row spacing increased, significantly more soil moisture was available at harvest, and protein content of the grain increased.

In general, the key to maximum grain yield is to minimize intraspecific and interspecific competition for all available resources.

2.2.4. Relative Time of Wheat and Weed Emergence

Any advantages one plant may have over another in the early stages of development are extremely important in the final outcome of competition between them (Pavlychenko and

Harrington 1934). Earlier germinating species become established sooner than later germinating ones and, therefore, have an advantage in competition for important resources such as soil moisture, soil nutrients, and light (Pavlychenko and Harrington 1934, O'Donovan *et al.* 1985).

At five days after emergence, cereals had a much larger assimilation surface than all dicotyledonous weeds studied, except wild mustard (Pavlychenko and Harrington 1934). However, by the bloom stage of the crop, all of the weeds had a much larger assimilation surface than the cereals. Therefore, cereals are best fitted to competition with weeds when both are in the early stages of growth.

Plants that emerge before or with the crop cause the greatest loss in crop yield. For every day wild oat emerged before the crop, the crop yield was reduced by 3% (O'Donovan *et al.* 1985). Similarly, the intensity of green foxtail competition increases if it emerges before wheat (Blackshaw *et al.* 1981b, Hume 1989). For green foxtail, the relative time of emergence and the outcome of competition with wheat is very much dependent on environment. Temperature, moisture, and seedbed conditions will be most important in determining the relative time of wheat and green foxtail emergence (Blackshaw *et al.* 1981a, Peterson and Nalewaja 1992).

Cereals generally germinate much sooner than weeds under dry conditions and are able to establish more quickly.

Therefore, small grains have a distinct advantage over weeds when available soil moisture is limiting at the time of seeding (Pavlychenko and Harrington 1934).

2.3. Wild Tomato

The Blackfoot aboriginal name for wild tomato is "Omeka-ka-taw-wan" or translated "gopher berries" (Johnston 1987). The name refers to the occurrence of the species on mounds of dirt thrown up by burrowing animals (Budd 1952, Johnston 1987).

2.3.1. Description

2.3.1.1. Taxonomy

Wild tomato belongs to the Sect. *Solanum* of the genus *Solanum*, which is a cosmopolitan group of approximately 30 annual and short-lived perennial, herbaceous weeds, commonly known as the nightshades (Bassett and Munro 1985). In Canada, eight recognized species of nightshade are found, three of which are predominant weeds: black nightshade (*S. nigrum* L.), hairy nightshade (*S. sarrachoides* Sendt.) and eastern black nightshade (*S. ptycanthum* Dun.). In addition, wild tomato can be a serious weed in lentil production in Saskatchewan (personal observation).

2.3.1.2. Morphology and Growth Pattern

Wild tomato is an annual with a weak, branching stem that spreads over the ground. Because it usually forms a dense circular mat, it is sometimes referred to as "carpet-weed" (Swingle *et al.* 1920). These mats can reach diameters of 10 to 60 cm (Swingle *et al.* 1920, Budd 1952). However, in Saskatchewan, without competition, plants can cover areas greater than 1.5 m in diameter (personal observation).

Flock (1942) describes wild tomato as "resembling a garden tomato in miniature, except the fruit remains green when ripe". The leaves of wild tomato are deeply lobed, and about 1-2 inches long (Swingle *et al.* 1920, Budd 1952), with ill-smelling foliage (Ogg and Rogers 1989).

Wild tomato has an indeterminate growth habit. The plants begin to flower 4 to 6 weeks after emergence, continue to flower, and produce biomass as long as growing conditions are favourable (personal observation). Flowers usually occur in clusters of three, are white to bluish white, 5 to 10 mm in diameter, and similar in shape to those of the potato (Swingle *et al.* 1920, Budd 1952, Ogg and Rogers 1989).

Wild tomato reproduces by seed. One to three berries will mature in each cluster (personal observation), and each berry contains between 75 and 90 seeds (Ogg and Rogers 1989). The seeds are lemon yellow to light brown in colour, about 2 mm long, flattened, ovate, dull, and finely granular (Swingle *et al.* 1920, Ogg and Rogers 1989).

Wild tomato belongs to the group of *Solanum* species containing solasodine glycosides (Schulz *et al.* 1992). The fruits contain between 1.1 and 10 mg of glycoalkaloid g^{-1} dry wt., depending on the year and the time of harvest. Leaves and fruits are the most toxic. Wild tomato berries are unfit for human consumption (Norman 1988, Schulz *et al.* 1992), and poisonous to livestock (Great Plains Flora Association 1986).

The berries have been used as preserves by some, and have caused violent sickness when eaten by others (Budd 1952). The Blackfoot aboriginal people boiled the berries of wild tomato and these were fed to children as a cure for diarrhoea (Johnston 1987). In New Mexico, the Zuñi Indians eat the ripe fruits of wild tomato raw, or boiled, ground, and mixed with chile and salt (Yanovsky 1936). Flock (1942) reported that in the late fall deer have been seen grazing where wild tomatoes grew in abundance.

2.3.2. Distribution

Wild tomato is native throughout the western United States and Canada (Swingle *et al.* 1920, Groh and Frankton 1949, Budd 1952, Ogg and Rogers 1989). In Canada, it can be found from B.C. and the Peace River area, to Northern Quebec (Groh and Frankton 1949). However, it is widely distributed on the Prairies, where about 10% of those areas surveyed were occupied by wild tomato.

In Saskatchewan, wild tomato can be found throughout the province and in all of the major soil zones except the Grey luvisolic soils (Douglas and Thomas 1985; Thomas and Wise 1987).

2.3.3. Emergence Pattern

Species differ in their period of dormancy and frequency of emergence within the life span of their seeds (Chepil 1946). The period of seed dormancy is one of the greatest single factors contributing to the seriousness of a weed. Chepil (1946) showed that wild tomato has a characteristic periodicity of emergence and time of peak emergence. Under dry-land conditions at Swift Current, SK., wild tomato emergence began about the last week in April and continued until mid-July. About 88% of these seedlings emerged between mid-May and the end of May each year. A similar emergence pattern was reported by Ogg and Dawson (1984), but emergence began about one month sooner and wild tomato seedlings did not emerge after June. About 95% of the seedlings emerged in April.

Chepil (1946) reported that the periodicity and time of maximum emergence were similar within and between years. Wild tomato seeds which were in the soil over one winter, germinated at the same time as those which were in the soil for more than one season. However, Ogg and Dawson (1984) reported that under irrigation at Prosser, WA., wild tomato seeds which were in the soil over one winter, germinated sooner than seeds which remained in the soil more than one year.

The emergence of black nightshade and eastern black nightshade is stimulated by tillage (Ogg and Dawson 1984). Therefore, pre-seeding tillage could be used as a means to encourage early germination. On the other hand, tillage did not increase emergence of hairy nightshade or wild tomato. For this reason early tillage may not be useful in encouraging wild tomato emergence before seeding lentil.

Tillage generally reduces seedling emergence whenever tillage follows seed germination by a few days, and results in the killing of seedlings prior to emergence (Ogg and Dawson 1984). They concluded that, if the soil was tilled during the period of maximum emergence, the number of wild tomato seedlings would be significantly reduced.

2.3.4. Seed Dormancy

In two separate studies done on dry land near Swift Current, SK., Chepil (1946) found the dormancy of wild tomato seeds depended of the sample taken and the year of origin. About 94% of the wild tomato seeds which originated in 1937 emerged in 1938, 5% in 1939 and 1% in 1940. The remaining seeds were collected in the fall of 1940 and placed in shallow trays in the laboratory. Additional wild tomato seeds failed to germinate after repeated germination tests

(Chepil 1946). On the other hand, seeds collected in the fall of 1938 and placed in 1 cm of moist sand failed to germinate after repeated germination tests in the laboratory. However, about 55% of the wild tomato seeds which originated in 1938 and were sown in October 1938, emerged in 1939, 8% in 1940, 5% in 1941, and less than 1% each year up to the end of 1944. Repeated germination attempts up to January 1946 failed to germinate any of the remaining wild tomato seeds (Chepil 1946).

In a study conducted under irrigation at Prosser, WA., Ogg and Dawson (1984) sowed the equivalent of 18,000,000 wild tomato seeds ha^{-1} in November of 1976 and 1977. Of these wild tomato seeds, only about 13% germinated over a two-year period. Of this percentage, 74% emerged in the first year, and 26% the second year. In Saskatchewan, the majority of the weedy species with a seed dormancy greater than three years are serious agricultural weeds (Chepil 1946).

Majek (1981) reported that at low densities, the berries and green foliage of nightshade species can interfere with harvest operations and contaminate seeds . Therefore, even a low percentage of nightshade seedlings emerging later in the season may cause harvest difficulties (Quakenbush and Andersen 1984).

The pattern of seedling emergence from hairy nightshade berries was different from that of seedlings emerging from seeds removed from berries (Quakenbush and Andersen 1984).

Fewer hairy nightshade seedlings emerged from berries, and emergence began later than seedlings emerging from seeds. On the other hand, emergence of eastern black nightshade seedlings from berries was lower than from seeds in 1981, but higher than from seeds, in 1982. No published data are available on what, if any, influence the berry of wild tomato has on the dormancy of wild tomato seeds.

2.3.5. Chemical Control

In Saskatchewan, metribuzin and trifluralin are the two herbicides most commonly used for broadleaf weed control in lentil. Metribuzin has very limited activity on wild tomato (Holm and Clayton 1991a, 1992a). Trifluralin has poor activity on wild tomato. However, ethalfluralin, which is not registered for use on lentil, has good to excellent activity on most nightshades (Ogg and Rogers 1989), and is registered for nightshade suppression in some other crops (Saskatchewan Agriculture and Food 1993). However, nightshade species vary in their response to herbicides (Vandeventer *et al.* 1982, Quakenbush and Andersen 1985, Ogg 1986, Ogg and Rogers 1989). Eastern black nightshade was more easily controlled by ethalfluralin than was garden huckleberry (*S. scabrum* Mill.) (Vandeventer *et al.* 1982). In newly planted spearmint, ethalfluralin at 0.8 kg of active ingredient/ha, controlled about 55 and 23% of the hairy nightshade and wild tomato plants, respectively (Esau and

Kruger 1992a). However, at an application rate of 1.6 kg active ingredient/ha, ethalfluralin controlled 90 and 35% of the hairy nightshade and wild tomato, respectively. In a similar study in pea (*Pisum sativum* L.), an application rate of 0.8 kg of active ingredient/ha of ethalfluralin controlled about 28 and 35% of the wild tomato and hairy nightshade, respectively (Esau and Kruger 1992b).

In Saskatchewan, Holm and Clayton (1991a,b) reported that imazethapyr, pyridate and higher rates of fomesafen have potential as post emergent wild tomato control agents in lentil. All three herbicides caused some injury to lentil, but the degree of injury varied among tests. Further testing in 1992, showed that imazethapyr and pyridate gave adequate early control of wild tomato, but only imazethapyr controlled wild tomato all season (Holm and Clayton 1992a,b). Greater than 80% control of wild tomato was achieved when imazethapyr was applied at 0.025 kg ha^{-1} active ingredient along with 0.25% v/v Agral 90. Wild tomato plants treated with pyridate were initially controlled, but recovered later in the season (Holm and Clayton 1992a, b). Similar results were obtained in 1993, when 0.25% v/v Agsurf was applied along with imazethapyr (Holm and Stuber 1993a). Lentil yield was not reduced by the application of imazethapyr in either year (Holm and Clayton 1992a,b, Holm and Stuber 1993a). In pea, imazethapyr at 50 g ha^{-1} active ingredient plus 0.5% v/v Agsurf, controlled wild tomato and hairy nightshade (Esau and

Kruger 1992b). On the other hand, Holm and Clayton (1992a, b) reported 87, 90, and 91% control of the wild tomato at imazethapyr rates of 25, 37.5, and 50 g active ingredient ha^{-1}, respectively, when 0.25% v/v Agral 90 was added with the spray solution. However, at one site (Holm and Clayton 1992b) 50 g active ingredient ha^{-1} of imazethapyr caused significant loss in lentil yield. If herbicide rates are reduced to prevent lentil crop injury, it can be expected that the level of wild tomato control will also be reduced.

The appearance of wild tomato in wheat fields in the dry land area of the western United States has been associated with the increased use of chlorsulfuron and the decreased use of 2,4-D (Ogg and Rogers 1989). In Saskatchewan, evidence suggests that wild tomato occurs more often in lentil, than in wheat crops. After the application of herbicides, wild tomato was the 39th most common weed found in Saskatchewan wheat fields, occurring in 1.8% of all wheat fields surveyed (Thomas and Wise 1987). In a another survey of some lentil fields in Saskatchewan, wild tomato was the 12th most common weed and occurred in 12% all lentil fields surveyed (Douglas and Thomas 1985). Herbicides used in lentil crops control almost all other grassy and broadleaf weeds, but do not control wild tomato (Holm and Slinkard personal communication).

2.3.6. Cultural Control

Wild tomato may be spread long distances, apparently by birds and other animals, but farm operations apparently play a major role in its spread within a field and from field to field (personal observation). If stepped on, the seeds adhere to shoes and drop off where chance may dictate. Wild tomato was very scarce in Montana until the land was brought under cultivation, but by 1920 it was common in all older settled sections of the northwest United States (Swingle *et al.* 1920).

Wild tomato persists as a troublesome garden weed on the Canadian prairies (Budd 1952). It is quite tender and easily destroyed by cultivation. If left alone, it forms a dense mat that covers the ground. Good cultivation is the only remedial measure required to control wild tomato (Swingle *et al.* 1920). However, if pulled and turned upside down it can develop rootlets along the stems and continue to grow (Budd 1952).

The most effective cultural control practices for nightshades are timely cultivation (Ogg and Dawson 1984), hand hoeing, and providing adequate competition from crops that emerge rapidly and form a dense canopy early in the growing season (Ogg and Rogers 1989).

2.3.7. *Solanum* spp. and Harvest Loss

Swingle *et al.* (1920) reported that the seeds of wild tomato do not readily escape from the pulp of the berries and for this reason are not often found as an impurity in crop seeds. However, the berries of wild tomato are toxic and are not easily removed from commercially grown processing pea. Pea contaminated with nightshade berries has been condemned as unfit for human consumption (Norman 1988). The Great Plains Flora Association (1986) reported wild tomato was a serious weed in bean (*Phaseolus vulgaris* L.) fields on the High Plains of the United States.

Although nightshades can compete with the crop and reduce yields, the most serious problems result from hampering the harvest of soybean (*Glycine max* [L.] Merrill) and edible dry beans at low weed densities (Majek 1981). The plants are not affected by light frosts and do not readily dry up in the fall. The stems and leaves become a sticky mass after entering the combine and plug combine rotors and screens. The berries break open easily during the harvest operation and exude seeds and a clear sticky juice which coats the bean seeds and the combine. This sticky berry juice cements soil, nightshade debris, and bean seeds into a hard brick-like material which plugs augers and other parts of the combine. At high densities, soybean yield may be reduced, and dockage levels may be increased (Misra 1984). In addition, the juice increases the moisture content of the soybean seeds resulting in flow problems in augers, wagons and bins, and reduced storage time.

Late season densities of hairy nightshade, black nightshade, and wild tomato in dry edible pea, were correlated with row spacing. The density of nightshades increased as row spacing increased from 25 to 101 cm (Wilson *et al.* 1992). Each nightshade plant can produce up to 1000 berries which contain 50 or more seeds and clear sticky juice. As a result, soybean harvest can be stopped by one nightshade plant per 3 m of row (Majek 1981). The level of wild tomato control required to prevent lentil yield loss, may not be enough to prevent problems at harvest (personal observation).

Nightshade seedlings which appear after the crop is growing vigorously do not compete well, but often grow vigorously late in the season when soybean begins to mature or after a hail storm opens the crop canopy (Majek 1981). Wild tomato growth rate appears to increase as lentil leaves drop at the time of maturity (Slinkard personal communication). Control of the late emerging nightshade seedlings is required to eliminate harvest problems related to their presence (Majek 1981).

MATERIALS AND METHODS

3.1. Experimental Sites

The objectives of this study were to: 1) determine if wheat and lentil yield or biomass are reduced by wild tomato competition 2) determine the emergence and survival patterns of naturally occurring wild tomato populations, 3) determine the extent and importance of the wild tomato seed bank, 4) confirm complainants that wild tomato berries and foliage can seriously interfere with the harvesting of a lentil crop, and 5) suggest wild tomato control strategies.

Four wheat and six lentil sites were studied from the spring of 1991 to mid 1993. Two wheat sites were studied in each of 1991 and 1992. In 1991, two lentil sites were studied, while in 1992, four lentil sites were studied. All sites were used for each of the experiments. In 1993, seedbank samples were collected at all ten sites and emergence data were collected at the 1992 study sites up to mid 1993.

3.1.1. Site selection

Individual experimental sites were selected based on the uniformity of the crop stand and level of wild tomato infestation. An average wild tomato density of 25 plants m^{-2} was set as the minimum requirement. This was to ensure an adequate wild tomato population to carry out the study. The crop loss, wild tomato emergence and survival, and seedbank studies were carried out at each site in both wheat and lentil. In addition, information was collected on how wild tomato interferes during the harvesting of a lentil crop. Harvest difficulties were observed and testimonials of harvest difficulties obtained through the cooperation of farm managers in the area of the sites.

3.1.2 Site characteristics

The sites were located in Saskatchewan near Delisle (Dark Brown soil zone), Vonda (boundary between Dark Brown and Black soil zones) and Laird (Black soil zone).

In 1991, all sites were sown by individual farm managers who followed their individual agronomic practices. The Vonda sites were direct seeded using an air-seeder, while the Delisle and Laird sites were pre-worked and sown with a press-drill. At Delisle and Vonda, the wheat sites were sown on 17 and 30 May, and the wild tomato began to emerge around 25 May and 5 June, respectively (Table 3.1). At Laird and Vonda, the lentil were sown on the 15 and 20 May, respectively (Table 3.2). The wild tomato began to emerge around 24 and 30 May at Vonda and Laird, respectively. For additional agronomic information on cultivars, seeding rates, and fertilizer rates refer to Tables 3.1 and 3.2.

In 1992, one wheat and two lentil sites were sown by individual farm managers who followed their individual agronomic practices. Therefore, at these experimental sites, it was not possible to determine if wild tomato seedlings were starting to emerge prier to the pre-seeding tillage operations. The Laird wheat site, was sown on 18 May (Table 3.1) and wild tomato began to emerge around 25 May. The Laird(B) and Vonda (B) sites were sown on 19 and 20 May, respectively. At Laird(B) and Vonda(B), the wild tomato began to emerge around 22 May and 2 June, respectively.

The wheat site at Vonda, and the Laird(A) and Vonda(A) lentil sites were sown using a Haybuster zero-till press-drill. The lentil at the Laird(A) site were direct-seeded on 15 May (Table 3.2). The wild tomato density ranged from 1 to 25 plants m^{-2} at the time of seeding and the wild tomato plants were in the cotyledon stage. The field had been harrowed in the fall of 1991 to spread wheat straw and the lentil crop was sown directly into the standing stubble. The soil at this site was very hard and quite wet, and it was difficult to achieve an adequate seeding depth. As a result of clumping, many of the lentil seeds were not covered with soil and many wild tomato seedlings were destroyed during the seeding operation. Lentil emergence was poor, but the seedlings grew vigorously and competed strongly with the few

Table 3.1. Agronomic information for the wheat experimental sites in 1991 and 1992.

Experimental sites	Year	Cultivar	Seeding date	Seeding rate (kg/ha)	Fertilizer (kg/ha) P_2O_5	N
Vonda (91)	1991	Katepwa	May 30	101	31	6
Delisle (91)	1991	Laura	May 17	101	30	6
Vonda (92)*	1992	CDC Makwa	May 14	84	29	32
Laird (92)	1992	Biggar	May 18	101	25	67

*Wheat sown using a zero-till press-drill. Wild tomato plants were emerging at the time of seeding.

remaining wild tomato seedlings.

The Vonda wheat site and Vonda(A) lentil sites, were direct-seeded on 14 May (Table 3.1 and 3.2). The wild tomatoes density ranged from 0 to 45 plants m^{-2}, and the wild

Table 3.2. Agronomic information for the lentil experimental sites in 1991 and 1992.

Experimental site	Year	Cultivar	Seeding date	Seeding rate (kg/ha)	Fertilizer (kg/ha) P_2O_5	N
Vonda (91)	1991	Laird	May 20	134	28	6
Laird (91)	1991	Laird	May 15	95	0	0
Vonda (A/92)*	1992	Laird	May 14	134	26	28
Vonda (B/92)	1992	Laird	May 20	101	17	3
Laird (A/92)*	1992	Laird	May 15	134	26	28
Laird (B/92)	1992	Laird	May 19	110	0	0

*Lentil sown using a zero-till press-drill. Wild tomato plants were emerging at the time of seeding.

tomato were in the cotyledon to 2-leaf stage. The soil had been pre-worked about 1 to 2 weeks before seeding. The soil was soft and the wild tomato plants were distributed very little by the seeding operation. It was very difficult to maintain a uniform seeding depth and at times the lentil seed was sown below 7 cm. Lentil seedling emergence and vigour were very poor, apparently due to excessive seeding depth, and some root rot. As a result, only about one-half the lentil seeds sown produced plants. However, the wheat emergence was very good and wheat seedling development was rapid.

Soil samples were collected in the spring of 1993. The results indicate that all sites were non-saline, except the 1991 wheat site near Vonda (Table 3.3 and 3.4). For information on soil Ph, soil electron conductivity, available N, P, K, SO_4-S, and % organic matter, refer to Tables 3.3 and 3.4.

3.2. Weather

In general, the 1991 cropping season was warm and wet. Precipitation was well above normal up to July. Precipitation interfered with the setting up and maintenance of experimental sites, especially during June (Table 3.5).

The 1992 cropping season was cool and dry. Average monthly temperatures were generally at or below the 30-year normal (Table 3.5). July precipitation was about twice the normal for the month.

In 1993 the weather was cooler than normal (Table 3.5). June precipitation was about half that reported for June of 1991, but twice that for June 1992. In general crops were

Table 3.3. Soil analysis for wheat sites in 1991 and 1992.

Location	Soil depth	Soil texture	pH	Cond. (mS/cm)	N	P (kg/ha)	K	SO4-S	O.M. (%)
Vonda (91)	0-6	Loam	8.0	0.5	20	65	816	1040	3.5
	6-12	Clay loam	7.9	2.1	20	12	300	4560	
	12-24	Clay	8.1	2.5	54	7	412	13600	
Delisle (91)	0-6	Clay loam	7.4	0.1	26	71	940	12	4.1
	6-12	Clay loam	8.4	0.1	12	12	416	13	
	12-24	Clay loam	8.9	0.2	32	14	624	36	
Vonda (92)	0-6	Loam	8.4	0.2	22	91	548	140	3.6
	6-12	Loam	8.8	0.1	25	33	462	72	
	12-24	Clay loam	8.6	0.3	168	13	1132	152	
Laird (92)	0-6	Loam	7.5	0.1	44	27	518	26	5.8
	6-12	Loam	7.8	0.1	40	5	228	17	
	12-24	Loam	8.7	0.1	38	9	328	34	

very lush. However, in some areas, lentil yields were reduced because of diseases, and failure of lentil to set seed (A.E. Slinkard, personal communication).

3.3. Experimental Design and Procedures

3.1.1. Crop Loss Study

The objectives of the crop loss study were to determine if the yield and biomass of wheat and lentil is reduced by wild tomato competition.

Crop loss determinations were conducted in 10 fields: 6 lentil fields near Laird and Vonda, and 4 wheat fields near Vonda, Laird and Delisle.

Table 3.4. Soil analysis for lentil sites in 1991 and 1992.

Location	Soil depth	Soil texture	pH	Cond. (mS/cm)	N	P (kg/ha)	K	SO4-S	O.M. (%)
Vonda (91)	0-6	Loam	8.4	0.2	22	91	548	140	3.6
	6-12	Loan	8.8	0.1	25	33	462	72	
	12-24	Clay loam	8.6	0.3	168	13	1132	152	
Laird (91)	0-6	Loam	6.9	0.1	62	41	646	22	5.1
	6-12	Clay loam	7.1	0.1	16	11	216	29	
	12-24	Clay loam	8.2	0.1	11	14	352	33	
Vonda (A/92)	0-6	Loam	8.3	0.2	21	187	1174	4	3.7
	6-12	Clay loam	8.9	0.1	9	59	932	4	
	12-24	Clay loam	8.1	0.7	26	25	2340	4960	
Vonda (B/92)	0-6	Clay loam	8.3	0.1	32	33	452	12	2.5
	6-12	Clay loam	8.9	0.1	8	5	196	10	
	12-24	Clay loam	8.5	0.6	12	6	348	2400	
Laird (A/92)	0-6	Clay loam	7.6	0.1	26	48	520	12	4.8
	6-12	Clay	8.2	0.1	14	5	178	19	
	12-24	Clay	8.5	0.1	23	8	320	50	
Laird (B/92)	0-6	Clay loam	8.0	0.1	33	32	568	11	5.5
	6-12	Clay	7.1	0.1	16	7	266	10	
	12-24	Clay	8.9	0.1	23	8	364	400	

In both years, the experimental design was a RCDB. The treatment blocks were arranged randomly throughout the sites, and special attention was paid to the uniformity of the crop within a block. Each treatment appeared once within each block. The arrangement of treatments within each block was determined by tossing a coin. A buffer zone of 15 cm was left around each quadrat (Figure 3.1). Quadrats were

Table 3.5. Total monthly precipitation and average monthly temperature at weather stations near the test sites in 1991, 1992, and 1993.

Year and weather station	Exp. site	April		May		June		July		Aug.		Sept.	
		P[y]	T[z]	P	T	P	T	P	T	P	T	P	T
1991													
Aberdeen	Vonda	58	6	67	12	121	17	46	16	46	21	27	11
Carlton	Laird	48	5	78	12	143	16	28	18	55	20	31	11
Vanscoy	Delisle	49	6	50	12	147	16	31	19	15	21	16	11
1992													
Martens-ville	Vonda	13	5	30	11	24	15	99	16	44	16	44	10
Carlton	Laird	26	4	43	10	31	14	101	16	28	14	30	9
Vanscoy	Delisle	*	5	52	10	20	15	108	16	49	15	36	9
1993													
Saskatoon	Vonda	28	5	37	11	58	14	75	15	64	16	43	10
Carlton	Laird	44	4	13	12	81	14	97	15	*	*	*	*
Vanscoy	Delisle	15	5	43	11	97	14	93	15	*	*	*	*
Normal[x]	Saskatoon	20	4	44	12	59	16	54	19	37	17	32	11

*Data not available.
[x]Thirty-year normal from the Saskatoon weather station. Normals for the other weather stations are not available.
[y]P = Precipitation in mm.
[z]T = temperature in °C.

arranged across the crop rows so all treatment quadrats within each block were using the same crop rows. The distance left between adjacent quadrats was a minimum of 45 cm, which provided room for walking between quadrats without disturbing the 15 cm buffer zone (Figure 3.1). With a row spacing of 15 cm, each 133 x 75 cm (1 m^2) quadrat contained eight wheat or lentil crop rows. The short sides of the quadrats within a block were parallel to the crop row and centred between the last row inside the quadrat and the next adjacent row out side the quadrat.

In 1991, the wheat and lentil treatments consisted of a plot free of wild tomato all season (t1), and one where wild tomato plants were present all season (t2). The blocks were replicated 10 times in both wheat and lentil. In lentil, the quadrats were two m^2 (266 cm long X 75 cm wide) and

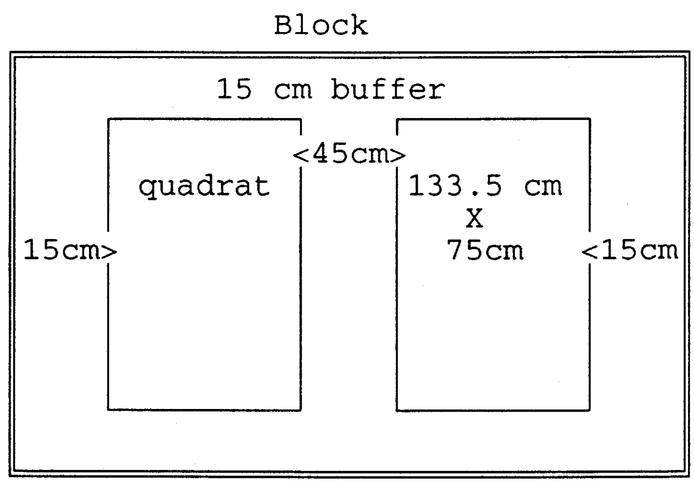

Figure 3.1. Schematic of block and quadrats for the crop loss studies in wheat and lentil in 1991 and 1992.

contained 16 lentil crop rows. In wheat, the quadrats were 1 m^2 (133 X 75 cm and contained 8 crop rows; Figure 3.1).

In 1992, an additional treatment was added to determine if removal of wild tomato at the early flowering stage in lentil, or early boot stage in wheat, would decrease the loss due to wild tomato competition (t3). In wheat, the treatment blocks were replicated 10 times. Since lentil emergence can be variable, the lentil treatment blocks were replicated 20 times. Each block contained three treatment quadrats and each treatment appeared once in each block. In 1992, all quadrats were 1 m^2 in both wheat and lentil.

In both years, weeds were removed from the weed-free check(t1) at emergence, or as soon as possible after crop emergence and the number of wild tomato seedlings removed was recorded. Additional wild tomato seedlings which emerged in t1 quadrats were removed every 1 to 2 weeks and their numbers recorded. The crop densities in all treatment quadrats, and the wild tomato densities within t2 and t3, (t3 only in 1992), were recorded before the branching stage in lentil, and before the wheat began to tiller. In 1992, the wild tomato density was also recorded when the wild tomato plants were removed from t3. In both years, the crop and wild tomato densities were recorded at harvest, along with the crop seed yield and biomass, and the wild tomato biomass. In 1992, cypermethrin (Cymbush) was applied to all the experimental sites to control Colorado potato beetle (CPB). The insecticide was applied on 25 June, at an application rate of 16 g active ingredient ha^{-1}. The lentil experimental sites required a second application of insecticide around mid-July.

It was not possible to do a combined analysis of years and locations within each crop because of the changes made in number of replications and treatments between years. However, it was of interest to pool the data for the same crops, but from different locations within a single year to remove the error for locations. Therefore, a test for homogeneity of error variances was conducted within crops and years, by comparing the error variance from each location to the pooled error over all locations.

The 1991 wheat and lentil, plus the 1992 wheat data were tested for homogeneity of error variances using the F-test as outlined by Gomez and Gomez (1983). In 1992, there were four lentil sites, therefore the error variances were tested for homogeneity using "Bartlett's test" as outlined by Steel and Torrie (1980).

The error variances for the 1992 wheat tested positive for heterogeneity. Therefore, the data for each wheat location was analyzed separately. The model for each wheat location consisted of:

Variate = μ + block + treatment + error

Means comparisons were determined by using the LSD(0.05). The F-test (Appendix A.2 and A.3), for treatments was non-significant for yield at Vonda and Laird. However, Chew (1977) states that with t treatments and (t-1) d.f., an F-test may be non-significant even when two or more treatments are significantly different. Chew explains that because the F-test for treatments is averaged over all treatment contrasts, the difference between two treatments may be masked by the overall non-significant difference between other treatments in the analysis of variance. Therefore, treatment contrasts should be considered even if the F-test is non-significant. As a result, the 1992 data on wheat yield and biomass at Vonda and Laird were subjected to a match paired t-test as a method for contrasting treatment differences. ie. yield for t2 was subtracted from yield for t1 within each block. The differences within each block, were stored in a separate column. The total number of entries in the column was equal to the number of replicates (blocks). A two-tail t-test was conducted on the column of differences. The null hypothesis was that the difference in yield or biomass between any two treatments within a block is equal to zero. The mean differences are presented in Tables 4.2 and 4.3, along with the standard deviation of the differences, and the calculated t-value.

The data for wheat and lentil in 1991, and lentil in 1992, were pooled over locations in each year and within the same crop (Steel and Torrie 1980). In each year the model consisted of:

$$\text{Variate} = \mu + \text{location} + \text{treatments} + \text{blocks within location} + \text{location*treatments} + \text{error}$$

Means comparisons were determined by calculating an LSD(0.05) (Steel and Torrie 1980). In addition, Satterthwaite's approximation was used to develop the approximate F-test and denominator df for locations.

3.1.2. Wild Tomato Demographics

3.1.2.1. Emergence and Survival

The objective of this study was to: 1) determine the emergence and survival patterns of naturally occurring wild tomato populations in Saskatchewan, and 2) record wild tomato seed production in wheat and lentil. This data will be of value in the development of wild tomato control strategies.

The emergence and survival of wild tomato plants were studied in wheat and lentil. Ten 1 m^2 (133 cm x 75 cm) quadrats were placed at random throughout each wheat and lentil site. The quadrats were placed across the crop rows, and each quadrat contained eight lentil or wheat rows. Weeds other than wild tomato were removed.

It was not always possible to place the quadrats out as soon as a site was located. Therefore, initially the different stages of wild tomato development were recorded each week until a site was selected. When the site was set up, the information collected on wild tomato development was used to separate the first cohort into 2 or 3 smaller cohorts. A cohort is defined as a group of seedlings emerging over a certain time period. Cohorts were separated by coloured cocktail straws. A different straw colour was used for each 1 to 2 week time period. Cocktail straws of the appropriate colour for that time period, were placed along side the stems of the newly emerged wild tomato seedlings. Special care was required to avoid damaging the seedlings. The number of wild tomato seedlings which emerged in every 1 to 2 week period, and the number that died, were recorded . This process continued throughout the growing season. Tables are presented for each site in wheat and lentil from 1991 and 1992, which indicates when wild tomato seedlings begin to emerge, how many emerged and survived every 1 to 2 week period, and the number of live wild tomato plants m^{-2} present on each counting date. The tables also indicate when peak emergence occurred and when emergence ceased.

In 1993, ten quadrats were placed randomly throughout the 1992 wheat and lentil sites, and the average number of wild tomato plants emerging each week was recorded. This process continued until mid-July when wild tomato emergence ceased.

3.1.2.2. Wild Tomato Seed Production

In the fall of each year wild tomato plants which survived the growing season were counted and collected by cohort from each quadrat. The number of wild tomato plants m^{-2}, and the number of berries produced by each cohort m^{-2} was recorded. In addition, the average number of seeds per berry was determined for each cohort using the following technique. Twenty wild tomato berries were randomly selected from each cohort within each a quadrat. The berries were crushed and the seeds washed into a 0.85 mm sieve. The number of seeds per berry was counted and recorded, and the mean and standard error were calculated. Not all cohorts within a plot produced 20 berries, therefore, the mean number of seeds per berry per plot is sometimes based on less than 20 berries. The estimated number of wild tomato seeds m^{-2} was calculated and averaged over the ten plots to develop the proper error term. In addition, the average number of wild tomato seeds per berry was determined for each cohort.

The viability of the wild tomato seeds was determined using tetrazolium as outlined by Ellis *et al.* (1985). In 1992, the wild tomato berries from the Vonda(A) experimental site were air dried at room temperature for six months before the seeds were extracted and tested for viability. The berries from the other five sites were initially oven dried at 35°C for 48 hours. However, the berries began to mould, therefore, the drying temperature had to be increased to 60°C to prevent spoilage. The dried berries were storied at room temperature for four months before the seeds were extracted and tested for viability. The viability of the seed from these five sites was much lower than for seed which had been air dried. Presumably, exposure to 60°C during drying reduced seed viability in most samples. Therefore the data from these five sites is not presented.

3.1.4. Seed Bank

3.1.3.1. Sampling and Storage

The objective of the seed bank study was to determine the extent and importance of the wild tomato seed bank in wheat and lentil to help in estimating the duration of the wild tomato seed bank and aid the development of wild tomato management strategies.

In 1991, 20 soil cores (depth of 10.2 cm and 5.7 cm in diameter) were collected from each site in both spring and fall. All cores were collected in a "W" pattern as outlined by Thomas (1985), with 5 samples taken on each arm of the "W". Because the sampling area was relatively small, cores were only 10 paces apart along each arm. The core samples from each site were bulked and frozen until they could be processed. The same procedure was followed in 1992 and 1993, except the individual seed bank samples from each site were kept separate, washed and counted individually. In addition core samples were taken at mid-season.

In 1993, all previous sites including those used in 1991, were sampled at mid-season. The 1991 Vonda lentil site was sown to wheat in 1992 and 1993, while the 1991 Laird lentil site was sown to field pea in 1992 and wheat in 1993. The 1991 Vonda wheat site was sown to lentil in 1992 and wheat in 1993. In 1992, the 1991 Delisle wheat site, was chem-fallowed, and sown to canola in 1993. The 1992 Vonda wheat site was sown to wheat in 1993, while the 1992 Laird wheat site, was sown to barley. In 1993, Vonda(A), Laird(A) and (B) were sown to wheat, while the 1992 Vonda(B) lentil site was sown to barley.

3.1.3.2. Sample Washing and Seed Extraction

The seed bank cores were washed through a 2 mm sieve and the wild tomato seeds were collected using a 0.85 mm screen. Once all the soil had been removed, the samples were washed into cheese cloth bags, and allowed to air dry. After the samples were dry, they were given a final sieving through a 2 mm screen followed by a 1.5 mm screen and collected in a 0.85 mm screen to remove additional debris. To aid seed extraction, white paper was spread out on the counter top and a sheet of clear glass was placed over the paper. Each core was spread out on top of the glass. The wild tomato seeds were removed from the samples using a magnifying glass and a micro-vac. The technique involves the use of a short pipette, a capillary tube, and some fun-tak to form a seal between the pipette and the capillary tube (Figure 3.2). A vacuum line is connected to the pipette and the wild tomato seeds are easily picked out of the samples.

The number of wild tomato seeds per core was recorded. When possible, 100 seeds from each site and sample date, were tested for percent viability using tetrazolium as outlined by Ellis et al. (1985). The average number of wild tomato seeds m^{-2} at each sampling date was estimated based on an average

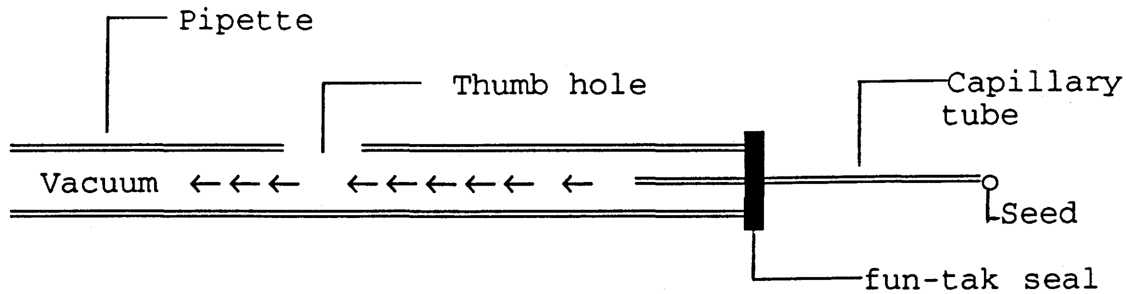

Figure 3.2. Schematic of micro-vac used to retrieve wild tomato seeds.

of the 20 cores.

The total number of seedlings, which emerged at each location was used to estimate the percentage of the spring and mid-season seedbank which emerged for that particular year. The average number of wild tomato seedlings which emerged up to July of 1993 at each of sites used in 1992 was used to estimate the percentage of the fall 1992 seedbank and mid-season 1993 seedbank which emerged in 1993.

3.4.4. Harvest Problems

The objectives of this study were: 1) to confirm complaints from some lentil producers that wild tomato berries and foliage can seriously interfere with the harvesting of a lentil crop and, 2) to confirm the suspicion that harvest equipment plays a major role in wild tomato seed distribution within a field. In addition, lentil seed samples were taken directly from combines during the harvesting of lentil crops to determine if wild tomato seed was stuck to the lentil seed.

In the fall of 1992, the harvest operation was observed in five lentil fields with various levels of wild tomato infestations. Wild tomato seeds are very sticky and adhere to farm equipment during harvest operations. Evidence collected shows how harvest equipment is aiding the distribution of wild tomato seeds within and between fields. Lentil seed samples were obtained from the clean grain tank of the combine at random intervals during the harvest operation within each field. A 100 gram sub-sample taken from each sample was examined to determine the number of wild tomato seeds stuck to the lentil seed, and the number of wild tomato seeds present in each sub-sample.

Lentil seeds are flat and it is hard to see both sides of the seed without flipping each one over. Therefore a drum was constructed with a 23 cm diameter and about 5 cm deep. A piece of clear glass was placed in one end and a mirror in the other. When the lentil sample is placed on the glass of the drum it is very easy to see both sides of the lentil seed without flipping each one over.

RESULTS AND DISCUSSION

4.1. Wild Tomato Competition in Wheat

In 1991, wheat canopy development occurred rapidly and by mid-July it was almost impossible to find the plots. Almost all sunlight was prevented from reaching ground level and the wild tomato plants. As a result, the wild tomato plants were almost all dead by mid-July, and neither wheat yield nor biomass were reduced by wild tomato competition at either site (Table 4.1 and Appendix A.1). Ogg and Roger (1989) state that generally, nightshade species are sensitive to crop competition, and shading can severely restrict plant growth and development.

In 1992, pocket gophers caused severe damage to block 7 at Laird so it was removed from the analysis. In addition, block 8 at Vonda was removed due to a what appeared to be a fertility or moisture gradient which ran right across the block and greatly increased variability.

At Vonda, in 1992, the wild tomato plants began to emerge 1 to 2 weeks before the wheat and ranged in density from 20 to 450 plants m^{-2}. The wheat canopy remained open all season, allowing berry production throughout the

Table 4.1. The effect of wild tomato competition on biomass and seed yield of wheat in 1991.

	Vonda			Delisle	
Treatment	Yield	Biomass		Yield	Biomass
	--------------------		($g\ m^{-2}$)	--------------------	
Weed-free	372	1027		245	941
Weedy	381	1064		242	933
LSD(0.05)	23	66		23	66

season. Although the F-test indicated that the treatment differences were not significant (Appendix A.2), a matched paired t-test indicated that wheat seed yield was reduced by 12%, and biomass by 10% (Tables 4.2). At \$111 $tonne^{-1}$ the economic loss is about \$30 ha^{-1}. Removing wild tomato during the early boot stage did not increase wheat yield or biomass. Had this site been sown later in the season, many of the wild tomato seedlings would have been destroyed by the pre-seeding tillage operations, and yield may not have been reduced.

The F-test for treatments for the Laird wheat site indicated that yield was not affected by the treatments (Appendix A.3). However, a matched paired t-test indicated that wheat yield was reduced by 16%, when the wild tomato plants were allowed to compete up to mid-season, but not if they were allowed to compete all season (Table 4.3). At this site, the wild tomatoes emerged at approximately the same

Table 4.2. The effect of wild tomato competition on wheat seed yield and biomass at Vonda in 1992.

Treatment	Yield[w] -------- ($g\ m^{-2}$) -------- Biomass[w]					
Weed-free	225			445		
Weeds removed at mid-season	231			458		
Weedy	198			401		
	Yield Means Comparisons[x]			Biomass Means Comparisons[x]		
	dif.[y]	S.E.D[y]	t[y]	dif.[y]	S.E.D.[y]	t[y]
Weed-free minus weeds removed at mid-season	-6	19	-0.3ns	-13	34	-0.4ns
Weed-free minus weedy all season	27	8	3.4**	44	19	2.36*
Weeds removed at mid-season minus weedy all season	33	24	1.4ns	56	45	0.2nsns

[w]Treatment means based on the average of 9 plots.
[x]Match pair t-test contrasting treatment differences, t = (0.025).
[y]dif. = difference; S.E.D. = Standard deviation; t = calculated t value.

time as the wheat, and the wild tomato densities were approximately half that at Vonda. The crop stand was variable due to drought, and the intrusion of gophers (three other blocks were sightly damaged). Wheat biomass was reduced by 10% and 13% if wild tomato competition was allowed to continue up to mid-season or all season, respectively (Table 4.3).

The results of this study indicate that wheat yield and biomass can be reduced by wild tomato competition. The outcome of wheat and lentil competition will likely depend on a combination of the relative time emergence of wild tomato and wheat plants, duration of competition, and the relative

Table 4.3. The effect of wild tomato competition on wheat seed yield and biomass at Laird in 1992.

Treatment	Yield[w] (g m^{-2})	Biomass[w] (g m^{-2})
Weed-free	134	405
Weeds removed at mid-season	112	366
Weedy	128	352

	Yield Means Comparisons[x]			Biomass Means Comparisons[x]		
	dif.[y]	S.E.D.[y]	t[y]	dif.[y]	S.E.D.[y]	t[y]
Weed-free minus weeds removed at mid-season	23	8	2.8ns	37	8	4.4**
Weed-free minus weedy all season	6	10	0.7ns	54	13	4.2**
Weeds removed at mid-season minus weedy all season	-16	12	-1.3ns	16	17	1.0ns

[w]Treatment means based on the average of 9 replications.
[x]Matched paired t-tests for contrasting treatment differences. t= (0.025).
[y]dif. = difference, S.E.D = standard deviation, t = calculated t value.

competitive abilities of the two species. Wheat is a much taller plant than wild tomato which remains very short and usually spreads over the ground. It appears that if wheat forms a dense canopy which greatly reduces the amount of light filtration, wild tomato competition will have little effect on seed or biomass yield of wheat. Although a few Colorado potato beetles (CPB) entered the experimental plots in 1992, their numbers were much smaller than in the lentil fields. It appears that the CPB prefers a much more open canopy and is not a major factor in determining wild tomato competitiveness in a cereal crop such as wheat. A matched paired t-test indicated that no detectable differences occurred in wheat plant densities or wild tomato plant densities between treatments within each block in 1991, or 1992.

4.2. Wild Tomato Competition in Lentil

In 1991, seed and biomass yield of lentil were not significantly reduced due to wild tomato competition (Table 4.4 and Appendix A.4). Despite a high CPB infestation which

Table 4.4. The effect of wild tomato competition on biomass and seed yield of lentil at Vonda and Laird in 1991.

	Vonda		Laird	
Treatment	Yield	Biomass	Yield	Biomass
	---(g m-2)---			
Weed-free check	390	1313	163	907
Weedy all season	366	1295	172	885
LSD(0.05)	31	52	31	52

caused continual defoliation of the wild tomato plants, about 50 wild tomato plants m^{-2} persisted until late July, although their growth and competitive ability were reduced. Had it not been for the CPB, wild tomato plants probably would have reduced the seed and biomass yield of lentil.

In 1992, wild tomato competition reduced the seed yield of lentil in three of four tests. At Vonda"A", in 1992, seed yield of lentil was reduced by 42% if wild tomato were allowed to compete up to mid-season (Table 4.5). An additional yield reduction of 20% occurred if wild tomato

Table 4.5. The effect of wild tomato competition on biomass and seed yield of lentil at Vonda(A) and (B), and Laird(A) and (B) in 1992.

	Vonda(A)		Vonda(B)		Laird(A)		Laird(B)	
Treatment	Y[x]	B[x]	Y[x]	B[x]	Y[x]	B[x]	Y[x]	B[x]
	($g\ m^{-2}$)							
Weed-free check	143a	388a	168a	622a	108	535a	187a	481a
Weeds removed at Mid-season	83b	228b	155ab	575b	111	486b	155b	419b
Weedy all season	54c	156c	150b	527c	109	458b	151b	396b
LSD(0.05)	13	32	13	32	13	32	13	32

[x]Means based on 10 replications. Means in columns with a common letter are not significantly different at the 0.05 level. Y = Yield B = Biomass.

competition was allowed to continue all season. The average wild tomato density was 460 wild tomato plants m^{-2} and the average lentil density was approximately 55 lentil plants m^{-2} (Appendix A.7). This site had been direct-seeded into previously worked lentil stubble. The ground was extremely soft and the lentil seeds were sown too deep despite efforts to seed shallow. Lentil seedlings which emerged were spindly, with poor vigour. The stand of wild tomato plants was so thick in some plots that the lentil seedlings virtually had no room to become established. Some lentil plants were also lost through heat canker. In addition, the wild tomato plants emerged about two weeks before the lentil plants. The crop canopy remained open all season, which allowed ample sunlight to reach the wild tomato plants.

At Vonda"B", in 1992, seed yield of lentil was reduced by 8% when wild tomato was allowed to compete all season, but competition to mid-season had no effect on seed yield (Table 4.5). The lentil density was approximately 103 plants m^{-2}, while the average wild tomato density was 136 plants m^{-2} (Appendix A.7). Although the lentil canopy practically closed, the wild tomato plants grew much larger than at either the Vonda(A) or Laird(B) sites which had much higher wild tomato densities.

At Laird "A", in 1992, wild tomato competition had no effect on seed yield of lentil (Table 4.5). The wild tomato density was about 94 plants m^{-2}, and the lentil density averaged 106 plants m^{-2} (Appendix A.7). The lentil plants in the weed-free plots remained green longer than the other two treatments and were damaged by frost in mid-August. This also contributed to a lighter than expected sample weight for the weed-free plots. This site had been directly sown into standing stubble. The wild tomato plants were emerging at the time of seeding, but many were destroyed during the seeding operation and few additional wild tomato seedlings emerged after seeding. Despite poor initial lentil emergence, the plants grew rapidly and the canopy nearly closed by the end of the season.

At Laird"B" in 1992, seed yield of lentil was reduced by 17% when wild tomato was allowed to compete with the crop until mid-season (Table 4.5). Seed yield was not reduced further by allowing the wild tomato plants to compete with the lentil crop all season. The average lentil and wild tomato densities were approximately 134 and 341 plants m^{-2}, respectively (Appendix A.7).

In 1992, the lentil biomass was reduced at all four lentil sites (Table 4.5 and Appendix A.5)). At the Laird(A) and (B) sites, lentil biomass was reduced by 9% and 13%, respectively, if wild tomato plants were allowed to compete until mid-season. No further loss in biomass occurred if wild tomato plants were allowed to compete all season. However, at Vonda (A) and (B), the reduction in biomass of lentil increased as the duration of wild tomato competition increased. An additional 39% and 7% of the lentil biomass was lost when wild tomato competition continued from mid-season to lentil harvest at Vonda(A) and (B), respectively (Table 4.5).

The results indicate that seed and biomass yield of lentil was reduced by wild tomato competition. Differences between locations and years suggest that the extent of the lentil yield and biomass reduction may depend on the: 1) relative time of the crop and wild tomato emergence 2) relative density of the lentil and wild tomato plants 3) relative vigour of the lentil and wild tomato plants, and 4) time required for canopy closure.

CPB has a major effect on the competitive ability of wild tomato plants in a lentil crop in Saskatchewan. In

1991, CPB essentially prevented wild tomato plants from becoming competitive, accordingly, at each lentil site in 1992, CPB was controlled to protect the wild tomato plants. Where insecticide was not applied, virtually all wild tomato plants were destroyed, with the exception of a few at the Vonda(B) lentil site where some wild tomato plants were able to set seed.

However, the impact the CPB have on lentil yield will depend on when they begin to feed on the wild tomato seedlings. For example: CPBs over-winter as adults in the soil (usually in the field where they were feeding) (Philip and Mengersen 1989). The adults emerge in May or June and fly in search of host plants. The adults mate, and the female lay eggs on the under-side of the leaves of wild tomato seedlings, or other host plants in the area. Within 5 to 10 days, the larvae begin to feed on the wild tomato plants. When the CPBs are present early in the season, yield loss due to wild tomato competition may be reduced (personal observation). When CPB enters the field relatively late, e.g., when the lentil plants are beginning to flower, CPB has less impact on seed and biomass yield of lentil. At three of the four sites in 1992, seed yield of lentil did not increase in plots maintained free of wild tomato plants from the time the lentil plants began to flower to maturity.

It is likely that the competitive effect wild tomato plants have on lentil plants will depend to some extent on the wild tomato distribution pattern. It was observed that up to 30 wild tomato seedlings can emerge from a single berry, radiate out from this central point, and act as a single plant. Therefore, it is difficult to compare the above situation to a plot with the same density, but with the wild tomato plants evenly distributed. The variation in wild tomato distribution patterns between plots is likely to mask treatment differences, particularly at lower densities.

4.3. Wild Tomato Demography in Lentil

At Laird in 1991, wild tomato plants began to emerge around 24 May, and all of the seedlings had emerged by 11 June (Table 4.6). Only 16% of the total wild tomato

Table 4.6. Emergence and survival of wild tomato plants in lentil at Laird in 1991.

	Number of each cohort alive[x]			
Cohort	June 11[y]	July 4	July 29	August 8
	------------------ Plants m^{-2} ------------------			
1	26	26	18	0
2	63	62	57	0
3	4	3	3	0
5		0	0	0
Total	93±19	91±19	78±18	0

[x]Average of 10 replications.
[y]Lentil was sown on May 15. Wild tomato emergence began around May 24.

seedlings had died by 29 July, despite severe defoliation by CPBs. The emergence and survival data collected from the

Vonda lentil site in 1991 were excluded because of heavy rains in the area which delayed the counting and separation of cohorts. In addition, CPB destroyed most of the wild tomato seedlings before an accurate count could be made.

In 1992, wild tomato plant emergence began around 13 May and continued to 16 July at Laird"A" (Table 4.7). The

Table 4.7. Emergence and survival of wild tomato plants in lentil at Laird(A) in 1992.

	Number of each cohort alive[x]					
Cohort	June 2[Y]	June 12	July 1	July 16	August 4	August 26
	(plants m^{-2})					
1	20	20	19	19	18	1
2	32	31	31	30	27	1
3	13	12	11	11	10	1
4		24	23	22	20	1
5			4	3	2	0
6				1	0	0
Total±SE	65±14	87±17	88±17	86±16	77±16	4±1

[x]Average of 10 replications.
[Y]Lentil direct sown May 15. Wild tomato emergence began around May 13.

largest number of seedlings emerged around 22 May, with 67% of all seedlings having emerged by 2 June. Only 8% of the wild tomato plants had died by 16 July, but only 4% were alive on 26 August.

At Laird"B" in 1992, wild tomato plants began to emerge around 22 May and continued to emerge up to 14 July (Table 4.8). About 87% of all the wild tomato seedlings emerged between 22 May and 5 June. Only 3% of the wild tomato

Table 4.8. Emergence and survival of wild tomato plants in lentil at Laird(B) in 1992.

	Number of each cohort alive[x]				
Cohort	June 5[Y]	June 11	June 30	July 14	August 4
	(plants m^{-2})				
1	24	24	24	24	24
2	40	40	40	40	39
3	82	82	81	79	77
4		13	11	11	10
5			5	5	5
6				4	4
Total±SE	146±35	159±39	161±41	163±41	159±39

[x]Average of 10 replication.
[Y]Lentil sown May 16. Wild tomato emergence began around May 22.

plants had died by 14 July, but all were dead by August 20.

At Vonda(A) in 1992, wild tomatoes began to emerge in early May, and continued to 11 July (Table 4.9). The greatest number emerged between 25 May and 9 June. About 88% of all wild tomato seedlings had emerged by 9 June. Wild tomato seedlings did not emerge after July 11. Only 10% of the plants had died by 11 July. Despite dry conditions, and frost in mid-August, 2% of the wild tomato plants were still alive on 18 September.

Wild tomato emergence began in late May to early June, at Vonda"B" in 1992, and continued to mid-July (Table 4.10). The largest emergence occurred between 2 June and 11 June. About 88% of all wild tomato seedlings had emerged by 11

Table 4.9. Emergence and survival of wild tomato plants in lentil at Vonda(A) in 1992.

Cohort	Number of each cohort alive[x]					
	May 25[Y]	June 9	June 23	July 11	August 7	September 18
	(plants m^{-2})					
1	22	22	21	20	18	0
2	212	206	204	179	171	5
3		463	441	424	407	8
4			96	84	84	2
5				3	2	0
Total±SE	234±64	691±124	762±133	710±123	682±120	15±8

[x]Average of 10 replications.
[Y]Lentil direct seeded on May 14. Wild tomato emergence began around May 11.

Table 4.10. Emergence and survival of wild tomato plants in lentil at Vonda(B) in 1992.

Cohort	Number of each cohort alive[x]				
	June 11[Y]	June 23	July 17	August 7	August 18
	(plants m^{-2})				
1	14	13	13	13	0
2	52	52	50	48	0
3	25	25	23	20	1
4		11	11	10	0
5			2	1	0
Total±SE	91±21	101±22	99±21	92±20	1±1

[x]Average of 10 replications.
[Y]Lentil sown May 20. Wild tomato emergence began around June 2.

June. Only 5% of the wild tomato seedlings had died by 17 July, but less than 1% were still alive on 18 August. The CPB population increased rapidly two weeks before harvest and destroyed many of the wild tomato plants by harvest.

4.4. Wild Tomato Demography in Wheat

At Delisle in 1991, wild tomato plants began to emerge in late May (Table 4.11). About 99% of all wild tomato seedlings had emerged 18 June. Wild tomato did not emergeafter 11 July. Over 80% of the wild tomato plants

Table 4.11. Emergence and survival of wild tomato plants in wheat at Delisle in 1991.

	Number of each cohort alive[x]		
Cohort	June 18[Y]	July 11	August 1
	------------ (plants m^{-2}) ------------		
1	19	6	0
2	51	15	0
3	70	7	0
4	11	0	0
5		1	0
Total	143±76	28±7	0

[x]Average of 10 replications.
[Y]Wheat sown May 17. Wild tomato emergence began around May 24.

were dead by 11 July, and all were dead by 1 August. Wild tomato began to emerge around 5 June, at the Vonda site in 1992, and continued to emerge until 15 July (Table 4.12). The largest recruitment occurred around mid-June, with 98% of all seedlings emerging by 20 June. Approximately 70% of the wild tomato plants were dead by 11 July, and all were dead by 7 August.

As mentioned previously, 1991 was an extremely wet, warm year which was ideal for crop canopy development. The wheat

Table 4.12. Emergence and survival of wild tomato plants in wheat at Vonda in 1991.

Cohort	Number of each cohort alive[x]		
	June 20[y]	July 15	August 7
	(plants m^{-2})		
1	2	1	0
2	28	13	0
3	112	27	0
4		2	0
5			0
Total	142±57	43±16	0

[x]Average of 10 replications.
[y]Wheat sown May 30. Wild tomato emergence began around June 5.

grew to a height of approximately 125 cm and the stand was extremely dense. Wild tomato berries were not produced at either wheat site in 1991.

In 1992, at Vonda, wild tomato plants began to emerge around 11 May and continued to emerge until 10 July (Table 4.13). The largest wild tomato seedling emergence occurred between 26 May to 3 June. About 96% of the wild tomato seedlings had emerged by 3 June, and none emerged after 10 July. Approximately 9% of the wild tomato plants had died by 10 July, and 11% were still alive on 18 September.

At Laird in 1992, wild tomato plants began to emerge around 25 May, and continued to emerge until 16 July (Table 4.14). Approximately 80% of the wild tomato seedlings emerged between 25 May and 2 June. About 20% of the wild tomato plants were dead by 16 July, and all were dead by 24 August.

Table 4.13. Emergence and survival of wild tomato plants in wheat at Vonda (1992).

	Number of each cohort alive[x]					
Cohort	May 26[Y]	June 3	June 23	July 10	August 4	September 18
	(plants m^{-2})					
1	46	45	37	37	35	3
2	162	155	154	150	139	43
3		326	324	303	266	15
4			13	11	6	0
5				9	7	1
Total±SE	208±50	526±72	528±69	509±64	454±60	62±32

[x]Average of 10 replications.
[Y]Wheat was direct seeded on May 14. Wild tomato emergence began around May 11.

In 1992, CPB were controlled at each site from mid-June to late July. In addition, 1992 was a much drier growing season than 1991, and the canopy remained open all season at every site, except at Vonda(A) and (B). As a result, the wild tomato densities remained stable until early August in both wheat and lentil. After early August, wild tomato densities declined rapidly and almost all wild tomato plants were dead at harvest. Wild tomato berries were produced in both wheat and lentil.

Ogg and Dawson (1984) found that shallow tillage at monthly intervals did not increase the number of wild tomato seedlings which emerged or change the time of emergence. However, tillage reduced the number of seedlings which

Table 4.14. Emergence and survival of wild tomato plants in wheat at Laird in 1992.

Cohort	Number of each cohort alive[x]				
	June 2[y]	June 12	June 30	July 16	August 4
	(plants m^{-2})				
1	30	23	23	19	19
2	32	29	28	28	28
3	33	31	30	27	27
4		15	14	13	12
5			4	3	3
6				4	4
Total±SE	95±12	98±13	99±13	94±13	95±13

[x]Average of 10 replications.
[y]Wheat sown about May 18. Wild tomato emergence began around May 25.

emerged whenever the scheduled tillage operation followed seed germination by a few days. Therefore, our estimates of emergence could be lower than what actually would have emerged, depending on when a particular field was worked in preparation for spring seeding.

In the spring of 1993 wild tomato seedlings began to emerge around 5 May at the 1992 test sites. On 14 May, the average wild tomato density ranged from a low of 1.4 plants m^{-2} at Vonda(B) to a high of 537 and 432 wild tomato plants m^{-2} at Laird(B) and Vonda(A) respectively (Table 4.15.). These fields were worked between May 14 and May 19, and sown to wheat or barley. Wild tomato plants did not emerge after seeding at any of these sites. Therefore, in 1993,

Table 4.15. Average number of wild tomato plants which emerged in the spring of 1993 at the lentil and wheat sites used in 1992.

Location[y]	Wild tomato[x]±SE
Vonda lentil(B)	1.4±0.5
Laird wheat	76±15
Vonda lentil(A)	226±37
Laird lentil(A)	250±86
Vonda wheat	432±67
Laird lentil(B)	537±97

[x]Average of 10 replications.
[y]Almost all emergence discontinued after mid-May when pre-seeding tillage was done by the farm managers.

cultivation after mid-May destroyed a large number of wild tomato seedlings. The data from 1991 and 1992, indicate that depending on location, cultivation of certain fields after mid-May would reduce the number of wild tomato seedlings present in a particular field.

In this study the time of initial and peak wild tomato emergence was about two weeks later than reported by Chepil (1946), and more than one month later than that reported by Ogg and Dawson (1984). However, the general emergence pattern, and end of wild tomato emergence, is consistent with those recorded at Swift Current by Chepil (1946) and at Prosser, WA, by Ogg and Dawson (1984).

No published data are available on wild tomato survivorship. However, observations made at each lentil site in 1991 and 1992 indicate that wild tomato survivorship is dependent on how large the CPB population is at each individual site, and when they migrate to a particular field. Wild tomato foliage has a strong characteristic aroma that is particularly evident at high densities. It could be that CPBs are attracted by this odour. If so, it would be helpful to know what wild tomato density is required to attract the CPBs into an area.

Wheat competition can greatly affect the mortality rate of wild tomato, particularly under wet growing conditions such as occurred in 1991. Evidence suggests that under similar growing conditions wheat can have a larger impact than lentil on the mortality rate of wild tomato. The wheat canopy closes faster than the lentil canopy, is taller, and less light reaches the wild tomato plants. Wild tomato plants were less vigorous in wheat than in lentil (personal observation). Generally, shading by neighbours severely reduces the productivity of nightshades species (Ogg and Rogers 1989). However, CPBs are less likely to be attracted to wild tomato plants in a wheat field, than to those in a lentil field (personal observation). The primary advantages for using a cereal in the rotation would be to break lentil disease cycles and to take advantage of herbicides which will control wild tomato. Each year, herbicides for broadleaf weed control were applied to the areas around the wheat sites. Wild tomato plants were not observed growing in these sprayed areas after the herbicide was applied.

In Saskatchewan, no herbicides are registered for control of wild tomato in lentil and, in most years the wild tomatoes emerge after the lentil crop has already been sown. However, CPB can severely reduce the competitive ability of wild tomato plants. Lentil producers require ways to encourage the migration of this natural biological control agent into their lentil fields.

4.5. Wild Tomato Seed Production

In 1991, wild tomato did not produce seed in wheat due to severe competition by wheat, or lentil due to severe defoliation by the CPB. In 1992, the average number of wild tomato seeds berry^{-1} ranged from a low of 28 seeds berry^{-1} at the Vonda wheat site (Table 4.17) to 53 seeds berry^{-1} at the Vonda(B) site (Table 4.16). These values are much lower than the 75 to 90 seeds berry^{-1} reported by Ogg and Rogers (1989). This disagreement in average number of seeds per berry should not be surprising if one considers the differences in environment, locations and years, competition, and obvious differences in ecotypes.

Wild tomato seed production (seed m^{-2}) was similar in the two wheat sites (Table 4.17) and 3 of 4 lentil sites, ie., Vonda(B), Laird(A) and Laird(B) (Table 4.16). However, wild tomato seed production was greater at the Vonda(A) site than

Table 4.16. Wild tomato berry and seed production in lentil at four sites in 1992.

	Location					
	Laird(A)			Laird(B)		
Cohort	B m^{-2}	S b^{-1}	S m^{-2}	B m^{-2}	S b^{-1}	S m^{-2}
1	48±8[X]	44±1[Y]	2230±453[Z]	75±34[X]	39±2[Y]	2700±1100[Z]
2	38±8	36±1	1462±388	62±13	32±1	2000±470
3	4±1	25±3	93±34	68±17	30±1	1900±480
4	9±3	29±3	274±119	5±1	21±2	105±30
5	-----	-----	-----	1±1	10±3	3±2
6	-----	-----	-----	2±1	20±3	29±16
Mean±SE	16±3	37±1	4059±796*	38±8	31±1	6753±1345*

	Location					
	Vonda(A)			Vonda(B)		
Cohort	B m^{-2}	S b^{-1}	S m^{-2}	B m^{-2}	S b^{-1}	S m^{-2}
1	109±40[X]	34±1[Y]	3600±1500[Z]	42±9[X]	56±1[Y]	2324±449[Z]
2	523±10 3	38±1	20000±4000	66±22	52±1	3508±1219
3	885±82	39±1	34000±3300	9±3	49±2	432±124
4	47±16	44±1	1980±731	2±1	51±4	83±47
5	3±1	27±5	37±24	-----	-----	-----
6	1±1	35±3	21±16	-----	-----	-----
Mean±SE	261±49	38±1	59861±6570*	24±6	53±1	6347±1690*

[X]Average number of berries per square metre from 10 replications (±SE).
[Y]Average number of seeds per berry (±SE).
[Z]Average number of seeds per square metre (±SE).

at the Vonda wheat site (Tables 4.16 and 4.17). Wild tomato plants produced berries in both wheat and lentil, ranging from about 16 berries m^{-2} at the Laird(A) lentil site to 261 berries m^{-2} at the Vonda(A) lentil site (Tables 4.16 and 4.17).

Table 4.17. Wild tomato berry and seed production in wheat at two sites in 1992.

	Location					
	Laird			Vonda		
Cohort	B m^{-2}	S b^{-1}	S m^{-2}	B m^{-2}	S b^{-1}	S m^{-2}
1	48±11^{x}	39±1^{y}	1955±503^{z}	14±4^{x}	28±1^{y}	363±112^{z}
2	26±6	32±1	903±284	73±18	30±1	2210±570
3	14±3	30±2	428±113	69±13	25±1	1766±360
4	14±5	36±2	519±226	1±1	25±13	11±7
5	1±1	29±5	20±13	1±1	32±3	23±12
6	1±1	31±5	31±18	-----	-----	-----
Mean±SE	17±3	34±1	3857±783*	34±7	28±1	4365±902*

^{x}Average number of berries per square metre from 10 replications (±SE).
^{y}Average number of seeds per berry (±SE).
^{z}Average number of seeds per square metre (±SE).

Wild tomato can be a prolific seed producer in wheat and lentil under dry land conditions similar to those in 1992. Wheat may not prevent wild tomato seed production, if the wheat canopy remains open all season, and a herbicide or some form of wild tomato control is not used during the growing season. In lentil, wild tomato seed production will depend on the occurrence of CPBs and the density of the wild tomato plants. Wild tomato seed produced at the Vonda(A) lentil site in 1992, were 94% viable.

4.6. Wild Tomato Seedbank

The seedbank samples taken in 1991 were bulked within each site, therefore it is impossible to separate the means because no measure of variance is available. However, the Vonda lentil site had the highest wild tomato seedbank at approximately 26,000 seeds m^{-2}, followed by the Vonda wheat site at about 18,000 seeds m^{-2} (Table 4.18). The Delisle

Table 4.18. Wild tomato seedbank in the spring and fall at the wheat and lentil sites in 1991.

Location	Average seeds (m^{-2})	Average emergence (Plants m^{-2})	%EM[x]	%Viable[x]
	Spring seed bank			
Vonda lentil	26,000	132	0.5	27
Laird lentil	10,000	143	1.4	35
Vonda wheat	18,000	93	0.5	18
Delisle wheat	13,000	143	1.1	78
	Fall seed bank			
Vonda lentil	33,000	NA	NA	34
Laird lentil	7,000	NA	NA	33
Vonda wheat	17,000	NA	NA	18
Delisle wheat	6,000	NA	NA	43
Delisle wheat	5,000	NA	NA	39

[x]%EM = estimated percentage of spring seedbank which emerged.
%Viable = viable using the tetrazolium test.

wheat site had approximately 13,000 seeds m^{-2}, and the lowest seedbank estimate, 10,000 m^{-2}, occurred at the Laird lentil site. Viability tests using tetrazolium indicated that the percentage of viable seed was; 18 for the Vonda wheat site, 27 for the Vonda lentil site, 35 for the Laird lentil site and 78 for the Delisle wheat site.

The percent emergence of wild tomato plants from these sites was very low in 1991; 0.5 for the Vonda lentil site, 0.5 for the Vonda wheat site, 1.4 for the Laird lentil site and 1.1 for the Delisle wheat site (Table 4.18). None of the wild tomato plants produced seed in either wheat or lentil, in 1991.

The combined ANOVA for the wild tomato seedbank data over the six sites and four sampling dates indicated a significant location by sampling date interaction (Appendix A.8). In 1992, the wild tomato seedbank increased at three of six sites (Table 4.19). The wild tomato seedbank at the Vonda(A) and (B) and the Laird wheat sites increased by an estimated 200%, 1750%, and 360% respectively. The wild

Table 4.19. Wild tomato seedbank in the spring, mid-season and fall of 1992, and mid-season of 1993, at the 1992 wheat and lentil sites.

			Sampling date			
Year	Location	LSD(0.05)	(1992) Spring	(1992) Mid-season	(1992) Fall	(1993) Mid-season
			(Seeds m^{-2})			
1992*	VLA	26,800	20,018c	43,057cb	60,326ba	74,321a
	VW	12,500	38,905a	25,066cb	32,297ba	17,328c
	LLB	5,700	838b	3,937b	6,140b	13,800a
	LW	5,400	2,807b	4,619b	12,962a	1,559b
	LLA	5,700	5,438ba	2,203b	8,635a	2,183b
	VLB	5,100	682a	1,053a	12,650b	3,625a

*Means based on 20 separate soil cores per sampling date. Mean comparisons for sampling date within each location. VLA = Vonda(A) lentil VLB = Vonda(B) lentil LLA = Laird(A) lentil LLB = Laird(B) lentil VW = Vonda wheat LW = Laird wheat Means followed by the same letter in a row, are not different at P= 0.05.

tomato seedbank remained unchanged at the Laird lentil (A) and (B) and Vonda wheat sites. Viability tests, using tetrazolium, indicated that 16 to 49% of the spring wild tomato seedbank was viable (Table 4.20 and 4.21).

Table 4.20. Viability of the wild tomato seedbank sampled in the spring, mid-season and fall of 1992, and mid-season of 1993 at the Vonda and Laird lentil sites.

Location	Sampling Date	%Viability using tetrazolium	%Emergence
LLA	Spring 92	49	2
	Mid-season 92	41	4
	Fall 92	92	3
	Mid-season 93	33	11
LLB	Spring 92	40	20
	Mid-Season 92	30	4
	Fall 92	81	9
	Mid-season 93	21	4
VLA	Spring 92	29	4
	Mid-Season 92	24	2
	Fall 92	67	0.4
	Mid-season 93	62	0.3
VLB	Spring 92	17	2
	Mid-Season 92	35	10
	Fall 92	93	4
	Mid-season 93	67	15

Note: %Emergence = percent of the wild tomato seedbank which emerged. Spring 1992 emergence data are used for Spring and mid-season 1992 estimates, and Spring 1993 emergence is used for the fall 1992 and mid-season 1993 estimates. VLA = Vonda(A) lentil; VLB = Vonda(B) lentil; LLA = Laird(A) lentil; LLB = Laird(B) lentil.

Approximately 2% of the spring wild tomato seedbank emerged at the Laird(A) and Vonda(B) lentil sites, and 4 to 20% at the Vonda(A) and Laird(B)lentil sites, respectively (Table 4.20). Only 1% of the wild tomato spring seedbank emerged at the Vonda wheat site and 4% at the Laird wheat site (Table 4.21).

Approximately 3% of the fall seedbank of wild tomato for the Laird(A) lentil, 9% for the Laird(B) lentil, 0.4% for the Vonda(A) lentil, and 4% of the Vonda(B) lentil sites, emerged in the spring of 1993 (Table 4.20). In addition, 1% and 0.6% of the fall seedbank emerged at VW and LW respectively (Table 4.21).

By mid-season of 1993, the wild tomato seedbank at the Vonda(B) lentil, Laird(A) and Laird wheat sites, had dropped to a level similar to what it had been in the spring of 1992 (Table 4.19.). However, the estimated seedbank remained high at the Vonda(A) lentil site, reduced at the Vonda wheat site, and increased at the Laird(B) lentil site.

Wild tomato berries average between 28 and 50 seeds $berry^{-1}$. Mature berries remain very close to the parent plant unless they are moved around by birds, animals, or farm machinery. If seedbank samples are taken in the fall or spring before cultivation has occurred, the berries will have a much more clumped distribution than if the field had been worked and sown before seedbank samples were collected. This could very well explain the large increase in mid-season (1993) seedbank at the Laird(B) lentil site.

Wild tomato seeds are part of a large seedbank which may take more than six years to deplete (Chepil 1946). It can be expected that between zero and 20% of the seedbank

Table 4.21. Viability of the wild tomato seedbank sampled in the spring, mid-season and fall of 1992, and mid-season of 1993 at the Vonda and Laird wheat sites.

Location	Sampling Date	%Viability using tetrazolium	%Emergence
VW	Spring 92	27	1
	Mid-season 92	10	2
	Fall 92	44	1
	Mid-season 93	12	3
LW	Spring 92	16	4
	Mid-season 92	44	3
	Fall 92	81	0.6
	Mid-season 93	15	5

Note: %Emergence = percent of the wild tomato seedbank which emerged. Spring 1992 emergence data are used for Spring and mid-season 1992 estimates, and Spring 1993 emergence is used for the fall 1992 and mid-season 1993 estimates. VW = Vonda wheat; LW = Laird wheat.

will germinate in any one year (personal observation). In the spring of 1992, there were an estimated 682 to more than 38,000 wild tomato seeds m^{-2} at the lentil and wheat sites (Table 4.20). Therefore, there is potential for yield loss in wheat or lentil and harvest difficulties in lentil if there are greater than 650 wild tomato seeds m^{-2} in the top 10 cm of soil in the spring. The environment a each site, the type of crop sown, the percentage of viable wild tomato seed and level of seed dormancy, and the agronomic practices implemented will determine the level of wild tomato interference.

4.7. Practical Considerations and Recommendations

Lentil fields were surveyed in 1992 in an effort to document harvest difficulties. The juice and seeds from wild tomato berries mix with the dust and debris during the harvest operation. This mixture builds up on the combine concaves, grain elevators and augers. Berries can be so numerous that wild tomato juice drips from the spout of the clean grain auger into the grain tank. The lentil seed became very damp, and was stained by wild tomato juice mixed with soil and dust from the harvest operation. Many wild tomato berries reached the grain tank intact. Wild tomato berries and seeds passed through the combine and were thrown great distances. In addition, wild tomato seeds became glued to the lentil seed. Wild tomato seed stuck to the tires of harvest equipment, and was carried to other parts of the field.

At this time it is not known whether wild tomato seed is spread by lentil seed contaminated with wild tomato seed. Although many wild tomato seeds were found in five lentil samples taken at harvest, none were found stuck to the lentil seed. This is a very small sample size and the results should not be considered conclusive. A much larger sample is required, and should include drill box samples during spring seeding.

Wild tomato seeds are being spread within fields and between fields by mechanical operations at harvest.

Therefore, it is recommended that: 1) Wild tomato patches be worked and harvested separately from the rest of the field. These patches could be sown to cereals. 2) Use Certified seed to avoid spreading wild tomato seed from field to field. 3) Harvest equipment should be thoroughly cleaned before leaving a wild tomato infested field. 4) Include a cereal in the crop rotation which facilitates delayed seeding, and/or the use of herbicides which wild control wild tomato. 5) Maintain records for each field to avoid seeding lentil in areas where wild tomato problems have occurred in the past. 6) CPB is a naturally occurring biological control agent. Adult beetles and larvae could be transferred to wild tomato patches from other host species such as potato and tomato. If disease is not a concern, it may be advantageous to seed this years lentil crop on a field adjacent to last years lentil crop. The adults CPBs which emerge in the spring from the previous years lentil field, may migrate into the adjacent lentil if wild tomato plants are present.

CONCLUSIONS

Wild tomato can reduce the yield and biomass of both wheat and lentil. However, wheat is generally a stronger competitor than lentil, and many more wild tomato control options are available in wheat. If herbicide control measures are used when growing wheat, it is unlikely that the yield will be reduced by wild tomato competition. On the other hand, herbicides registered for use in lentil will not control wild tomato and, in Saskatchewan, the majority of the wild tomato seedlings emerge after the optimum seeding date for lentil. The lentil canopy remains open for an extended period of time, providing time for wild tomato seedlings to become established. Wild tomato reduced the seed yield of lentil in three of six sites, and biomass yield in four of six sites. Wild tomato plants will reduce the seed and biomass yield of wheat if a herbicide is not used to control wild tomato plants, if there is a high population of wild tomato plants, if the wheat crop remains relatively short, and if the wheat canopy remains open all season.

The CPB is a naturally occurring biological control agent which plays a major role in reducing the competitiveness of wild tomato plants. Therefore, if wild tomato patches develop within a lentil field, CPB and larvae should be transferred to these areas from other host species. ie. potato and tomato plants. In addition, tests should be conducted to evaluate whether potato plants could be used to attract CPB into areas within a field where wild tomato plants have been troublesome. Perhaps planting a row or two of potato into these areas each year is all that is required to effectively control wild tomato. Although CPB appears to prefer wild tomato to potato, further evaluations are required to know for certain.

Wild tomato emergence generally begins in early to mid-May. Peak emergence occurs around 1 June, plus or minus two weeks. Few wild tomato plants emerge after mid-July, and later maturing seedlings produce fewer fruits or seeds. Late spring cultivation or delayed seeding of early maturing cereal crops such as barley or oat could be used to reduce wild tomato populations and prevent wild tomato seed production.

Wild tomato competes well in a lentil crop and can produce an abundance of seed. Wild tomato can be a prolific seed producer in wheat if a herbicide is not used to control wild tomato, and the wheat crop remains relatively short and the canopy remains open all season.

The number of wild tomato plants that emerge in a year is a very small proportion of the viable seed in the soil. Wild tomato seeds form a large enduring seed bank that is not depleted by emergence in a single year. Therefore, farm managers should maintain records of areas within a field where wild tomato has been a problem and these areas should be sown to cereals which provide a wide choice of wild tomato control options and much stronger competition.

Harvest equipment is probably the single greatest contributor to the spread of wild tomato seed. Wild tomato patches should be harvested separately form the rest of the field to avoid spreading seeds throughout the field. In addition, harvest equipment should be thoroughly cleaned before it is removed and used in other fields.

High densities of wild tomato berries in a lentil field can cause a significant increase in the moisture content of the lentil seed as it is harvested. The juice from the wild tomato berries mixes with the dust and debris during the harvest operation. The result is often clogged concaves, sieves, elevators and augers, and stained lentil seed. This problem, although frustrating, has not yet become widespread. However, as lentil production continues and other shorter, less competitive crops than cereals are grown, it is likely that more producers will encounter harvest difficulties due to wild tomato. Therefore, wild tomato is a potentially serious weed in lentil production systems.

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APPENDIX:

A.1. ANOVA for biomass and seed yield of wheat as affected by wild tomato competition at Vonda and Delisle in 1991.

Source	DF	SS	MS	F	P
Biomass					
Location[x]	1	118023	118023	11.00	0.050*
Treatment	1	1993	1993	0.40	0.641ns
Block(Location)	18	199516	11084	2.22	0.050*
Location*Treatment	1	4991	4991	1.00	0.331ns
Error	18	89923	4996		
Total	39	414446			
Yield					
Location[Y]	1	177777	177777	34.00	0.001**
Treatment	1	75	75	0.25	0.702ns
Block(Location)	18	100267	5570	9.34	0.000***
Location*Treatment	1	296	296	0.50	0.490ns
Error	18	10734	596		
Total	39	289149			

[x]F-test and degrees of freedom were calculated using "Satterthwaite's approximation". F = (0.05); df= 1,4.
[Y]F-test and degrees of freedom were calculated using "Satterthwaite's approximation". F=(0.05); df= 1,15.

Example Calculations:

Approximate F value (for locations) in the ANOVA for biomass (Table A.1) using Satterthwaite's approximation.

$$F = 118023/(11084 + 4991 - 4996) = 10.7$$

Approximate denominator df for biomass (Table A.1), calculated using Satterthwaite's approximation.

$$df = \frac{(11084 + 4991 - 4996)^2}{(11084^2/18 + 4991^2/1 + 4996^2/18)} = 4$$

A.2. ANOVA for seed and biomass yield of wheat as affected by wild tomato competition at Vonda in 1992.

Source	DF	SS	MS	F	P
Yield					
Treatment	2	5444	2722	1.85	0.190ns
Block	8	67008	8376	5.68	0.002**
Error	16	23598	1475		
Total	26	96049			
Biomass					
Treatment	2	15744	7872	1.49	0.256ns
Block	8	235433	29429	5.56	0.002**
Error	16	84706	5294		
Total	26	335883			

A.3. ANOVA for seed and biomass yield of wheat as affected by wild tomato competition at Laird in 1992.

Source	DF	SS	MS	F	P
Yield					
Treatment	2	2491	1245	2.65	0.101ns
Block	8	13273	1659	3.53	0.015*
Error	16	7518	470		
Total	26	23281			
Biomass					
Treatment	2	13843	6921	9.86	0.002**
Block	8	20283	2535	3.61	0.014*
Error	16	11229	702		
Total	26	45355			

A.4. ANOVA for biomass and seed yield of lentil as affected by wild tomato competition at Vonda and Lairde in 1991.

		Biomass			
Source	DF	SS	MS	F	P
Location[x]	1	1665228	1665228	167.00	0.000***
Treatment	1	34	34	0.01	0.939ns
Block(Location)	18	168777	9376	3.04	0.012*
Location*Treatment	1	3693	3693	1.20	0.288ns
Error	18	55471	3082		
Total	39	1893202			
		Yield			
Location[x]	1	445771	445771	65.00	0.001**
Treatment	1	574	574	0.21	0.729ns
Block(Location)	18	94006	5223	4.67	0.001**
Location*Treatment	1	2791	2791	2.50	0.131ns
Error	18	20122	1118		
Total	39	563264			

[x]F-test and degrees of freedom were calculated using "Satterthwaite's approximation".
F = (0.05); df= 1,5.

A.5. ANOVA for biomass and seed yield of lentil as affected by wild tomato competition at Vonda(A) and (B) and Laird (A) and (B) in 1992.

Source	DF	SS	MS	F	P
Biomass					
Location[x]	3	3261342	1087114	29.00	0.001**
Treatment	2	6191125	309563	10.47	0.011*
Block(Location)	76	780595	10271	4.01	0.000***
Location*Treatment	6	177443	29574	11.55	0.000***
Error	152	389181	2560		
Total	239	5227686			
Yield					
Location[Y]	3	222285	74029	7.90	0.009**
Treatment	2	52916	26458	3.30	0.108ns
Block(Location)	76	137482	1809	4.02	0.000***
Location*Treatment	6	48047	8008	17.80	0.000***
Error	152	68392	450		
Total	239	528923			

[x]F-test and degrees of freedom were calculated using "Satterthwaite's approximation". F = (0.05); df= 3,9.
[Y]F-test and degrees of freedom were calculated using "Satterthwaite's approximation". F=(0.05); df= 3,8.

A.6. Plant densities of wheat and wild tomato in wild tomato competition studies in wheat in 1991 and 1992.

	Wheat (Spring)			Wheat (Fall)			Wild tomato (Spring)			Wild tomato (Fall)		
1991	t1	t2	t3	t1	t2	t3	t1	t2	t3	t1	t2	t3
	(plants m^{-2})											
Delisle	----	----	NA	148 (30)	161 (42)	NA	----	100 (92)	NA	NA	0	NA
Vonda	190 (24)	176 (22)	NA	207 (28)	205 (31)	NA	----	142 (141)	NA	NA	0	NA
1992	t1	t2	t3	t1	t2	t3	t1	t2	t3	t1	t2	t3
Laird	139 (19)	138 (17)	132 (22)	144 (26)	146 (23)	147 (20)	35 (30)	97 (39)	86 (42)	NA	104 (51)	101 (37)
Vonda	153 (19)	122 (18)	136 (24)	161 (34)	180 (25)	184 (32)	174 (94)	150 (79)	168 (87)	NA	311 (164)	243 (120)

Note: Numbers in brackets are standard deviations. t1 = Weed-free all season; t2 = Weedy all season; t3 = Weeds removed at mid-season.

A.7. Plant densities of lentil and wild tomato in wild tomato competition studies in lentil in 1991 and 1992.

	Lentil (Spring)			Lentil (Fall)			Wild tomato (Spring)			Wild tomato(Fall)		
1991	t1	t2	t3	t1	t2	t3	t1	t2	t3	t1	t2	t3
Laird	142 (13)	147 (9)	NA	136 (17)	136 (11)	NA	----	80 (55)	NA	NA	51 (38)	NA
Vonda	130 (34)	134 (38)	NA	138 (32)	149 (42)	NA	----	32 (35)	NA	NA	0	NA
1992	t1	t2	t3	t1	t2	t3	t1	t2	t3	t1	t2	t3
Laird (A)	101 (17)	93 (15)	96 (17)	113 (18)	118 (14)	116 (15)	60 (61)	102 (82)	118 (14)	NA	90 (54)	102 (82)
Laird (B)	123 (21)	115 (22)	119 (21)	143 (40)	152 (50)	153 (56)	340 (319)	355 (300)	327 (272)	NA	327 (272)	355 (300
Vonda (A)	50 (15)	44 (11)	47 (12)	64 (17)	62 (14)	65 (17)	338 (121)	499 (254)	482 (267)	NA	482 (267)	499 (254
Vonda (B)	98 (13)	95 (11)	96 (11)	109 (14)	111 (11)	109 (16)	99 (67)	152 (105)	138 (84)	NA	138 (84)	152 (105

Note: Numbers in brackets are standard deviations. t1 = Weed-free all season; t2 = Weedy all season; t3 = Weeds removed at mid-season.

A.8. Combined Anova for wild tomato seedbank at the six wild tomato competition sites in 1992 with four sampling dates.

Source	DF	SS	MS	F	P
Location[x]	5	1.3912Ex11	2.7824Ex10	9.90	0.000***
Date	3	8.76443Ex9	2.9214Ex9	1.25	0.328ns
Location x Date	15	3.5162Ex10	2.34415Ex9	5.67	0.000***
Core(location)	114	5.0268Ex10	4.4094Ex8	1.07	0.327ns
Error	342	1.4141Ex11	4.1347Ex8		
Total	479	3.7472Ex11			

[x]F-test and degrees of freedom were calculated using "Satterthwaite's approximation", F = (0.05); df= 5, 15.