THE EFFECTS OF INCREASING DENSITIES OF VOLUNTEER CEREALS ON THE GROWTH AND YIELD OF FLAX (*LINUM USITATISSIMUM*) AND CANOLA (*BRASSICA NAPUS*)

BY

WESLEY ROTHER

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ABSTRACT

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The Effects of Increasing Densities of Volunteer Cereals on the Growth and Yield of Flax (Linum usitatissimum) and Canola (Brassica napus)
Major Professors: George Marshall and Ian N. Morrison

Field trials were conducted at Portage la Prairie (1982 and 1983) to determine the effects of increasing densities (0, 7.5, 15, 30, 45 and 60/m^2) of volunteer wheat (*Triticum aestivum*) or volunteer barley (*Hordeum vulgare*) on the growth and yield of flax (*Linum usitatissimum*) or canola (*Brassica napus*). Constant densities of wild oats (*Avena fatua*) at 30-35/m^2 and green foxtail (*Setaria viridis*) at 150-180/m^2 were also seeded to simulate a weed flora which might occur under normal farming practices. The graminaceous weeds were selectively removed with herbicides in order that crop growth and final yield could be assessed in the presence and absence of weeds. Both the shoot vegetative dry weight and the seed yield of flax and canola were increasingly reduced as volunteer density increased. The greatest incremental reduction in oilseed yield occurred between the weed-free situation and the first density increment. Volunteer barley was more competitive than wheat in both crops. At densities of only 15 volunteer barley plants/m^2 the yield of flax was reduced by 35% and 44% (1982 and 1983, respectively), significantly higher than comparable reductions of 12% and 14% (1982 and 1983, respectively) recorded in canola. The accuracy of predictive assessments of the potential yield reductions caused by volunteer barley or wheat was influenced by the presence of mixed

weed populations (including green foxtail and wild oats) and the weather throughout the season. The results obtained could be used to determine the cost/benefit relationship where known volunteer infestations are to be selectively controlled in crops by graminicides.

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DEDICATION

To my parents and Patrice

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1. INTRODUCTION

Flax (*Linum usitatissimum*) and canola (*Brassica napus*) are two important oilseed crops grown in Canada (Tables 1.1 and 1.2). More than 75% of Canadian flaxseed production is exported as seed. Canadian flaxseed is well received on the world market because it has a higher oil content and iodine value than seed produced elsewhere (Anon. 1976). Canola is a major oilseed crop grown in Western Canada. For Canada, canola has become the third most valuable field crop, following wheat (*Triticum aestivum*) and barley (*Hordeum vulgare*) and ahead of flax (Adolphe 1974). Canola has changed Canada's position from a net importer to an exporter of edible oilseeds (Table 1.3).

Table 1.1 Value of production of principal crops for Manitoba and the prairie provinces[1].

	Manitoba			Prairie provinces		
Crop	1984	1983	1982	1984	1983	1982
	($ '000,000)					
Wheat	611	593	569	3992	4059	3110
Barley	216	191	227	1169	1108	1100
Canola	109	152	190	594	970	1106
Flaxseed	104	96	131	181	144	213

[1] Anon. (1984a, b, e)

Table 1.2 Area planted to principal crops in Manitoba and the prairie provinces[1].

	Manitoba			Prairie provinces		
Crop	1984	1983	1982	1984	1983	1982
	('000 ha)					
Wheat	1801	1862	1619	11332	12161	11069
Barley	728	708	809	4107	3905	4714
Canola	486	384	344	2894	2246	1720
Flaxseed	405	304	364	704	431	627

[1] Anon. (1984a, b, e)

Table 1.3 Value of principal crops exported from Canada[1].

Crop	1984	1983	1982
	($ '000,000)		
Wheat	4709	4648	4287
Barley	636	815	886
Canola	648	432	419
Flaxseed	168	186	137

[1] Anon. (1984f)

Both flax and canola are adapted to warm, moist regions of Western Canada and are capable of producing high yields of seed (Table 1.4). Methods of crop production and equipment for sowing, harvesting and threshing are the same for flax and canola as for

Table 1.4 Average yields for principal crops for the prairie provinces[1].

Crop	1984	1983	1982	Av. 10 year
	(kg/ha)			
Wheat	1567	1937	2125	1849
Barley	2198	2376	2700	2441
Canola	1080	1159	1271	1182
Flaxseed	960	1035	1167	998

[1]Anon. (1984c, d)

other small grains such as wheat and barley. Oilseeds are especially well suited to rotation with wheat and barley crops (Legge 1982). However, the shedding of small grains due to excessive combine-operating speeds and the straw trail may produce an overwintering seed reservoir. Such a reservoir may result in volunteer cereals as a crop weed the following spring. Cussans (1978) reported that a 0.75-5.0% loss in cereal seed during harvest could reuslt in 70-470 potential volunteer plants/m^2. Volunteer cereals have been shown to compete with the crop being produced, interfere with field operations and reduce the marketability of the crop (Soper 1978).

Historically, volunteer cereals have not been considered to be a problem in oilseed production: emphasis was on the control of weed such as green foxtail (*Setaria viridis*), wild oat (*Avena fatua*) and broadleaf weeds. However, in the last decade, the advent of new generation selective graminicides (e.g. diclofop-methyl, flampropmethyl, sethoxydim, fluazifop-butyl) has resulted in a trend away from summerfallow and delayed seeding as a means of weed control to a more continuous cropping scheme. The acreage of flax and canola seeded into stubble is much greater than those seeded on summerfallow (Table 1.5).

Table 1.5 Percentage of flaxseed and canola seeded on summerfallow from 1976 to 1985[1].

	Manitoba		Prairie provinces	
Year	Canola	Flaxseed	Canola	Flaxseed
	(%)			
1976	48	19	72	46
1977	40	17	63	53
1978	32	16	59	48
1979	32	13	56	44
1980	37	12	64	44
1981	32	9	58	40
1982	16	7	44	34
1983	19	7	42	31
1984	19	7	41	35
1985[2]	12	4	35	25

[1]Anon. (1984c)

[2]Estimated

This change in farming practices has resulted in an increased prominence of volunteer cereals in crop production and weed control strategies. In cereal-oilseed rotations in Manitoba, volunteer wheat or volunteer barley frequently occurred in flax and canola fields (Table 1.6). In the 1981 Weed Survey of Cultivated Land in

Table 1.6 Ranking of the top 30 weed species from the Manitoba survey of cultivated land, 1982[1].

Rank	Species	Rank	Species
1	Green foxtail	16	Bluebur
2	Wild oats	17	Hemp-nettle
3	Wild buckwheat	18	Field horsetail
4	Smartweed	19	Thyme-leaved spurge
5	Canada thistle	20	Shepherd's-purse
6	Lamb's-quarters	21	Volunteer wheat
7	Wild mustard	22	Cow cockle
8	Sow thistle	23	Volunteer barley
9	Redroot pigweed	24	Prostrate knotweed
10	Catchfly	25	Dandelion
11	Stinkweed	26	Round-leaved mallow
12	Quackgrass	27	Dog mustard
13	Barnyard grass	28	Chickweed
14	Volunteer flax	29	Black medic
15	Russian thistle	30	Rose spp.

[1]Thomas (1982)

Manitoba (Thomas 1982), volunteer wheat and volunteer barley ranked as the 11th and 14th most abundant weeds in flax and 8th and 17th most abundant weeds in canola, respectively. Wild oats and green foxtail ranked first and second, respectively.

Volunteer cereals are well adapted to present agronomic practices, having been bred specifically for crop production. Volunteer cereals compete well for available nutrients, water and light thereby reducing yields and interfering with crop production (Anderson 1976). Graminicides (e.g. dichofop-methyl) until recently did not selectively control volunteer cereals in oilseeds. However, new herbicides such as sethoxydim and fluazifop-butyl, have enabled farmers to control common grassy weeds (wild oat and green foxtail) as well as volunteer cereals in flax and canola.

Researchers ultimately wish to be able to predict yield reductions due to weed competition before they occur and in this way to cost the economic returns to be gained from weed control practices and in particular the use of herbicides. Friesen (1967), speaking in Vienna, posed a series of weed-crop ecology questions with regard to the understanding of any weed species (Appendix 8.1). For many major weeds which reduce crop yields, information is insufficient to precisely calculate expected reductions as demanded by Friesen (Sagar 1968).

This research was undertaken because no information regarding growth and yield losses caused by volunteer cereals in flax and canola was available. The primary purpose was to determine the effects of increasing volunteer wheat and volunteer barley densities on the final yield of flax and canola. The results obtained might provide oilseed growers with a measure of the cost-benefit relationship where volunteer infestations are to be controlled by herbicides.

2. LITERATURE REVIEW

Weeds in crops reduce yields by competiting for nutrients, moisture, light and space (Clements *et al*. 1907). The growth of such plants in a multispecific community is influenced at some or all stages of development by biological and physical processes which are frequently referred to as competition.

2.1 Definition of Competition

The literature on the subject of competition is vast and is equalled only by the number of definitions given to the word (e.g. de Wit 1960a; Milthorpe 1961; Donald 1963; Harper 1964). The definition of competition put forward by Clements *et al*. (1929) remains a classic in the study of the plant world. It was stated that competition is purely a physical process. Competition arises from the reaction of one plant upon the physical factors about it in relationship to another plant. Clements further clarified this idea by suggesting that competition between two plants does not take place as long as the water content, the nutrient material and the light are in excess of the needs of both. Thus, when the immediate supply of a single necessary factor falls below the combined demands of the plants, competition begins.

The term competition, however, remains open to further interpretations. Harper (1961) noted the term's strong association with human activities such as sports and with certain principles of economics and its lack of scientific meaning. Hall (1974) stated that competition is often used to describe ecological and agronomic phenomena in a rather loose manner with little scientific foundation. Hall further acknowledged that this might lead to a misunderstanding of the actual processes involved.

2.2 Competition Vs. Interference

Harper (1961, 1964, 1977) in a series of papers proposed the use of 'interference' as a substitute for competition. Harper intended this new term to comprise all changes in the environment brought about by the proximity of individuals. Interference would also include the effect of neighbours due to the consumption of resources in limited supply, the production of toxins or changes in conditions such as protection from wind and influences on the susceptibility to pests and diseases. Thus, plant interference relates to the response of an individual plant or plant species to its total environment as this is modified by the presence and/or growth of other individuals or species.

Competition itself is only one facet of interference between plants. However, at times it may be the most dominant. Competition is the most commonly used term in agricultural literature (Glauninger and Holzner 1982).

2.3 Non-competitive Vs. Competitive Competition

Competition, or interference, can be partitioned into two processes: non-competitive and competitive competition (Hall 1974). Non-competitive processes occur when one species modifies the light and temperature microenvironment of another by virtue of its differential growth characteristics. The growth of the associated species could be either reduced because the level of illuminance became too low for optimum growth, or, in some cases, encouraged because the plant was intolerant of high illuminance levels. Competitive competition is competition in the strictest sense of what is available: nutrients, light and space. Perhaps the use of indirect and direct competition would be more appropriate. However, research is often focused on the effects of competitive (direct) competition.

2.4 Approaches to Studying Competition

Weed control measures are focused directly or indirectly on improving the competitive ability of the crop with respect to the weeds. Spitters and van den Bergh (1982) advocated a system-analytical approach for studying competition. Their idea was to analyze the system as a whole. Such an approach would be particularly useful in obtaining an outline of the relations within the system, their structure and relative importance. They realized that a simulation model, when developed, would enable the prediction of results of situations not yet tested.

Researchers have three major approaches for studying competition: additive experiments, replacement experiments and experiments designed to simulate competition in time. Other models are usually hybrids of these.

2.4.1 The Additive Model

Additive experiments are most commonly used by researchers. A known population of a weed is added to a known crop population. It is common to express crop yield in weed infested plots as a percentage of weed-free yield. This model is useful in helping answer the most common agricultural question, "What will a given weed density do to my crop yield?" However, the main disadvantage of this approach is the lack of adequate mathematical models to quantify and qualify the results of competition and to make predictions of various competitive situations (de Wit and Baeumer 1967).

2.4.2 **The Replacement Model**

The second approach is the use of a replacement or substitution model. Here, a monoculture of species A is progressively replaced with those of species B until a monoculture of the latter is obtained. Many mathematical models have been developed by de Wit and his colleagues Ennick and van den Bergh in a series of papers (de Wit 1960a,b; de Wit and van den Bergh 1965; de Wit et al. 1966; van den Bergh 1968) in attempts to quantify the competition effects in replacement experiments. Trenbath (1978) and Spitters (1980) have both shown that de Wit's model published in 1960a is the most adequate. The major drawback of this experimental approach is that it does not directly coincide with practical weed problems in the field.

2.4.3 **The Dynamic Model**

Baeumer and de Wit (1968) developed a model for dynamic simulation of competition, the third approach available to researchers. This model was used to predict the competitive relations in a mixture of species at any given time on the basis of parameters derived from a spacing experiment with the species grown in monocultures and harvested at set intervals. The model is based on the hyperbolic relationship between biomass and plant density. As the degree of curvature increases, the species occupies a greater part of the available space. The authors used 'space' to embrace all growth requisites including light, water and nutrients for which the species compete. The species which is able to occupy the available space at an earlier time will be the stronger competitor. The model has been tested by Baeumer and de Wit (1968) with mixtures of oats and barley, oats and peas, long and short peas, by de Wit (1970) with a mixture of two barley cultivars, and by Rerkasem (1978) with mixtures of wheat and ryegrass. In these experiments, the model gave satisfactory predictions of the competition effects observed.

2.5 Competition Experiments

Clements et al. (1929) studied interplant competition. They cited four points concerned with a plant's competitive ability: (1) duration or perennation--owing its effects to occupation and height; (2) rate of growth--most effectively expressed by expansion and density of the shoot and root systems; (3) rate and amount of germination--initial advantage; and (4) vigour and hardiness--ability to survive under stress. Most competition studies tend to focus on one or more of these points.

Thomas Pavlychenko provided the foundation for many of the principles of modern weed science through classic studies (Bubar and Morrison 1982). In one study, he quantified the relative distribution and lengths of roots of many plant species. Pavlychenko and Harrington (1934) defined plant competition as a powerful natural force tending towards the limitation or extinction of the weaker competitor. The species or variety which is able to utilize the environment most efficiently attains competitive supremacy. Pavlychenko (1935, 1937) extensively studied annual weed and cereal crop competition. Cereal crops were found to vary in their competitive efficiencies. Barley was the most competitive small grain followed by rye, wheat and oats in descending order. Flax was the poorest competitor. This ranking has been confirmed by other researchers (Bowden and Friesen 1967; Bell and Nalewaja 1968a, b). Canola was not included in any of these studies.

To further qualify the relative competitive abilities of the cereals, Pavlychenko and Harrington (1935) studied their respective root systems. The authors provided evidence of a close correlation between competitive efficiency and development of the root system: barley had the most competitive root system while the other cereals followed in the order as mentioned before. It was also observed that plant competition did not take place where the plants were spaced far enough apart that their root systems did not meet underground. Competition was, however, observed as soon as the spacing between neighbouring plants was reduced to the extent that their root systems began to overlap. It can be surmized that levels of water and nutrients, important environmental factors (Clements et al. 1907) would be less than those required by the competing root systems. Vengris et al. (1953) reported that large quantities of major nutrient elements absorbed by weeds are the limiting factor in crop production.

Water and nutrients are available only at certain times and in certain quantities in the soil zone. A farmer is able to manipulate and optimize these only to a limited extent. However, the amount of available light is a constant value to the aerial portion of the plant. Weeds can compete with crops for light by growing faster and higher, developing larger leaves and utilizing climbing devices (Fogelfors 1972). Goodwin (1984) studied the effects of companion crops, flax and rapeseed, on the light penetration to alfalfa seedlings over the growing season. Goodwin noted a sharp decrease in light penetration to alfalfa seedlings in plots sown to either companion crop. The greatest amount of light reduction occurred 5 weeks after crop emergence. Flax reduced light penetration to 25% of full sunlight and rapeseed to only 9%. Rapeseed reduced light penetration to a greater extent than flax throughout the growing season.

The use of different models and approaches for studying competition fall under the umbrella of experimental ecology. It has been proposed by Donald (1958) that growth factors such as light, water and various essential nutrients may be interrelated. Thus, results obtained from competition research are difficult to interpret and their applications may be limited. Donald reported results from which he concluded that an interaction between light and nutrient competition was evident. However, other researchers (King 1971; Snaydon 1971) using similar techniques were not able to arrive at the same conclusions. It still remains debatable whether different factors do actually 'interact' or are merely additive (Hall 1974).

2.6 Volunteers As Weeds

A volunteer cereal can be defined as a cereal plant growing as a weed in a subsequent crop. Several conditions can lead to a volunteer crop problem: (1) shattering of the crop prior to harvest, often accentuated by late swathing; (2) grain passing through the combine; (3) poor germination of the preceding crop; and (4) poor germination of shattered grain in the fall or before planting in the spring.

Klinner (1979) has described how losses occur before harvest. A standing crop is subject to progressive shedding and deterioration. Actual harvested losses also increase with time regardless of the harvesting method used. Therefore it is economically sound to plan for minimal delay after the crop has reached maturity--factors which slow down the speed of working of a normal combine would contribute to the losses as much as would the use of slow working machines (Bell 1977).

Some grain crops lack dormancy mechanisms. Moist, warm conditions will cause most crop seeds to germinate before the next crop is planted. Volunteers usually suffer from winter kill or uprooting by various tillage operations. However, Cussans (1978) in the United Kingdom found some volunteer cereal seeds were able to germinate up to 14 months after seeding.

2.7 Flax

Pavlychenko and Harrington (1935) demonstrated flax to be a poor competitor with weeds. Tests conducted in Manitoba (Friesen and Shebeski 1960) showed average yield reductions of flax due to mixed weed populations were 27, 31 and 22% for the years 1956 to 1958, respectively. Yield losses due to weeds were consistently greater in flax than in barley, wheat or oats.

Gruenhagen and Nalewaja (1969) studied competition between wild buckwheat (Polygonum convolvulus) and flax at various locations in North Dakota. Maximum yield losses of flax sown at 47.2 kg/ha were 11.1 and 12.4 bu/ha during 1964 and 1965, respectively. Wild buckwheat densities between 5.4 and 10.8 plants/m^2 reduced flaxseed production as much as did higher wild buckwheat densities of 216 plants/m^2. However, the percent yield reduction caused by P. convolvulus appeared dependent upon flax stands and their ability to withstand the stresses of competition.

Wild oat competition in flax was studied by Bell and Nalewaja (1968a). Averaged over two locations and two fertilizer levels, 67 wild oat/m^2 reduced yield 60.1% in 1964 and 134 plants/m^2 by 82.1 and 86.1% in 1965 and 1966, respectively. Flaxseed yield components, including bolls/m^2, plants/m^2 and weight/1000 seed were reduced by wild oat competition. A reduction in the number of branches and bolls/m^2 accounted for 90.7% of the yield loss.

Similar yield reductions of flax due to wild oat competition was reported by Bowden and Friesen (1967). Eight wild oats/m^2 were sufficient to reduce yields significantly on both summerfallow and stubble land. Severe competition was found to have already occurred prior to the 2-3 leaf stage of the weed in 1964. Competitive effects increased drastically with time and with wild oat density. In 1966, a high rainfall year, yield losses did not become significant until wild oat density reached 33 plants/m^2. The results suggested that wild oat control at an early stage was essential to the successful production of a flax crop.

Other researchers have conducted varying weed-crop competition studies and have obtained similar results, all indicating the relatively poor competitive ability of flax: Alex (1968) with cow cockle (Saponaria vaccaria), Burrows and Olson (1955) with wild mustard (Brassica kaber), Dew (1975b, 1978a) with tartary buckwheat (Fagopyrum tataricum), and Alessi and Power (1970) with green foxtail. It can be concluded from the foregoing review that flax is less competitive than any of the cereal crops. Although canola was seldom included in experiments, the relative competitive ability would be expected to fall between that of flax and rye. The distinction between the competitive abilities of the crops, however, is not as well defined and results have varied with different climatic and cultural conditions.

2.8 Canola

The literature available on canola-weed competition is limited. The majority of studies are reported annually in the Western Section of the Expert Committee on Weeds.

Competition work done by Dew with wild oats, tartary buckwheat (1975a, b) and wild buckwheat (1977) proved to be inconsistent, often due to adverse weather conditions resulting in erratic seed germination and poor competition. Similar results were reported by Keys (1975) working with wild oats. However, the data collected by both researchers indicated the relative ability of canola to withstand weed competition as compared to other crops.

Separate experiments involving tartary buckwheat competition in canola (Dew 1975b) and flax (Dew 1978a) showed that a minimum of 150 tartary buckwheat plants/m^2 was required to cause a highly significant yield reduction in canola. However, only 25 tartary buckwheat plants were required to produce the same effect in flax.

The influence of various densities of volunteer barley on canola yields was studied by de St. Remy and O'Sullivan (1984). Westar (*Brassica napus*) and Tobin (*B. campestris*) yields were reduced proportionally as the density of volunteer barley was increased. Losses were greater in Westar than in Tobin when volunteer barley was present at a similar density.

Hühn and Schuster (1975) quantitatively estimated the competitive effects of neighbouring plants in winter rape (*B. napus*) populations. They found that the yield components plant height and number of kernels per siliqua were insensitive to competition. However, grain weight per plant, number of siliquae per plant and 1000-kernel weight were very sensitive to competition.