THE EFFECTS OF WILD OAT HERBICIDES ON CROP YIELD AND THE WILD OAT POPULATION UNDER CONTINUOUS WHEAT AND BARLEY CULTURE

A Thesis

Submitted to the Faculty

of

Graduate Studies

The University of Manitoba

by

Ross Montgomery Rankin

In Partial Fulfilment of the

Requirements for the Degree

of

Master of Science

May 1980.

THE EFFECTS OF WILD OAT HERBICIDES ON CROP YIELD AND THE WILD OAT POPULATION UNDER CONTINUOUS WHEAT AND BARLEY CULTURE

BY

ROSS MONTGOMERY RANKIN

A thesis submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

MASTER OF SCIENCE

ACKNOWLEDGEMENTS

The author wishes to express sincere thanks to the following individuals and organizations for assistance given during this study.

Dr. E.H. Stobbe, my advisor, for his encouragement, support and guidance given freely throughout this project.

Dr. G. Laliberte, Department of Agricultural Engineering and Professor G.M. Young, Department of Plant Science for reviewing this manuscript.

Dr. I.N. Morrison for his suggestions, advise and interest shown in this project.

My fellow graduate students, Allan Sturko and Martin Owino for technical assistance, advise and friendship.

The University of Manitoba and Manitoba Pool Elevators for financial assistance provided during this study.

To my wife, Shelley and our children for love, support and sacrifice during this period.

ABSTRACT

Rankin, Ross Montgomery, M.Sc., The University of Manitoba, May, 1980.

The effects of wild oat herbicides on crop yield and the wild oat population under continuous wheat and barley culture.

Major Professor: E.H. Stobbe

Field experiments were conducted in wheat and barley crops to determine the effects of wild oat herbicides on the crop yield and the wild oat population in 1975, 1976 and 1977.

The effects of the wild oat herbicides were shown by comparing with a weedy check, the differences in yield, wild oat areal seed density, wild oat panicle density and the wild oat seed population in the soil.

The herbicides, barban, benzoylprop ethyl, diclofop, difenzoquat, triallate and trifluralin were applied under two herbicide application schemes; a yearly herbicide application scheme and an alternate-year herbicide application scheme.

The plots treated with the wild oat herbicides, in general, showed a significant yield increase and a reduced wild oat areal seed density and panicle density in comparison to the weedy check. Reductions in the wild oat areal seed density and panicle density appeared greater within the barley crop than within the wheat crop.

The yearly application of wild oat herbicides was more effective in reducing the wild oat population within the crop and increasing the crop yield than the alternate-year herbicide application scheme.

Substantial reductions in the number of wild oat areal seed density were required to significantly reduce the wild oat seed population in the soil.

TABLE OF CONTENTS

LIST OF FIGURES

Page

LIST OF TABLES

INTRODUCTION

Wild oats (*Avena fatua* L.) represent the most serious weed problem facing small grain farming in Western Canada. It is estimated that this weedy species infests 75-85% of cultivated prairie farmland (Manson, 1932; Alex, 1965). Wild oats are highly competitive with the major cultivated field crops, i.e., wheat, barley, flax and rapeseed, resulting in yield losses estimated at $100-300 million per year (Shuttleworth, 1972; Friesen, 1974a; Honey, 1977). As well, indirectly, wild oats are responsible for large dockage, cleaning and transportation expenditures (Shuttleworth, 1972).

Wild oats are uniquely adapted to survive within a cultivated crop despite concentrated efforts to eliminate them. The basis for their success is complex. Periodicity of germination, seed dormancy, early seed maturation and the ability to readily shatter and reseed all contribute to the success of the wild oat species.

Traditional means of wild oat control have been by agronomic practices such as delayed seeding, summer fallow, crop rotation and fall tillage schemes. For the most part these methods have achieved only limited success. The relatively recent developments in specific herbicides selective to wild oats has provided a seemingly effective means to completely control wild oats within a field crop. However, the wild oat problem still persists.

The object of this study was to examine the effectiveness of several herbicides for the control of wild oats. Field experiments were carried out in wheat and barley crops under a continuous cropping practice. The herbicides were applied under two application methods; a yearly herbicide application scheme and an alternate-year herbicide application scheme. Crop yield, wild oat seed yield within the crop, and wild oat panicle density were the criteria which determined the effectiveness of the herbicide. The wild oat seed population in the soil was estimated within each treated area to determine the effect each herbicide had upon this population.

LITERATURE REVIEW

Competition

Plant competition occurs when essential growth elements, i.e. water, nutrients, light and space are limiting. Weeds in competition with a crop result in yield and/or crop quality reduction. Blackman and Templeman (1938) observed that the intensity of weed competition depended upon the weed species, those species capable of rapid early development caused the greatest yield reductions. They noted reduced tillering, fewer fertile shoots and smaller head size as a direct result of weed competition

Pavlychenko and Harrington (1934, 1935) suggested that under the dry climatic conditions of the western Prairies moisture was the limiting factor and, therefore, species capable of producing a superior root system would hold a competitive advantage. They were able to show that wild oats produced more root material than the wheat and barley crops studied and that this root system fully occupied the soil region from surface to a great depth (70 cm). They suggested that the only reason a cereal crop could compete at all with wild oats was that wild oats are relatively slow to germinate and that its root development, at least initially, was slow in comparison to the cereal crop.

The earlier a cereal crop is planted, germinates, and emerges in relation to its weedy competitor the greater its competitive effect upon the weed and the smaller the effect of the weed upon yield (Williams, 1969). Barley, a good competitor with wild oats was not able to overcome the damage caused by early competition even when the wild oats were removed at the beginning of tillering (Kock, 1967).

Thurston (1962) showed that a dense crop of any autumn-sown cereal could effectively control wild oat competition, however, even the heaviest crop did not completely suppress the wild oats. On the other hand moderate wild oat infestations of 10-40 plants/yd^2 can cause significant yield reductions in spring wheat and flax (Bowden and Friesen, 1967). Chancellor and Peters (1974) observed that no significant yield reductions occurred in spring wheat or barley until wild oats reached densities of 20-100 plants/m^2 while Bell and Nalewaja (1968b) showed that 70-160 seedlings/yd^2 reduced spring wheat yields by 22.1% and 39.1% respectively when compared to weed-free checks. In flax, an extremely poor competitor with wild oats, yield reductions as high as 86% were caused by wild oat densities of 160 plants/yd^2 (Bell and Nalewaja, 1968a). An infestation of 160 plants/yd^2 is not unreasonable considering the fact that Friesen and Shebeski (1960) found an average of 224 weeds/m^2 in a study composed of 142 farm fields over a three year period in Manitoba. Wild oats was a prominent species in this study.

Dew (1972) developed an "index of competition" for wild oats within specific crops. Using this value and knowing the wild oat densities and the expected weed-free yield he was able to predict yield losses due to wild oat competition.

Wild Oat Biology

The optimum temperature for the germination of wild oats is in the range of 10-21^{o}C (Sharma *et al.*, 1976; Atwood, 1914; Kock, 1968; Friesen and Shebeski, 1961). Chancellor and Peters (1972) reported wild oat germination in the spring at soil temperatures of 6-7^{o}C and Banting (1973) noted 60% germination within five days at 4.4^{o}C and over 80% at 10^{o}C.

Temperature, however, is not the only factor affecting wild oat germination; soil moisture has a profound effect on the germination and emergence of wild oat seedlings. Sharma *et al.* (1976) noted that emergence was maximized at soil moistures of 50-75% of field capacity while at field capacity nearly all seeds rotted within 11 days of planting. Kock (1968) observed maximum emergence of wild oats at soil moistures of 65-90% field capacity and a temperature range of 10^{o}C - 30^{o}C.

Spring periodicity of wild oat germination has been well documented (Chepil, 1946; Thurston, 1951; Miller and Nalewaja, 1975; Wilson and Cussans, 1975). Few wild oat seeds germinated in the autumn and hardly any germinated during the summer (Thurston, 1951; Miller and Nalewaja, 1975). The spring periodicty of wild oat germination is coincident with the ideal moisture and temperature conditions prevalent in the spring, as well, primary dormancy of the wild oat seed has dissipated during the winter after-ripening period (Banting, 1973; Bibbey, 1935; Bibbey, 1948).

In general, the wild oat is capable of emergence from greater depth than cereal crop (Banting, 1973). The wild oat emerges by elongation of the coleoptile and the first internode while wheat and barley emerge by elongation of the coleoptile (Avery Jr., 1930; Boyd and Avery Jr., 1936). Thurston (1951) noted wild oat seedling emergence from 22 cm, Sharma *et al.* (1976) reported emergence from 20 cm, while Holroyd (1964) and Miller and Nalewaja (1975) observed wild oat emergence from 18 cm. The majority of wild oat seedlings, however, emerged from the top 8 cm of the soil (Holroyd, 1964; Sharma *et al.*, 1976; Miller and Nalewaja, 1975).

Banting (1966a) noted similar results in that the wild oat seeds in the upper 0 – 5 cm layer of soil germinated more readily as compared to lower soil layers. He also noted that 93% of the seed on the soil surface failed to germinate. The failure to germinate and/or the high mortality rate of seed exposed on the soil surface over the winter period had been reported by other researchers (Chepil, 1946; Wilson, 1972; Wilson and Cussans, 1975). Light inhibition of wild oat germination was observed by Johnson (1935).

Wild oats is an annual species and, therefore, relies upon a viable soil seed population to survive. Some wild oat seeds have been reported to persist in the soil systems for up to five years (Thurston, 1951; Banting, 1966a). However, since the vast majority of wild oat seeds either germinate or perish within the first year, prevention of reseeding is essential to wild oat control (Wilson, 1972; Wilson and Cussans, 1975).

The rapid development, early maturity and ready shattering ability of wild oats is well known. Chepil (1946) and Wilson (1972) report wild oat maturity and shattering by early August, well before crop maturity and harvest. As well, wild oat seeds are known to ripen unevenly, with seeds at top of the panicle ripening and shedding even before the seeds at the base of the panicle are completely filled (Banting, 1973). Shattering of wild oat seed is easily accomplished by the nature of the rachillae which becomes stiff and fragile upon maturity (Naylor and Jana, 1976; Thurston, 1951).

Seed dormancy plays a major role in the success of wild oats within cultivated crops. The dormancy characteristics have proven to be extremely complex. Early work showed that wild oat seed germinated poorly and unevenly following shedding but increased germinability occurred with time (Atwood, 1914).

Wild oat seed upon shattering is in a state of primary dormancy requiring a certain period of after-ripening before germination is possible. Johnson (1935) observed that storage in frozen condition increased germinability. Banting (1966b) reported that warm dry conditions were more conducive to after-ripening than cold, humid conditions. He found that most seed had after-ripened within three years. Johnson (1935) was able to correlate the period of after-ripening with the position of the seed on the wild oat panicle. Primary seeds of the panicle required less of an after-ripening period than the secondary seeds. Johnson (1935) and Banting (1966b) noted that if incompletely after-ripened seeds were placed in germinative conditions secondary dormancy resulted.

Bibbey (1948) concluded that the majority of primary dormancy disappeared during the first winter season. He reported that any seeds which failed to germinate in the spring did so only due to environmental dormancy. He felt that environmental dormancy was the major factor in soil seed longevity and that although secondary dormancy could be demonstrated in the laboratory it was not evident in the field. Thurston (1951) also noted that secondary dormancy did not occur in the field and that seedlings arising from seed more than one year old were less vigorous. In 1962, Banting reported that primary dormancy was mainly responsible for wild oat seed persistence and not lack of germinative conditions as Bibbey (1948) had suggested. However, in further studies, Banting (1966b) noted that a condition of secondary dormancy could be induced in after-ripened seeds by high soil moisture levels. Secondary dormancy had been shown to result from lack of oxygen (Black, 1959; Hay, 1962). Banting (1962) postulated that if wild oat reseeding were prevented the dormant seeds would then predominate in the soil seed population. He found, however, that a variation in the percentage of dormant seed in the soil occurred within the year and between years (Banting 1966a). He suggested that this dormancy characteristic indicated the induction of secondary dormancy within the soil system. Both Banting (1966a) and Thurston (1961) reported that burial of wild oat seed below 5 cm extended the life-span of the seed. This was presumably due to induced dormancy caused by low oxygen levels.

Many different wild oat genotypes exist within and between natural wild oat populations. Friesen and Shebeski (1961) tested five different "types" of wild oat seed; classified by seed color, for germinability and dormancy. They found large differences in the degree of dormancy and the germination requirements between these types. Naylor and Jana (1976) suggested that the length of dormancy can be a function of the environment and genotype. They reported that the differences between dormancy and germinative behavior among local wild oat populations could be a result of genetic adaptation to the selective pressures of agronomic pratices.

Cultural Control

Delayed seeding is an important cultural method for wild oat control. The occurrence of a spring periodicity of wild oat germination has been indicated (Chepil, 1946). Early spring cultivation tends to aerate the soil and increase the soil temperature, this further stimulates spring wild oat germination (Chancellor, 1964; Chancellor and Peters, 1972). By delaying spring seeding until after the peak period of wild oat germination, the majority of wild oats can be eliminated by cultivation before the crop is planted in early June (Korven, 1960; Banting, 1962; Sexsmith and Pittman, 1962).

Whybrew (1964) and Selman (1968) reported that late sowing was effective in controlling wild oats in continuous-cropped spring barley. However, this method could only reduce wild oats to a low level. Yield reductions due to late seeding were noted in wheat and oat crops but not barley (Anderson and Henning, 1964).

Holroyd (1964) found delayed seeding an ineffective means of wild oat control under conditions of heavy infestations. He found that the spring cultivations designed to kill the wild oat flush could cause stimulation of other wild oat seeds to germinate in the region of the cultivation or deeper and as well that many wild oat seedlings could re-establish under moist conditions.

Banting (1966b) observed that 32 - 40% of wild oat seed that had started to germinate could survive seven days of desiccation and rapidly germinate upon rewetting.

A great deal of experimental work has been done concerning the effects of fall tillage on the wild oat seed population in the soil. Weed seeds are stimulated to germinate by cultivation due to soil disturbance and aeration (Bibbey, 1948; Chancellor, 1964; Roberts and Feast, 1972). Fall cultivation has been reported to stimulate fall germination of wild oat seed (Whybrew, 1964; Banting, 1966a; Wilson and Cussans, 1972).

Thurston (1961) concluded that cultivation had no effect on the persistence of wild oats outside of the normal spring period of germination. She noted as well that seeds buried below 5 cm by cultivation tended to remain viable longer than seed on the surface or buried to a depth of 5 cm. The increased persistence of wild oat seed buried below 5 cm was confirmed by Banting (1966a) and Miller and Nalewaja (1975).

Fall tillage resulted in a large increase in wild oat germination in the following spring (Miller and Nalewaja, 1975; Wilson and Cussans, 1975; Whybrew 1964). However, wild oat seeds left undisturbed on the soil surface deteriorated rapidly and most seeds were not viable after one year (Thurston, 1961; Wilson, 1972; Wilson and Cussans, 1975). Banting (1966a) suggested that the wild oat seeds stimulated to germinate in either the fall or following spring by the fall tillage operation were seeds which left undisturbed on the soil surface would have perished over the winter. Wilson and Cussans (1975) had shown that the greatest loss of newly shed wild oat seed occurred when stubble was left uncultivated throughout the autumn. In this respect a case can be made for wild oat control by zero tillage (Stobbe, 1979).

The use of summer fallow as an effective means of wild oat control is dubious. Studies have shown that once the spring period of wild oat germination is over further cultivation has little effect on the wild oat population (Thurston, 1961; Banting, 1966a). Delayed seeding should, therefore, be as effective as summer fallowing in controlling wild oats (Banting, 1962). A minimum of five years summer fallow is needed to eliminate wild oats from heavy clay soils but two years consecutive summer fallow or a two year rotation of summer fallow and crop, where wild oat re-seeding is prevented is effective in the reduction of a wild oat infestation (Banting, 1962).

In direct contrast to summer fallow is the practise of sowing land to a semi-permanent pasture. This prevents the re-seeding of wild oats and should result in the growing out and depletion of the wild oat seed population in the soil. Thurston (1966) did not find semi-permanent pastures to be an effective means of reducing the wild oat seed population in the soil. She reported that even after five years of pasture there was still enough original wild oats seed in the soil to reinfest a cereal crop.

Other cultural techniques to limit or control wild oats have been reported. Increased crop seeding rates have been used to reduce the effect of wild oats by competition (Godel, 1935; Pfeiffer and Holmes, 1961; Thurston, 1961). In this respect the use of a highly competitive crop such as rye, soybeans or barley have been reported to significantly reduce the wild oat soil seed population (Miller and Nalewaja, 1977).

Fertilizers have been reported to affect wild oat populations. Sexsmith and Pittman (1962) observed that early spring broadcast and disked-in applications of nitrogen fertilizers caused increased germination of wild oat seed in the soil. Johnson (1935) had reported that nitrates increased the germination of dormant wild oat seeds. Early application of nitrogen fertilizers in conjunction with delayed crop seeding should be effective in reducing the soil seed supplies and controlling wild oats within the crop.

The addition of fertilizer did not give the crop a competitive advantage since nitrogen fertilizer stimulated the crop and wild oat growth to a similar degree (Pfeiffer and Holmes, 1961; Thurston, 1962).

In general, cultural control methods for wild oats can be highly effective, however, such methods are not completely reliable and depend heavily on favourable climatic conditions (Friesen, 1974).

Chemical Control

Triallate is a soil-incorporated herbicide for the selective control of wild oats in wheat and barley. The herbicidal activity of triallate is primarily via the coleoptile with the region 10 - 15 mm above the coleoptile node being the most sensitive (Friesen *et al.*, 1962; Parker, 1963).

Wheat and barley exhibit a sensitivity to triallate in the early stages of coleoptile emergence (Friesen *et al.*, 1962; Parker, 1963). Barley is more tolerant to this herbicide that wheat (Parker, 1963). Wild oats shows a more prolonged sensitivity to triallate with a later stage of sensitivity which coincides with the initiation of the crown node (Friesen *et al.*, 1962).

Selectivity is achieved through morphological differences between the seedling emergence of wild oats and that of wheat and barley (Molberg *et al.*, 1964; Parker, 1963; Banting, 1967). Wild oats emerge via coleoptile and first internode elongation while wheat and barley seedlings emerge solely by coleoptile elongation (Avery Jr., 1930).

Selective control of wild oats is achieved by seeding wheat to a depth of 7.5 cm and the pre-emergence soil incorporation of triallate to depth of 5 cm. The 2.5-cm layer of untreated soil above the wheat seed acts as a protective layer to the sensitive area of the emerging wheat coleoptile (Molberg *et al.* 1964). Pre-seeding incorporation of triallate can be employed with barley which is less sensitive to triallate requiring only 1.25 cm of untreated soil as a protective layer (Parker, 1963).

Hay (1973) reported that 95% control of wild oats could be achieved under ideal conditions while under average conditions 80 - 85% wild oat control was possible.

Trifluralin is a pre-emergence soil-applied herbicide for selective control of many annual grasses and broadleaf weeds in dicotyledonous crops such as rapeseed, sunflowers and flax. Chow (1976) reported excellent wild oat and green foxtail control and good crop tolerance with trifluralin in rapeseed over a three-year period In cereals, trifluralin is primarily used for green foxtail control (Rahman and Ashford 1972a, 1972b). Some wild oat control using trifluralin in wheat has been observed (Moyer and Dryden, 1977).

Prendeville *et al.* (1967) reported that trifluralin was most effective when applied to the shoot zone of a seedling; little effect occurred on the foliage due to root application although root growth was inhibited. Wheat and green foxtail were particularly sensitive to trifluralin applied to the region of the coleoptile node (Rahman and Ashford, 1970). Parker (1966) suggested that trifluralin was more effective when taken up by the roots. Herbicidal selectivity is achieved by utilizing morphological difference between the seedling emergence of green foxtail and the crops of wheat and barley (Rahman and Ashford 1972a, 1972b). Shallow pre-emergence soil incorporation of trifluralin provides the untreated layer of soil necessary to protect the germinating crop seed from herbicide action.

Green foxtail control of 90 - 100% in barley has been reported (Rahman and Ashford, 1972a).

Barban is a post-emergence foliar-applied wild oat herbicide for use in wheat and barley.

Banting (1960) reported that 8 oz/ac barban resulted in a 50 - 100% wild oat control and an average yield increase of 7.8 bu/ac in wheat, barley and flax. Faivre-Dupaigre (1963) found that 12 oz/ac barban gave 80 - 95% wild oat control in spring barley.

The selective herbicidal activity of barban between wild oats and the tolerant crop species is biochemical. Shimabukuro *et al.* (1976) reported that the coleoptile was a physical and physiological barrier to barban activity. Metabolism of barban in the coleoptile of tolerant wheat varieties was higher than in barban sensitive wild oats.

Barban was observed to be most effective when applied in low volumes of water and at early stages of wild oat seedling development (1½ - 2 leaf stage) (Friesen, 1961).

Barban was shown to act more as a growth inhibitor than actually killing the wild oat plants, this resulted in giving the crop a competitive advantage (Friesen, 1961). In competition studies between barley and tame oats (Pfeiffer and Holmes, 1961) and barley and wild oats (McBeath *et al.*, 1970) it was shown that barban applications, at rates of 0.20 kg/ha - 0.67 kg/ha, produced significant yield increases and achieved up to 80% tame oat and wild oat control.

Difenzoquat is a selective, postemergence wild oat herbicide in barley and some wheat varieties. Friesen and Litwin (1975) reported wild oat control by difenzoquat to be equal to or better than that of barban in spring barley. Winfield and Caldicott (1975) reported good to excellent wild oat control and good crop tolerance using difenzoquat in spring and winter wheat and barley.

The most effective wild oat control was achieved when application of difenzoquat was at a relatively late stage of wild oat seedling growth (3-5 leaf) (Friesen and Litwin, 1975; Winfield and Caldicott, 1975). Friesen and Litwin (1975) concluded that the late stage of application may mean that yield reducing competition by wild oat has already occurred.

Friesen and Litwin (1975) also reported that good herbicide coverage of the wild oat plant was necessary in order to kill the plant. In heavy wild oat infestation and at the late 3-5 leaf stage of wild oats a shading effect occurred which prevented good difenzoquat coverage and resulted in less effective wild oat control. Winfield and Caldicott (1975) however, reported wild oat control and yield increases were greatest where the heaviest wild oat populations occurred.

Selective herbicidal activity of difenzoquat is biochemical. Barley is capable of metabolizing difenzoquat to a non-toxic form while the herbicide remains lethal to wild oats (Friesen and Litwin, 1975).

Benzoylprop ethyl is a post-emergence wild oat herbicide for use in most varieties of wheat.

Chow and Dryden (1975) reported that benzoylprop ethyl gave good control of wild oats in wheat resulting in significantly higher yields. More effective wild oat control was achieved when the herbicide was applied at later 4-5 leaf stages of wild oats than at the earlier 1½ - 2 leaf stage.

Stovell and Bowler (1972) reported that benzoylprop ethyl applied in wheat at the 3 - 6 leaf stages of wild oats resulted in yield increases of 32 - 148% in heavy wild oat infestations, 14 - 60% in moderate wild oat infestations and 5 - 25% in light wild oat infestations. They claimed that wheat yield reductions were a result of the wild oats shading the flag leaf of the crop impairing photosynthesis. Late removal of wild oats at the 4 - 6 leaf stage therefore achieves as good a yield advantage as earlier removal of wild oats at the 1½ leaf stage.

The selective activity of benzoylprop ethyl is biochemical. Wild oats metabolize the herbicide to an active and toxic form while metabolism of benzoylprop ethyl by tolerant wheat varieties is low (Jeffcoat and Harris, 1973; Hill *et al.*, 1978).

Benzoylprop ethyl results in severe stunting and inhibition of leaf growth of the wild oat plant (Friesen and Dew, 1972; Jeffcoat and Harris, 1973). Barber (1976) reported a reduction in seed size of wild oats from plants affected but not killed by benzoylprop ethyl.

Diclofop is a post-emergence herbicide providing selective control of wild oats and green foxtail in wheat and barley (Friesen et al., 1976; Todd and Stobbe, 1977).

Owino (1977) reported excellent wild oat and green foxtail control resulting in significant yield increases with application of diclofop in both wheat and barley.

Diclofop was most effective when applied at the 2-4 leaf stages of wild oat growth (Owino, 1977; Friesen *et al*. 1976).

The selective activity of diclofop is biochemical. Wild oats and green foxtail are extremely sensitive to diclofop, wheat is tolerant to the herbicide while barley tends to become more sensitive to diclofop in latter growth stages (i.e. 5-6 leaf) (Owino, 1977; Todd and Stobbe, 1977). Application of diclofop on or below the meristematic area of the stem apex resulted in necrosis and eventual death of wild oat and green foxtail plants. Owino (1977) observed yellowing and leaf necrosis of wild oat and green foxtail plants affected by diclofop four days after herbicide application, death of the weedy species followed.

In general the use of herbicides to control wild oats is more effective than cultural control methods.

Selman (1968) observed greater yield increases when using triallate to control wild oats compared to late seeding of barley as a wild oat control method. Roebuck and Hughes (1972) compared late seeding to pre-emergence triallate and post-emergence barban. All wild oat control methods reduced the wild oat populations and increased the crop yield in comparison to a weedy check. The herbicides resulted in better wild oat control and higher yield increases than did the method of late seeding. Triallate or alternate yearly use of triallate and barban gave the greatest yield increases and the best wild oat control.

Baldwin and Livingston (1976) compared the herbicides benzoylprop ethyl, difenzoquat and diclofop in spring barley at various times of application. Benzoylprop ethyl and difenzoquat gave the highest level of wild oat control over a longer period of application. Diclofop was effective only when applied at early stages of wild oat growth. All herbicides resulted in yield increases, the greatest increases occurred where the wild oat infestations were the heaviest and herbicidal control approached 100%. Lower yield responses occurred with late growth stage application as compared to early herbicide application.

Baldwin and Finch (1976) compared the herbicide difenzoquat, diclofop and barban in spring barley. Difenzoquat showed the best and most consistent wild oat control over a longer period of application. Early application of barban and diclofop resulted in yield responses with increases dependent directly upon intensity of wild oat population.

Fay and Nalewaja (1977) compared the effectiveness of cultural and chemical methods of wild oat control in reducing the wild oat seed population in the soil. In general excellent wild oat control and increased yield resulted in all methods of control. The wild oat seed reservoir in the soil steadily diminished in all cases. The herbicides tended to be more effective in wild oat control and in reducing the seed reservoir than did cultural control methods. Results showing the comparative effectiveness of the herbicides triallate, barban, difenzoquat and diclofop were variable depending upon the location and environmental conditions. Wild oat control approaching 100% was observed at some point with all herbicides.

MATERIALS AND METHODS

General Procedures

Field experiments were conducted at Carman, Manitoba in 1975, 1976 and 1977. The soil type was an Almasippi very fine sandy loam (75.6% sand, 11.5% clay, 8.6% silt and 4.3% organic matter).

Wild oat seeds were broadcast over the entire experimental plot area in the spring of 1975 using a hand held cyclone broadcast spreader. Seedbed preparations were by shallow cultivation and harrowing. Soil fertility was supplemented by the addition of 67 kg/ha nitrogen and 17 kg/ha phosphorus.

The climatic data for the 1975, 1976 and 1977 growing seasons are presented in the Appendix (Tables 1, 2, 3).

In the fall of each year the straw was removed by hand raking and the plots were cultivated to a depth of 7 - 10 cm.

In 1975 the experiments were conducted on oat stubble. A six-treatment by six-replicate latin-square design was used, each plot measuring 4 m x 8 m.

In 1976 these plots were sub-divided into two sides each 2 m x 8 m. The same split-plot design was used in 1977 (Figure 1). The herbicide treatments were applied as follows; in 1975 the entire plot area received a treatment, in 1976 only the left hand side received a treatment while the right hand side was untreated, and in 1977 both sides of the plots received treatments (Figure 1).

The herbicide spray treatments were applied by air pressure, using a bicycle-wheel type sprayer. A Tee Jet 65015 flat fan

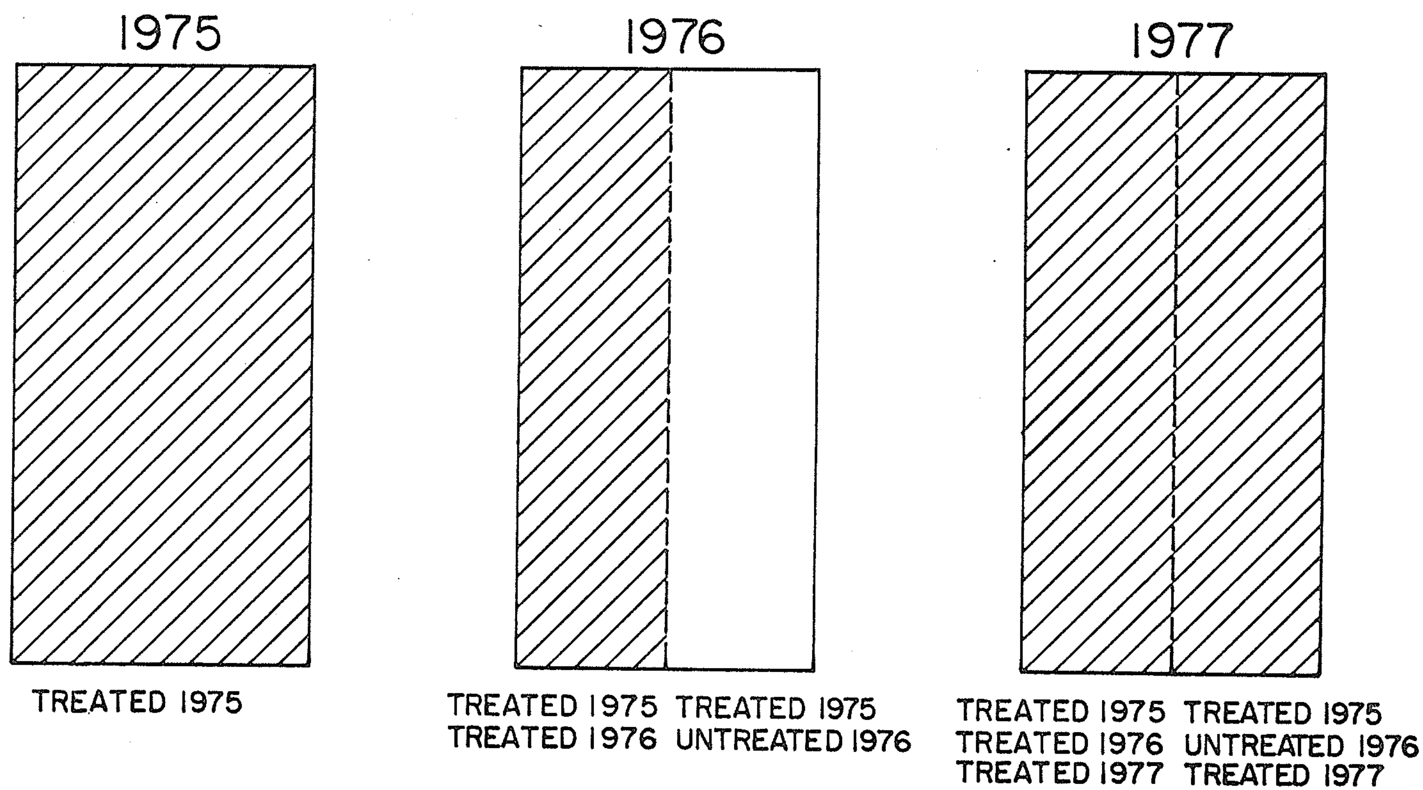

FIGURE 1. Schematic diagram showing the plot area which received wild oat herbicide treatments in 1975, 1976 and 1977. (Shading indicates treatments.)

nozzle delivering 116 L/ha at 245 kPa pressure was used to apply the herbicides triallate, trifluralin, difenzoquat, benzoylprop ethyl and diclofop. A Tee Jet 65067 flat fan nozzle delivering 55 L/ha at 310 kPa was used to apply barban. The nozzle angle was 90^{o} in the case of triallate, trifluralin and diclofop, while a 45^{o} forward angle was used to apply barban, difenzoquat and benzoylprop ethyl.

Incorporation of the soil-applied herbicides triallate and trifluralin was by two harrowing operations using a diamond harrow.

Seeding of both wheat and barley was by double-disc press drill to a depth of 7.5 cm and a row width of 15.0 cm.

Both crops were harvested by straight combining using a Hege 125 combine.

Three separate soil sampling operations were conducted, an initial sampling May 26, 1975, a fall sampling September 4, 1975, and a spring sampling May 2, 1977.

The 1975 samples were obtained by pressing a 12.7-cm diameter cylinder to a depth of 16.5 cm into soil loosened by a shovel. In 1977 the soil samples were obtained using a 7.0-cm diameter soil auger to a depth of 7.0 cm.

In the spring of 1975 thirteen soil samples (ave. 4 kg) were taken at random from within the experimental area. The fall 1975 samples were obtained by taking three random soil samples (ave. 3 kg) from each of the 4-m x 8-m plots of the two experimental areas. In the spring of 1977, four random soil samples (ave. 3/4 kg) were collected from the treated 2-m x 8-m sides of each split plot of the two experiments.

Soil samples were placed in 24-cm x 38-cm nylon window screen bags and the soil was washed away by gentle agitation in a 200-L water tank. Wild oat seeds were dried, counted and tested for viability.

Viability tests were conducted in a germination cabinet at 20°C, 100% relative humidity and darkness. Two 25-seed lots, from each sample were tested where possible. The wild oat seeds were spaced embryo up on two layers of Whatman No. 1 filter paper in a 10-cm Petri dish. All seeds were dusted with the fungicide Arasan. Seeds were germinated in a 500-ppm gibberellic acid solution, after seven days the seed coats of ungerminated seeds were pierced with a sterile needle. Any seeds that had failed to germinate after 28 days were considered dead.

All quantitative assessments were statistically analyzed and the treatment means compared using Tukey's honestly significant difference procedure (or "W" procedure). Only differences significant at the five-percent level of probability were considered meaningful.

Yield data (kg/ha) were statistically analyzed. The wild oat aerial seed data, wild oat panicle data and the wild oat seed in the soil data were transformed according to log (x + 1), where x represents each of the parameters and were statistically analyzed.

Experiment 1: The effect of yearly and alternate-year applications of wild oat herbicides on the wheat yield and the wild oat population under continuous wheat culture; 1975, 1976, 1977.

In 1975 and 1976 Napayo wheat was seeded at the rate of 106 kg/ha and in 1977 Sinton wheat was seeded at 85 kg/ha.

Seeding dates, harvesting dates, and herbicide treatments and application dates are presented in Table 1.

Wild oat sampling was carried out in all three years to determine the wild oat areal seed density within the wheat crop (Table 1). In 1975 sampling was accomplished by the random harvest of four 1/16-m^2 areas within each of the 4-m x 8-m plots. In 1976 and 1977 sampling was carried out by the random harvest of four 1/16-m^2 areas from each of the 2-m x 8-m sides of each plot. The wild oat panicles were separated and counted from each 1/16-m^2 sample, and, as well, the wild oat seeds from each panicle were counted. Sampling was done prior to shedding of the most mature seeds of the wild oat panicle.

Experiment 2: The effect of yearly applications of wild oat herbicides on the wild oat seed population in the soil under continuous wheat culture.

Soil samples were taken from the treated area of the wheat plots (Experiment 1) in the spring of 1975, the fall of 1975 and the spring of 1977. The wild oat seed population in the soil and the wild oat seed viability was determined as described previously.

TABLE 1. Herbicide treatments, seeding and sampling dates for plots under continuous wheat culture.

TREATMENT	RATE	STAGE	1975	1976	1977
Weedy check					
Triallate	1.40 kg/ha	Pre-em. harrow 5 cm	May 27	May 10[1]	May 21
Trifluralin	0.56 kg/ha	Pre-em. harrow 5 cm	May 27	May 14	May 21
Barban	0.35 kg/ha	1½ - 2 leaf	June 6	May 27	May 30
Benzoylprop ethyl	1.40 kg/ha	3 - 5 leaf	June 23	June 12	June 9
Diclofop	1.12 kg/ha	2 - 3 leaf	June 11	May 31	May 31
Wheat crop seeded			May 22	May 13	May 17
Broadleaf treatment			June 9[2]	June 18[3]	June 1[4]
Wild oat sampling			July 16	July 13	July 18
Crop harvest			August 21	August 16	August 18

[1] Pre-plant incorporate
[2] 0.56 kg/ha bromoxynil octanoate + MCPA ester
[3] 0.56 kg/ha MCPA + 0.14 kg/ha dicamba
[4] 0.35 kg/ha bromoxynil

Experiment 3: The effect of yearly and alternate-year applications of wild oat herbicides on the barley yield and the wild oat population under continuous barley culture; 1975; 1976, 1977.

In 1975 and 1976 Bonanza barley was seeded at the rate of 112 kg/ha and in 1977 Klondike barley was seeded at 85 kg/ha.

Seeding dates, harvesting dates, and herbicide treatments and application dates are presented in Table 2.

Wild oat sampling within the barley crop was carried out in all three years (Table 2). The random sampling of the wild oat population was conducted as previously described in Experiment 1.

Experiment 4: The effect of yearly applications of wild oat herbicides on the wild oat seed population in the soil under continuous barley culture.

Soil samples were taken from the treated area of the barley plots (Experiment 3) in the spring of 1975, the fall of 1975 and the spring of 1977. The wild oat seed population in the soil and the wild oat seed viability were determined as described previously.

TABLE 2. Herbicide treatments, seeding and sampling dates for plots under continuous barley culture.

TREATMENT	RATE	STAGE	1975	1976	1977
Weedy check					
Triallate	1.68 kg/ha	P.P.I - harrow 5 cm	May 14	May 10	May 12
Trifluralin	1.12 kg/ha	Pre-em harrow 5 cm	May 27	May 14	May 21
Barban	0.35 kg/ha	1½ - 2 leaf	June 6	May 27	May 30
Difenzoquat	0.84 kg/ha	3 - 5 leaf	June 23	June 12	June 9
Diclofop	1.12 kg/ha	2 - 3 leaf	June 11	May 31	May 31
Barley crop seeded			May 22	May 13	May 17
Broadleaf herbicide treatment			June 9[1]	June 18[2]	June 1[3]
Wild oat sampling			July 16	July 13	July 18
Crop harvest			August 20	August 16	August 17

[1] 0.56 kg/ha bromoxynil octanate + MCPA ester
[2] 0.56 kg/ha MCPA + 0.10 kg/ha dicamba
[3] 0.35 kg/ha bromocynil.

RESULTS AND DISCUSSION

In 1975 a heavy and uniform wild oat infestation covered the entire experimental plot area. This population resulted from the combination of a natural infestation plus the broadcast seeding of wild oats.

The wild oat seedlings emerged at approximately the same time as the cereal crops in 1975, 1976 and 1977. In 1976 a second wild oat flush occurred two weeks after crop emergence.

A natural green foxtail infestation was evident within the experimental area. No treatments other than those herbicides directed at the wild oat population and the overall broadleaf herbicide applications were employed to eliminate the effects of the green foxtail species within these trials. It must be noted, however, that trifluralin and diclofop are effective against both green foxtail and wild oats while barban, benzoylprop ethyl, triallate and difenzoquat affect only wild oats.

Results and Discussion of Wheat Experiments

The results of the wheat experiments (experiments 1 and 2) are shown in Tables 3, 4, 5, 6 and 7.

Yield

The wheat yields from plots treated with wild oat herbicides were, in general, higher than the yields obtained from the weedy check plots (Tables 3, 4 and 5, parts a).

TABLE 3. Wheat yields, wild oat areal seed density, wild oat panicle density and wild oat seeds/panicle from plots treated with wild oat herbicides in 1975.

a) Wheat Yield (kg/ha)	kg/ha	%[1]
Weedy check	1203a	
Barban	1464ab	22
Benzoylprop ethyl	1472ab	22
Trifluralin	1503ab	25
Triallate	1770 b	47
Diclofop	2152 c	79

b) Wild Oat Areal Seed Density (million seeds/ha)	million seeds/ha
Weedy check	109a
Trifluralin	66ab
Barban	36 bc
Triallate	33 c
Benzoylprop ethyl	15 d
Diclofop	10 d

c) Wild Oat Panicle Density (panicles/m^2)	panicles/m^2
Weedy check	456a
Barban	266ab
Trifluralin	223 b
Diclofop	111 c
Triallate	103 c
Benzoylprop ethyl	90 c

d) Wild Oat Seeds/Panicle (seeds/panicle)	seeds/panicle
Triallate	34
Trifluralin	31
Weedy check	25
Benzoylprop ethyl	19
Barban	15
Diclofop	10

[1]Percent yield increase over weedy check.

TABLE 4. Wheat yields, wild oat areal seed density, wild oat panicle density and wild oat seeds/panicle under yearly herbicide application and alternate-year herbicide application in 1976.

a) Wheat Yield (kg/ha and %[4])	Yearly[1] kg/ha	Yearly[1] %	Alternate[2] kg/ha	Alternate[2] %	Difference[3] kg/ha
Weedy check	420a		453a		-33 n.s.
Trifluralin	713 b	70	530ab	17	183 *
Barban	1048 c	149	628abc	39	420 *
Benzoylprop ethyl	1303 d	210	830 c	83	473 *
Triallate	1475 d	251	735 bc	62	740 *
Diclofop	2053 e	389	731 bc	61	1322 *

b) Wild Oat Areal Seed Density (million seeds/ha)	million seeds/ha	million seeds/ha	Difference[3]
Weedy check	129a	143a	n.s.
Trifluralin	111a	135a	n.s.
Barban	81a	127a	n.s.
Benzoylprop ethyl	10 b	89a	*
Triallate	7 b	122a	*
Diclofop	5 b	134a	*

c) Wild Oat Panicle Density (panicles/m^2)	panicles/m^2	panicles/m^2	Difference[3]
Weedy check	1259a	1197a	n.s.
Trifluralin	785a	989a	n.s.
Barban	706a	918ab	n.s.
Benzoylprop ethyl	99 b	518 b	*
Diclofop	90 b	780ab	*
Triallate	33 c	801ab	*

d) Wild Oat Seeds/Panicle (seeds/panicle)	seeds/panicle	seeds/panicle
Triallate	36	16
Trifluralin	13	14
Barban	11	14
Benzoylprop ethyl	10	18
Weedy check	10	12
Diclofop	6	17

[1]Yearly herbicide applicaton scheme, treated in 1975 and 1976.
[2]Alternate-year herbicide application scheme, treated in 1975, untreated in 1976.
[3]Difference between yearly and alternate-year application schemes within each herbicide treatment.
[4]Percent yield increase over weedy check.

TABLE 5. Wheat yields, wild oat areal seed density, wild oat panicle density and wild oat seeds/panicle under yearly herbicide application and alternate-year herbicide application in 1977.

a) Wheat Yield (kg/ha and %[4])	Yearly[1] kg/ha	Yearly[1] %	Alternate[2] kg/ha	Alternate[2] %	Difference[3] kg/ha
Weedy check	1220a		1289a		-69 n.s.
Trifluralin	1595 b	31	1376ab	7	219 *
Benzoylprop ethyl	1806 bc	48	1690 bc	31	116 n.s.
Barban	1913 bc	57	1746 c	35	167 n.s.
Triallate	1982 c	62	1707 c	32	275 *
Diclofop	2590 d	112	2276 c	77	314 *

b) Wild Oat Areal Seed Density (million seeds/ha)	million seeds/ha	million seeds/ha	Difference[3]
Weedy check	103a	103a	n.s.
Trifluralin	82ab	90ab	n.s.
Triallate	29ab	65ab	n.s.
Barban	27 b	43ab	n.s.
Diclofop	6 c	11 c	n.s.
Benzoylprop ethyl	3 c	26 bc	*

c) Wild Oat Panicle Density (panicles/m^2)	panicles/m^2	panicles/m^2	Difference[3]
Weedy check	305a	305a	n.s.
Trifluralin	225a	305a	n.s.
Barban	140ab	249a	*
Triallate	67 bc	164a	*
Benzoylprop ethyl	32 c	187a	*
Diclofop	26 c	63 b	*

d) Wild Oat Seeds/Panicle (seeds/panicle)	seeds/panicle	seeds/panicle
Triallate	47	41
Trifluralin	37	23
Weedy check	34	22
Diclofop	28	20
Barban	21	18
Benzoylprop ethyl	19	15

[1]Yearly herbicide application scheme, treated in 1975, 1976 and 1977.
[2]Alternate-year herbicide application scheme, treated in 1975, untreated 1976, and treated 1977.
[3]Difference between yearly and alternate-year application schemes within each herbicide treatment.
[4]Percent yield increase over weedy check.

TABLE 6. The wild oat seed population in the soil and seed viability from wheat plots receiving yearly herbicide application.

	Wild Oat Seed Population million seeds/ha	% Viability
a) Spring 1975		
Initial population	172	61
b) Fall 1975		
Trifluralin	184a	97 a
Weedy check	171ab	93 a
Barban	128abc	92 a
Diclofop	99 bc	93 a
Triallate	98 bc	93 a
Benzoylprop ethyl	81 c	91 a
c) Spring 1977		
Trifluralin	209a	32 a
Weedy check	200a	41 a
Barban	140a	40 a
Diclofop	53 b	47 a
Benzoylprop ethyl	53 b	34 a
Triallate	51 b	51 a

TABLE 7. Average wheat yields over three years from plots under yearly herbicide application and alternate-year herbicide application.

Average Wheat Yields (kg/ha and %[4])	Yearly[1] kg/ha	Yearly[1] %	Alternate[2] kg/ha	Alternate[2] %	Difference[3] kg/ha
Weedy check	944a		978		-34
Trifluralin	1265 b	34	1132ab	16	133
Barban	1467 bc	55	1274 bc	30	194
Benzoylprop ethyl	1517 bc	61	1324 bc	35	193
Triallate	1730 c	83	1398 c	43	332
Diclofop	2249 d	138	1714 d	75	535

[1]Yearly herbicide application scheme, treated in 1975, 1976 and 1977.
[2]Alternate-year herbicide application scheme, treated in 1975, untreated in 1976 and treated in 1977.
[3]Difference between yearly and alternate-year application schemes within each herbicide treatment
[4]Percent yield increase over weedy check.

In 1975, the wheat yield from the plots treated with diclofop was significantly higher than that of all other treatments showing a 79% increase over the weedy check (Table 3, part a). The plots treated with triallate achieved the second greatest yield increase compared to the weedy check although this increase was not significantly different from the yields on the plots treated with benzoylprop ethyl, barban or trifluralin. These latter three herbicide treatments appeared to increase the wheat yield in comparison to the weedy check; however, these differences were not significant.

In 1976, wheat yields from the area under yearly herbicide application showed that all herbicide treatments resulted in significant yield increases over the weedy check (Table 4, part a). The plots treated with diclofop achieved the largest yield increase 389% greater than the yield on the weedy check and significantly greater than the yield increases for all the other treatments.

In 1977, again all plots treated with wild oat herbicides under the yearly herbicide application scheme showed significant yield increases as compared to the weedy check.

The yield differences within each year were due, primarily, to the degree of wild oat control achieved by the herbicides although yields were also influenced by the presence of a natural green foxtail infestation. Significant yield losses due to competition from wild oats and green foxtail have been reported (Blackshaw, 1979; Sturko, 1978; Bell and Nalewaja, 1968a; Bowden and Friesen, 1967).

The weedy check plots were infested with a uniform, heavy wild oat population during each year of this study. The wheat yields obtained from the weedy check plots were 1203 kg/ha in 1975, 420 and 453 kg/ha in 1976 and 1220 and 1289 kg/ha in 1977. Yield differences among the years were due to variations in climatic conditions.

In 1976, drought conditions resulted in the wheat crop growing under stress and less able to compete with the wild oats infestation. The low wheat yield (420 kg/ha) from the weedy check plots in 1976 demonstrates the effect that wild oat competition has on a crop under environmental stress. However, on the plots where wild oats were controlled in 1976, and the competition from wild oats removed, large yield increases occurred (Table 4, parts a and b). The plots treated with diclofop in 1976 showed a yield of 2053 kg/ha, 389% greater than the yield in the weedy check; this yield was only slightly less than the yields from the plots treated with diclofop in 1975 (2152 kg/ha) and in 1977 (2590 kg/ha).

In 1975 the entire plot area had a uniform, heavy wild oat infestation. Wheat yield differences occurred between the treatments (Table 3, part a), however, these differences were less pronounced than in subsequent years (Tables 4 and 5, parts a). In 1976 and 1977, the plots treated with herbicides had a reduced wild oat population due to the previous year(s) herbicide treatment(s) and the yield differences among the treatments were more pronounced.

In 1976, the plots under the alternate-year herbicide application scheme (untreated in 1976) showed considerably lower yield results in comparison to the plots under the yearly herbicide application scheme (Table 4, part a). The wheat yield difference between the two application schemes was shown to be significant within each herbicide treatment. The uncontrolled wild oat population had effectively reduced the wheat yields of the plots under the alternate-year herbicide application scheme. However, yield differences among the treatments did occur. The plots treated in 1975 with benzoylprop, diclofop and triallate showed a significant yield increase over the yield of the weedy check in 1976. Treatment with benzoylprop ethyl in 1975 resulted in an 83% yield increase over the yield of the weedy check in 1976, this yield was significantly greater than all other treatments. The yield differences in 1976 on the plots under the alternate-year herbicide application scheme (untreated in 1976) were a direct result of the wild oat control realized by the herbicide treatments in the previous 1975 growing season.

The increased wild oat seed production/ha evident on the untreated plots in 1976 (Table 4, part b) showed a wild oat seed production/ha similar to that of the weedy checks (Tables 3, 4, 5, part b). This increased wild oat seed production/ha on the untreated plots in 1976 resulted in an increased wild oat population on the plots under the alternate-year herbicide application scheme in 1977. Competition from the increased wild oat populations in 1977 resulted in lower wheat yields which were similar to the 1975 results (Tables 3 and 5, parts a).

The yearly application of wild oat herbicides showed significant yield increases compared to the weedy check within each year (Tables 3, 4 and 5, parts a). Wheat yield increases were a direct result of the removal of wild oat competition regardless of climatic conditions, although the yield increases achieved on the plots treated with each herbicide were not similar. The control of wild oats by the yearly application of herbicides prevented wild oat reseeding and reduced the wild oat population that affected the crop in the following year(s). In 1975 and 1977, wheat yields in the weedy check plots were similar, but the wheat yields of the treated plots were greater in 1977 than in 1975.

The average wheat yields obtained over the three-year study indicate the relative effectivness, in terms of yield, of each herbicide treatment as compared to the weedy check (Table 7). All plots that received herbicide treatments under both application schemes, with the exception of trifluralin under the alternate-year application scheme, produced significant average wheat yield increases compared to the weedy check. The yearly herbicide application scheme produced a larger average yield increase within each herbicide treatment than did the alternate-year herbicide application scheme. The larger average wheat yield advantage realized by the yearly herbicide application scheme appears more than sufficient to cover the expense of the additional year of herbicide applications.

Wild Oat Population

The wild oat is an annual plant which relies upon yearly reseeding and a viable soil seed reservoir to maintain a wild oat plant population within cultivated soils. Wild oat control measures are, therefore, designed to prevent wild oat reseeding and to deplete the soil seed reservoir. Some wild oat seeds, however, can remain dormant within the soil system for as long as five years (Banting, 1966a; Thurston, 1961). The dormancy characteristic of wild oats tends to act as a buffering mechanism making the elimination of wild oats a protracted affair.

The initial wild oat seed population in the soil was estimated at 172 million seeds/ha in the spring of 1975 (Table 6, part a). This soil seed reservoir consisted of the indigenous wild oat seed population in the soil prior to spring germination plus the wild oat seeds which were broadcast over the experimental area. The large viable wild oat seed population in the soil resulted in a uniform and heavy wild oat infestation over the entire experimental plot area in 1975.

The initial wild oat population on the weedy check in 1975 and the subsequent wild oat populations on the weedy check plots in 1976 and 1977 appeared to have reached a maximum in terms of wild oat seed production/ha within a wheat crop (Tables 3, 4, 5, parts b). The weedy check produced 109 million seeds/ha in 1975, 129 and 143 million seeds/ha in 1976 and 103 million seeds/ha in 1977. In 1976, the plots under the alternate-year herbicide application scheme (untreated in 1976) showed a wild oat seed production in the range of 87 - 135 million seeds/ha indicating that the wild oat population had returned to levels comparable to the wild oat population of the weedy check.

The effect of the wild oat herbicide treatments on the wild oat population within the wheat crop were shown by differences in the number of wild oat seeds produced/ha, differences in the number of wild oat panicles produced/m^2 and subsequent changes in the wild oat seed population in the soil (Tables 3, 4 and 5, parts b and Table 6).

In general, the wild oat herbicide treatments acted to reduce the number of wild oat seeds produced/ha. In 1975, on plots heavily infested with wild oats, all herbicide treatments appeared to reduce the number of wild oat seeds produced/ha (Table 3, part b). The plots treated with diclofop, benzoylprop ethyl and triallate showed a dramatic reduction in wild oat seeds/ha; 10, 15, and 33 million seeds/ha respectively as compared to the 109 million seeds/ha produced on the weedy check.

In 1976 and 1977, similar reductions in the number of wild oat seeds produced/ha occurred on the plots treated with wild oat herbicides (Tables 4 and 5, parts b). The reduction of wild oat seeds produced/ha in one year resulted in a reduced wild oat population in the following year. On the plots treated yearly with the benzoylprop ethyl, wild oat seed production/ha was shown as 15 million seeds/ha in 1975, 10 million seeds/ha in 1976 and three million seeds/ha in 1977.

In 1976, on the plots under the alternate-year herbicide application scheme (untreated in 1976), no differences in wild oat seeds produced/ ha occurred between the weedy check or the herbicide treatments, although all treatment wild oat seeds/ha values appeared less than the weedy check (Table 4, part b). This apparent reduction in the wild oat seeds produced/ha may have been due in part to a slight reduction in the wild oat population resulting from the 1975 herbicide treatments. Treatment with benzoylprop ethyl in 1975 resulted in lowest number of wild oat seeds produced/ha (89 million seeds/ha) in 1976, this was not, however, significantly different from the 143 million wild oat seeds produced/ha on the weedy check.

In 1977, on the plots under the alternate-year herbicide application scheme (treated in 1975 and 1977), the herbicide treatments effectively reduced the number of wild oat seeds produced/ha (Table 5, part b). The plots treated with diclofop and benzoylprop ethyl significantly reduced the number of wild oat seeds produced/ha as compared to the wild oat seeds produced/ha on the weedy check.

Differences in the number of wild oat panicles/m^2 were shown on the plots treated with the wild oat herbicides and reflected changes in the wild oat population (Tables 3, 4 and 5, parts c). The application of wild oat herbicides tended to reduce the wild oat panicles produced/m^2. The plots treated yearly with diclofop, triallate and benzoylprop ethyl consistently showed a significant reduction in the number of wild oat panicles/m^2 in comparison to the weedy check during the three year study.

In 1976, on the plots under the alternate-year herbicide application scheme (untreated in 1976) only the plots treated with benzoylprop ethyl in 1975 showed a significant reduction in the wild oat panicles/m^2 as compared to the weedy check (Table 4, part c). In 1977, on plots under the alternate-year herbicide application scheme (treated in 1975 and 1977) barban, benzoylprop ethyl and triallate appeared to reduce the number of wild oat panicles/m^2, however, only the diclofop treatment resulted in a significant reduction in wild oat panicles produced/m^2 as compared to the weedy check (Table 5, part c).

The number of wild oat seeds/panicle was indication of wild oat plant vigor. Severe plant competition, climatic conditions and growth inhibition due to partial herbicide effects tended to reduce the number of wild oat seeds/panicle.

The number of wild oat seeds/panicle produced on the weedy check plots were lower than from plots treated with the soil-applied herbicides, triallate and trifluralin, but generally higher than the number of wild oat seeds/panicle on the plots treated with the foliar-applied herbicides barban, benzoylprop ethyl or diclofop (Tables 3, 4 and 5, parts d). The relatively reduced number of wild oat seeds/panicle on the weedy check plots was due to severe plant competition from the heavy wild oat infestation within the wheat crop of the weedy check plots.

The wild oat plants growing on the plots treated with soil-applied herbicides, triallate and trifluralin which escaped the herbicidal activity of these herbicides and tended to grow vigorously. The number of wild oat seeds/panicle were greater on the wild oat plants from the plots treated with triallate and trifluralin during all three years of the study as compared to the wild oat seeds/panicle on the wild oat plants of the other plots.

The foliar-applied herbicides, barban, benzoylprop ethyl and diclofop caused complete or partial inhibition of wild oat plant growth, this resulted in less vigorous wild oat plant growth and was reflected in a generally low number of wild oat seeds/panicle.

In 1976, under drought conditions, the number of wild oat seeds/panicle were for the most part lower than in either 1975 or 1977.

A reduction in the number of wild oat seeds produced/ha resulted in a reduction in the wild oat seed population in the soil.

In the fall of 1975, the plots treated with diclofop, triallate and benzoylprop ethyl showed wild oat seed populations in the soil of 99, 98, and 89 million seeds/ha respectively, a reduction by approximately one half the initial soil seed population (Table 6, parts a and b). The weedy check, however, had a soil seed population of 171 million seeds/ha, relatively unchanged from the initial soil seed population of 172 million seeds/ha.

The wild oat seed populations in the soil estimated in the spring of 1977 show the effects of two consecutive years of wild oat control by herbicide applications (Table 6, part c). The plots treated with the herbicides diclofop, benzoylprop ethyl and triallate had wild oat seed populations in the soil of 53, 53 and 51 million seeds/ha respectively. These soil seed populations are a reduction of approximately one half the wild oat seed population in the soil estimated on these plots in the fall of 1975 (Table 6, part b). The weedy check had an increased wild oat seed population in soil which was estimated at 200 million seeds/ha in the spring of 1977.

The wild oat seed viability was apparently not affected by the herbicide treatments. No significant difference in seed viability occurred between wild oat seed from the plots receiving wild oat herbicide treatment or the weedy check in either the fall of 1975 or the spring of 1977 (Table 6, parts b and c).

In the spring of 1977 the viable wild oat seed population in the soil on the weedy check was estimated at 82 million seeds/ha while the plots treated with triallate had a viable wild oat seed population in the soil of 26 million seeds/ha. The magnitude of these soil seed populations is exceedingly large if compared to the approximately three million seeds/ha introduced into the soil system when seeding wheat at the rate of 106 kg/ha.

The ability of the wild oat herbicides to reduce the number of wild oat seeds produced/ha and the wild oat seed population in the soil is apparent; however, the large viable wild oat seed population in the soil is capable of producing a vast number of wild oat seeds/ha even under conditions of excellent wild oat control. The plots treated with diclofop showed a wild oat seed production/ha of 10 million seeds/ha in 1975, five million seeds/ha in 1976 and six million seeds/ha in 1977.

Left uncontrolled, the large viable wild oat seed reservoir in the soil resulted in a large wild oat plant population producing a vast number of wild oat seeds/ha. In 1976, no significant differences in wild oat seeds/ha occurred between the weedy check and the plots under the alternate-year herbicide application scheme (untreated in 1976) (Table 4, part b).

It is suggested that the wild oat seed population in the soil would have to be substantially smaller in order to prevent the extensive wild oat reseeding such as occurred in 1976 on the plots under the alternate-year herbicide application scheme. The yearly application of wild oat herbicides indicates a trend toward the gradual yearly reduction of the viable wild oat seed population in the soil (Table 6).

Results and Discussion of Barley Experiments

The results of the barley experiments (experiments 3 and 4) are shown in Tables 8, 9, 10, 11 and 12.

Yield

Barley is considered a stronger competitor to wild oats than rye, oats, wheat or flax (Pavlychenko and Harrington, 1934). The high barley yields achieved affirm the competitive ability of barley with wild oats, however, significant barley yield differences were shown to occur between the weedy check and the plots treated with wild oat herbicides (Tables 8, 9 and 10, parts a).

Barley is able to compete with green foxtail to such an extent that under favourable growing conditions no yield loss occurred due to competition from green foxtail (Rahman and Ashford, 1972b).

The barley yield results within each year show the effect of wild oat competition on the barley yield. The differences in the yield results between the weedy check and the treated plots are due to the degree of wild oat control achieved by the herbicide treatments. In general, the effect of the wild herbicide treatments was a reduction in wild oat competition and an increase in barley yield as compared to the weedy check.

The weedy check plots were infested with a heavy uniform wild oat infestation during 1975, 1976 and 1977. The barley yields obtained from the weedy check plots were 2898 kg/ha in 1975, 877 and 872 kg/ha in 1976, and 2170 and 2313 kg/ha in 1977. These yield values indicate the effects of an uncontrolled wild oat population on barley yield. The differences in barley yields between the years were due to variations in climatic conditions.

TABLE 8. Barley yields, wild oat areal seed density/ha, wild oat panicle density and wild oat seeds/panicle from plots treated with wild oat herbicides in 1975.

a) Barley Yield (kg/ha)

	kg/ha	%[1]
Weedy check	2898a	
Difenzoquat	3608 b	24
Trifluralin	3811 bc	32
Barban	4291 cd	48
Triallate	4530 d	56
Diclofop	5195 e	79

b) Wild Oat Areal Seed Density (million seeds/ha)

	million seeds/ha
Weedy check	106a
Trifluralin	67a
Triallate	60ab
Barban	8 bc
Difenzoquat	7 c
Diclofop	5 c

c) Wild Oat Panicle Density (panicles/m^2)

	panicles/m^2
Weedy check	531a
Trifluralin	269a
Triallate	214a
Difenzoquat	116 b
Barban	104 b
Diclofop	47 b

d) Wild Oat Seeds/Panicle (seeds/panicle)

	seeds/panicle
Triallate	28
Trifluralin	25
Weedy check	20
Diclofop	13
Barban	10
Difenzoquat	7

[1]Percent yield increase over weedy check.

TABLE 9. Barley yields, wild oat areal seed density, wild oat panicle density and wild oat seeds/panicle under yearly herbicide application and alternate-year herbicide application in 1976.

a) Barley Yield (kg/ha and %[4])	Yearly[1] kg/ha	Yearly[1] %	Alternate[2] kg/ha	Alternate[2] %	Difference[3] kg/ha
Weedy check	877a		872a		5 n.s.
Trifluralin	1710 b	95	1416 b	62	294 *
Barban	2405 c	174	1981 c	127	424 *
Difenzoquat	2484 c	183	2149 cd	146	335 *
Triallate	2819 cd	221	2126 cd	144	693 *
Diclofop	3103 d	254	2436 d	179	667 *

b) Wild Oat Areal Seed Density (million seeds/ha)	million seeds/ha	million seeds/ha	Difference[3]
Weedy check	112a	164a	n.s.
Trifluralin	96a	140a	n.s.
Barban	29 b	124a	*
Triallate	8 c	123a	*
Diclofop	5 c	127a	*
Difenzoquat	4 c	113a	*

c) Wild Oat Panicle Density (panicles/m^2)	panicles/m^2	panicles/m^2	Difference[3]
Weedy check	1211a	1514a	n.s.
Trifluralin	573a	1143a	*
Barban	231 b	784a	*
Diclofop	59 c	764a	*
Difenzoquat	57 c	697a	*
Triallate	36 c	889a	*

d) Wild Oat Seeds/Panicle (seeds/panicle)	seeds/panicle	seeds/panicle
Triallate	30	14
Trifluralin	17	12
Barban	13	16
Diclofop	9	17
Weedy Check	9	11
Difenzoquat	9	17

[1]Yearly herbicide application scheme, treated in 1975 and 1976.
[2]Alternate-year herbicide application scheme, treated in 1975, untreated in 1976.
[3]Differences between yearly and alternate-year application schemes within each herbicide treatment.
[4]Percent yield increase over weedy check.

TABLE 10. Barley yields, wild oat areal seed density, wild oat panicle density and wild oat seeds/panicle under yearly herbicide application and alternate-year herbicide application in 1977.

a) Barley Yield (kg/ha and %[4])	Yearly[1] kg/ha	Yearly[1] %	Alternate[2] kg/ha	Alternate[2] %	Difference[3] kg/ha
Weedy check	2170a		2313a		-143 n.s.
Trifluralin	2902 b	34	2770a	20	+132 n.s.
Barban	2991 b	38	2721ab	18	+270 n.s.
Triallate	3152 b	45	2558ab	11	+594 *
Diclofop	3214 b	48	3307 b	43	- 93 n.s.
Difenzoquat	3263 b	50	2936ab	27	+327 n.s.

b) Wild Oat Areal Seed Density (million seeds/ha)	million seeds/ha	million seeds/ha	Difference[3]
Weedy check	55a	55a	n.s.
Trifluralin	33a	37ab	n.s.
Barban	11ab	18abc	n.s.
Diclofop	2 bc	3 c	n.s.
Triallate	0.6 c	11abc	*
Difenzoquat	0.5 c	7 bc	*

c) Wild Oat Panicle Density (panicles/m^2)	panicles/m^2	panicles/m^2	Difference[3]
Weedy check	178a	178a	n.s.
Trifluralin	74ab	115ab	n.s.
Barban	50 b	88abc	*
Triallate	14 c	31 c	*
Diclofop	13 c	27 c	*
Difenzoquat	9 c	45 bc	*

d) Wild Oat Seeds/Panicle (seeds/panicle)	seeds/panicle	seeds/panicle
Trifluralin	48	35
Weedy check	33	33
Diclofop	28	13
Barban	25	24
Triallate	16	80
Difenzoquat	13	18

[1]Yearly herbicide application scheme, treated in 1975, 1976 and 1977.
[2]Alternate-year herbicide application scheme, treated in 1975, untreated in 1976 and treated in 1977.
[3]Difference between yearly and alternate-year application schemes within each herbicide treatment.
[4]Percent yield increase over weedy check.

TABLE 11. The wild oat seed population in the soil and seed viability from barley plots receiving yearly herbicide application.

	Wild Oat Seed Population million seeds/ha	% Viability
a) Spring 1975		
Initial population	172	61
b) Fall 1975		
Weedy check	263a	89 a
Trifluralin	197a	86 a
Triallate	111a	91 a
Barban	73 b	79 a
Diclofop	60 c	81 a
Difenzoquat	59 c	76 a
c) Spring 1977		
Weedy check	209a	30 a
Trifluralin	154ab	25 a
Barban	76 bc	32 a
Triallate	72 c	38 a
Difenzoquat	53 c	23 a
Diclofop	52 c	25 a

TABLE 12. Average barley yields over three years from plots under yearly herbicide application and alternate-year herbicide application.

Average Barley Yields (kg/ha and %[4])	Yearly[1]		Alternate[2]		Difference[3]
	kg/ha	%	kg/ha	%	kg/ha
Weedy check	1151a		1570a		-59
Trifluralin	2272 b	50	1901ab	21	+371
Difenzoquat	2532 bc	68	2236 bc	42	+296
Barban	2561 bc	69	2192 bc	40	+369
Triallate	2681 bc	78	2210 bc	41	+471
Diclofop	2988 c	98	2620 c	67	+368

[1]Yearly herbicide application scheme, treated in 1975, 1976 and 1977.
[2]Alternate-year herbicide application scheme, treated in 1975, untreated in 1976 and treated in 1977.
[3]Difference between yearly and alternate-year application schemes within each herbicide treatment.
[4]Percent yield increase over weedy check.

In 1976, drought conditions resulted in a barley crop growing under stress and less able to compete with the wild oat infestation. The low barley yields (877 kg/ha and 872 kg/ha) from the weedy check plots in 1976 demonstrates the effect that wild oat competition has on a barley crop under environmental stress. On the plots where wild oats were controlled in 1976, the competition from wild oats was reduced and large yield increases occurred (Table 9, part a). The plots treated with diclofop showed a yield of 3103 kg/ha; a 254% increase over the weedy check.

In 1975, the entire plot area was infested with a heavy, uniform wild oat population and significant barley yield difference occurred between all treated plots and the weedy check (Table 8, part a). Barley yield differences also occurred between the plots treated with the different wild oat herbicides, indicating differences in the effectiveness of these herbicides in controlling the heavy wild oat population. The plots treated with diclofop showed the largest yield increase at 5195 kg/ha, a 79% increase over the weedy check.

In 1976 and 1977, the plots under the yearly herbicide application scheme were infested with a reduced wild oat population due to the effects of the previous year(s) herbicide treatment(s). The competitive ability of barley against this reduced wild oat population was more effective and yield differences between the treated plots and the weedy check were more pronounced than in 1975 (Tables 8, 9 and 10, parts a). The yield differences between the different herbicide treatments, however, were less and in 1977 after three consecutive years of herbicide application, no differences in yield occurred on plots treated with herbicides (Table 10, part a). By 1977, the wild oat population on the plots under yearly herbicide application had apparently reached a level where the ability of barley to compete with wild oats and the degree of wild oat control achieved by the herbicide treatments resulted in no yield difference between herbicide treatments.

In 1976, the plots under the alternate-year herbicide application scheme (untreated in 1976) showed significantly lower yield results in comparison to the treated plots under yearly herbicide application (Table 9, part a). The uncontrolled wild oat population competitively reduced the barley yields on the plots under alternate-year herbicide application. Significant yield differences, however, did occur between the weedy check and all other plots under the alternate-year herbicide application scheme. These yield differences were a direct result of reduced wild oat competition which resulted from the degree of wild oat control achieved by the herbicide treatments during the previous 1975 season. It must be noted that no differences in wild oat seeds/ha or wild oat panicles/m^2 were observed between any treatments under the alternate-year herbicide application scheme (untreated in 1976) in 1976.

The general reduction in wild oat seeds produced/ha and wild oat panicles/m^2 on the weedy check in 1977 in comparison to the number of wild oat seeds/ha and panicles/m^2 on the weedy check plots in 1975 and 1976 indicates a suppression of wild oat growth during 1977 (Tables 8, 9 and 10, parts b and c). The wild oat seeds/ha on the weedy check plots were 106 million seeds/ha in 1975, 112 and 164 million seeds/ha in 1976 and 55 million seeds/ha in 1977. Reduced wild oat plant competition in 1977 was indicated by the relatively small yield difference between treatments and/or herbicide application schemes in 1977 as compared to the yield results of 1975 and 1976 (Tables 8, 9 and 10, part a).

The 1977 barley yields on the plots under the alternate-year herbicide application scheme (treated in 1975 and 1977) were generally lower than the yields from the plots of the yearly herbicide application scheme. Only the plots treated with diclofop in 1977 under the alternate-year herbicide application scheme produced a significant yield increase in comparison to the weedy check (Table 10, part a).

The average barley yields obtained over the three-year study indicated the relative effectiveness of each herbicide, in terms of average yearly yield, as compared to the weedy check (Table 12). All treated plots under both herbicide application schemes, with the exception of trifluralin under the alternate-year application scheme, showed significant average barley yield increases compared to the weedy check. The yearly herbicide application scheme, however, showed a larger average yield increase within each herbicide treatment when compared to the alternate-year herbicide application scheme.

The larger average yields achieved on the plots under yearly herbicide application appear sufficient to cover the expense of the additional year of herbicide application.

Wild Oat Population

The ability of wild oats to reseed yearly is essential in maintaining and increasing the wild oat plant population within a cultivated crop. Barley is a relatively strong competitor with wild oats (Pavlychinko and Harrington, 1934). However, in direct competition with wild oats, barley is, generally, unable to suppress this weedy species and the wild oat population increases. Significant barley yield losses due to wild oat competition have been reported; yield losses increased with increasing wild oat plant densities (Bell and Nalewaja, 1968b).

In general, the application of wild oat herbicides acted to reduce the wild oat plant population within the barley crop and enhance the competitive ability of barley with wild oats. The degree of wild oat control achieved by the wild oat herbicides was shown by differences in the number of wild oat seeds produced/ha and the subsequent changes in the wild oat seed population in the soil as compared to the weedy check (Tables 8, 9 and 10, parts b).

The plots treated with wild oat herbicides showed differences in the number of wild oat panicles/m^2 and the average number of wild oat seeds/panicle. The applications of wild oat herbicides resulted in a reduction of panicles/m^2, this reflected a reduced wild oat plant population (Tables 8, 9, and 10, parts c). The weedy check showed the highest number of panicles/m^2 during each year of this study.

In 1975, on plots heavily infested with wild oats, all herbicide treatments appeared to reduce the number of wild oat seeds produced/ha (Table 8, part b). The plots treated with barban, difenzoquat and diclofop showed a wild oat seeds/ha production of eight, seven and five million seeds/ha, respectively, as compared to the 106 million seeds/ha produced on the weedy check.

Similar reductions in the number of wild oat seeds produced/ha occurred on the plots treated with wild oat herbicides in 1976 and 1977 (Tables 9 and 10, part b).

On the plots under the yearly herbicide application scheme, a substantial reduction in the number of wild oat seeds produced/ha in one year resulted in reduced wild oat population in the following year. The plots treated with difenzoquat showed a wild oat seed production/ha of seven million seeds/ha in 1975, four million seeds/ha in 1976 and 0.5 million seeds/ha in 1977.

In 1976, on the plots under the alternate-year herbicide application scheme (untreated in 1976), no significant differences in the number of wild oat seeds produced/ha occurred between the weedy check and the treatments, although all treatment seeds/ha values appeared less than the number of wild oat seeds produced/ha on the weedy check (Table 9, part b). The plots treated with difenzoquat in 1975 showed the least number of wild oat seeds/ha in 1976, 113 million/ha; this was not significantly different, however, from 164 million seeds/ha produced on the weedy check.

In 1977, the plots under the alternate-year herbicide application scheme (treated in 1975 and 1977), showed reductions in the number of wild oat seeds/ha which were similar to the seeds/ha results shown in 1975 (Tables 8 and 10, parts b).

In general, a reduction in the number of wild oat seeds produced/ha within a year resulted directly in a reduction in the wild oat seeds population in the soil (Table 11). The large wild oat seed population in the soil, however, was not as rapidly reduced in numbers as the large reductions in wild oat seeds produced/ha would suggest. The plots treated with diclofop in 1975 showed a wild oat seed production/ha of five million seeds/ha as compared to the 106 million wild oat seeds produced/ha on the weedy check (Table 11, parts a and b). In the fall of 1975, the wild oat seed population in the soil showed 60 million seeds/ha from the plots treated with diclofop and 263 million seeds/ha from the weedy check. The initial wild oat seed populations in the soil was estimated at 172 million seeds/ha.

The plots treated with barban, diclofop and difenzoquat in 1975 showed a substantial reduction in the wild oat seed population in the soil, 73, 60 and 59 million seeds/ha respectively in the fall of 1975, as compared to the initial wild oat seed population in the soil of 172 million seeds/ha in the spring of 1975. Left uncontrolled, the wild oat population on the weedy check resulted in an increase in the wild oat seed population in the soil to 263 million seeds/ha in the fall of 1975.

The effects of two consecutive years of wild oat herbicide application on the wild oat seed population in the soil were estimated in the spring of 1977 (Table 11, part c). The plots treated with trifluralin, triallate, difenzoquat and diclofop in 1975 and 1976 showed a reduced wild oat seed population in the soil in the spring of 1977 as compared to the soil seed population of these plots in the fall of 1975 (Table 11, parts b and c). This reduction in the wild oat seed population in the soil was not substantial.

The plots treated with barban, triallate, difenzoquat and diclofop in 1976, however, showed significant and substantial reductions in the wild oat seed populations in the soil as compared to the weedy check in the spring of 1977.

GENERAL DISCUSSION

The field experiments showed that the application of wild oat herbicides caused, in general, a significant reduction in the wild oat population within a crop and that this reduction in wild oat plant competition resulted, directly, in a crop yield increase as compared to a weedy check. Wheat and barley yield increases resulting from the control of wild oats by herbicides have been reported (Hay, 1973; Chow and Dryden, 1975; Owino, 1977).

The wild oat herbicides were not similar in degree of wild oat control or yield advantage. The differences in the degree of wild oat control were due to the inherent properties of the herbicides, and to a certain extent, the differences in the ability of the crop to compete with wild oats.

Barley is considered a stronger competitor to wild oats than wheat (Pavlychenko and Harrington, 1934). The results of these experiments, however, showed that the percent yield increases over the weedy check achieved by each herbicide within each year and averaged over the three-year study were relatively similar for both the wheat and barley crops (Tables 7 and 12). The exception was in 1976 on the plots under the alternate-year herbicide application scheme, the percent barley yield increases over the weedy check were substantially higher than the percent wheat yield increases of the similarly treated wheat plots (Tables 4 and 9, part a). The greater percent barley yield increases over the weedy check in 1976 were attributed to the superior ability of the barley crop to compete with the reduced wild oat population in 1976 on the plots under the alternate-year herbicide application scheme (untreated in 1976).

The relative reductions in the number of wild oat seeds produced/ ha due to each herbicide treatment appeared to be greater within the barley crop than within the wheat crop (Tables 3, 4, 5, 8, 9, 10, parts b). The reduction in the wild oat seed population in the soil due to the effects of the wild oat herbicide applications, however, was similar in each crop (Tables 6 and 11). Miller and Nalewaja (1977) had reported a greater reduction in the wild oat seed population in the soil due to the influence of barley as compared to wheat.

The presence of a natural green foxtail infestation tended to complicate equating the wheat yield increases to the degree of wild oat control. Significant yield losses due to competition with green foxtail had been reported in wheat (Sturko, 1978; Rahman and Ashford, 1970). Rahman and Ashford (1972b) suggested that under favourable cropping conditions, little or no barley yield loss occurs due to green foxtail competition with barley.

It was concluded that within the heavy wild oat population infesting the wheat and barley plots the presence of a green foxtail population had no effect on crop yield. However, as the application of wild oat herbicides reduced the wild oat population, the possibility of the green foxtail infestation affecting the wheat yields increased.

The herbicides triallate, barban, difenzoquat and benzoylprop ethyl are selective against wild oats. The herbicides diclofop and trifluralin are selective against both green foxtail and wild oats.

The effects of green foxtail competition were considered when comparing the wheat yield results from the plots treated with the individual herbicides.

The average number of wild oat seeds/panicle was an indication of wild oat plant vigor. Wild oat plants suffering the effects of wild oat herbicides or plant competition from the crop and/or other wild oat plants showed a low average number of wild oat seeds/ panicle.

The relatively low average number of wild oat seeds/panicle on the weedy check plots was attributed to the effects of plant competition from the high wild oat population within the crop. Similarly, a low average number of wild oat seeds/panicle resulted in 1976, on the plots under the alternate-year herbicide application scheme (untreated in 1976), where the wild oat population, left uncontrolled had returned to population densities comparable to the weedy check (Tables 4 and 9, parts d).

Triallate, a soil-incorporated wild oat herbicide, acted to eliminate the wild oat seedlings at or before emergence, resulting in minimal wild oat competition to the crop. The plots treated with triallate showed significant wheat and barley yield increases compared to the weedy check during all three years of the study (Tables 3, 4, 5, 8, 9 and 10, parts a).

The effects of triallate on the wild oat population were shown by significant reductions in the number of wild oat seeds produced/ha and the number of panicles/m^2 on the plots treated with triallate as compared to the weedy check. The wild oat plants which escaped the triallate treatment, however, grew vigorously as indicated by the high average number of wild oat seeds/panicles on the plots treated with triallate as compared to the weedy check and/or the plots treated with the foliar-applied herbicides. Such plants, although few in number, produced a large number of wild oat seeds/ha confounding the effects of triallate to prevent reseeding and reduce the wild oat seed population in the soil. In 1977, on the wheat plots treated with triallate under the yearly herbicide application scheme, 29 million wild oat seeds/ha were produced, this value was not significantly different from the weedy check (Table 5, part b).

The herbicide, trifluralin, was applied to the soil following seeding at the rates of 0.56 kg/ha in wheat and 1.12 kg/ha in barley and was immediately harrow-incorporated to 5 cm. The shallow (5-cm) incorporation of trifluralin has been reported to give excellent green foxtail control in wheat and barley (Rahman and Ashford, 1970, 1972). The selective control of wild oats by the shallow incorporation of trifluralin, however, is minimal. To be effective against wild oats trifluralin must be absorbed through the roots; relatively few wild oat plants germinate with the root system in the upper 5-cm layer of the soil.

Significant, although relatively small, wheat and barley yield increases occurred on the plots treated with trifluralin when compared to the weedy check. The possibility of attributing the wheat yield increases on the plots treated with trifluralin to the removal of green foxtail was considered. However, the effects of green foxtail competition on the wheat yield within the large wild oat population still present on the plots treated with trifluralin are not known.

The effects of trifluralin on the wild oat population were not significant, although, the plots treated with trifluralin appeared to show a reduction in the number of wild oat seeds produced/ha and panicles/m^2 in both wheat and barley as compared to the weedy check (Tables 3, 4, 5, 8, 9 and 10, parts b and c).

The wild oat herbicide, barban, acts to reduce the growth and development of wild oats rather than the actual killing of the plant (Friesen, 1961). The early removal (1½-leaf stage) of wild oat competition by barban was reflected in significant yield increases in both wheat and barley as compared to the weedy check (Tables 3-12). Barley, a strong competitor to wild oats under normal conditions, showed a greater percent yield increase over the weedy check than did wheat on plots treated with barban.

The ability of barban to inhibit wild oat growth and development was shown in the relatively low number of wild oat seeds/panicles of plants on the plots treated with barban. However, the wild oat population within the crops was not significantly reduced by the inhibitory effect of barban as evidenced by the high number of panicles/m^2 and consequently the number of wild oat seeds produced/ha was large.

The number of wild oat seeds produced/ha on the plots treated with barban was not dramatically different from the weedy check. The barley plots treated with barban under the yearly herbicide application scheme appeared to show a greater reduction in the number of wild oat seeds produced/ha within each year compared to the wheat plots treated yearly with barban. The number of wild oat seeds produced/ha, however, fluctuated widely between years in both the wheat and barley crops.

The wild oat seed populations in the soil on the wheat plots treated with barban were similar to the weedy check in both the fall of 1975 and the spring of 1977 (Table 6). The more competitive barley crop showed a wild oat seed population in the soil on the plots treated with barban that was significantly different from the weedy check in both the fall of 1975 and the spring of 1977. A net reduction in the wild oat seed in the soil due to the effects of barban occurred only within the barley crop.

The plots treated with the wild oat herbicides, benzoylprop ethyl and difenzoquat, proved similar in their effects on the wheat and barley yields, respectively, and in their effects on the wild oat populations within the crops. Both benzoylprop ethyl and difenzoquat are applied at the later, three-to-five-leaf stage of wild oat growth, and both herbicides tend to act to severely stunt the growth of the wild oat plants rather than killing the plants.

Significant yield increases in both wheat and barley resulted from the elimination of wild oat competition due to the inhibition in wild oat growth caused by these herbicides (Tables 3 - 12). The late stage of herbicide application (three-to-five-leaf) meant that a good deal of wild oat competition with the crop had occurred prior to the herbicide application and therefore, the yield increases tended to be less dramatic than for herbicides applied prior to planting or at an earlier stage.

The effect of benzoylprop ethyl and difenzoquat on the wild oat population was dramatic. The plots treated with benzoylprop ethyl and difenzoquat showed the lowest average number of wild oat seeds/panicle in comparison to wild oat plants of the other plots. The number of wild oat seeds/ha and panicles/m^2 were also drastically reduced on the plots treated with these herbicides in comparison to the weedy check. The wheat plots treated yearly with benzoylprop ethyl showed 15 million wild oat seeds produced/ha in 1975 (Table 3, part b), 10 million seeds/ha in 1976 (Table 4, part b), and three million seeds/ha in 1977 (Table 5, part b) while the barley plots treated yearly with difenzoquat showed seven million seeds/ha in 1975 (Table 8, part b), four million seeds/ha in 1976 (Table 9, part b) and 0.5 million seeds/ha in 1977 (Table 10, part b).

The effects of benzoylprop ethyl and difenzoquat on the wild oat population in 1975 appeared to cause an effect on the subsequent wild oat population in 1976. Both benzoylprop ethyl and difenzoquat showed the lowest number of wild oat seeds produced/ha in 1976 on the plots under the alternate-year herbicide application scheme (untreated in 1976) although the number of wild oat seeds/ha values was not different advantage in both the wheat and barley crops as compared to the weedy check and/or the plots which received the other herbicide treatments (Tables 3, 4, 5, 8, 9 and 10, parts a). Diclofop acts to kill wild oats and green foxtail plants within the wheat and barley crops (Friesen *et al.* 1976). The post-emergence application of diclofop at the two-to-three leaf stage of wild oats tended to remove wild oat and green foxtail competition at a relatively early stage of crop development and resulted in large crop yield increases.

The effects of diclofop on the wild oat population within the crop were dramatic.

Significant reductions in the number of wild oat seeds produced/ha, panicles/m^2 and the wild oat seed population in the soil were observed on the plots treated yearly with diclofop in both the wheat and barley crops (Tables 3, 4, 5, 8, 9 and 10, parts b and c). A greater reduction in the wild oat population occurred on the barley plots treated with diclofop as compared to the similarly treated wheat plots. This larger reduction in wild oat population within the barley crop was attributed to the stronger competitive ability of barley against wild oats than wheat.

The wild oat seed population in the soil was significantly reduced compared to the weedy check on the plots treated with diclofop (Tables 6 and 11). The reduction in the wild oat seed population in the soil was similar in both the wheat and barley crops in the spring of 1977 after two consecutive years of diclofop application.

The presence of a natural green foxtail infestation within the from the weedy check (Tables 4 and 9, parts b). Benzoylprop ethyl, on the wheat plots under the alternate-year herbicide scheme (untreated in 1976) showed the lowest number of wild oat panicles/m^2 in 1976, significiantly lower than all other treatments (Table 4, part c). The reduced wild oat seeds/ha and panicles/m^2 in 1976 were explained by the effectiveness of benzoylprop ethyl and difenzoquat in controlling the wild oat population in 1975.

The seeds produced by the wild oat plants on the plots treated with benzoylprop ethyl appeared smaller and less robust in comparison to wild oat seeds produced on the other plots. Barber (1976) had reported reduced wild oat seed size from wild oat plants treated with benzoylprop ethyl. The percent seed viability of the wild oat seed in the soil on the plots treated with benzoylprop ethyl and difenzoquat, however, were not significantly different from the wild oat seed in the soil of the weedy check or the other herbicide treated plots in the fall of 1975 or the spring of 1977 (Tables 6 and 11).

The effects of benzoylprop ethyl and difenzoquat on the wild oat seed population in the soil were substantial and resulted in significant net reductions in the wild oat seed reservoir in soil in both the fall of 1975 and spring of 1977, as compared to the initial wild oat seed population in the soil in the spring of 1975 and the soil seed populations of the weedy check in the fall of 1975 and the spring of 1977 (Tables 6, 12).

The plots treated with the diclofop achieved the largest yield plots of these experiments has been noted. The effects of this green foxtail infestation on the crop yield potential, however, were not quantitatively assessed. Sturko (1978) and Blackshaw (1979) reported wheat yield losses due to green foxtail competition, however the significant wheat yield losses occurred primarily within semi-dwarf wheat varieties, late crop seeding dates and climatic conditions especially favourable to green foxtail germination.

The competitive effect of green foxtail within the heavy wild oat infestations of the weedy check plots was considered negligible. However, on the wheat plots where the wild oat herbicides effectively removed wild oats as a source of competition, the green foxtail infestation was present and competitively able to supress wheat yields. On the wheat plots treated with triallate the effective, early removal of wild oats left the green foxtail infestation in a position to reduce the wheat yields. The shallow application of trifluralin on the other hand effectively controls green foxtail and the wheat yield increases on the plots treated with trifluralin could be attributable at least in part to the removal of green foxtail.

The plots treated with diclofop, however, show wheat yields resulting from plots essentially free of plant competition from wild oats and green foxtail. It is interesting to note that the wheat yield difference between the weedy check and the wheat plots treated with trifluralin added to the increase in wheat yield achieved on the plots treated with triallate shows a yield increase surprisingly similar to that of the plots treated with diclofop.

SUMMARY AND CONCLUSIONS

The application of the wild oat herbicides resulted in a reduction in the wild oat population in comparison to a weedy check within both the wheat and barley crops. The effects of the wild oat herbicides on the wild oat population were shown as a reduction in the number of wild oat seeds produced/ha and wild oat panicles/m^2. The wild oat seed population in the soil was, as well, reduced on the plots treated with wild oat herbicides.

Significant yield increases in both wheat and barley crops resulted from the reduced wild oat plant competition on the plots treated with wild oat herbicides.

The yearly application of wild oat herbicides resulted in larger yield increases and greater reductions in the wild oat populations within the crop as compared to the alternate-year herbicide application scheme.

The effectiveness of the different wild oat herbicides in reducing the wild oat populations within the crop and in achieving crop yield increases were not similar.

The herbicides, triallate and diclofop, acted to kill wild oat plants at an early growth stage, resulting in substantial yield increases and large reductions in the wild oat population within the crop.

Barban acted early (1½-leaf stage of wild oats) to inhibit the competitive ability of wild oats and increase crop yield. The effects of barban on the wild oat population within the wheat crop, however, were slight. In barley, a stronger competitor to wild oats than wheat, the barban application, generally resulted in a significant reduction in the wild oat population.

The plots treated with benzoylprop ethyl and difenzoquat showed significant reductions in the wild oat populations within the crop and the wild oat seed populations within the soil. The yield increases realized on the plots treated with benzoylprop ethyl and difenzoquat were not as substantial as the yield increases on the plot treated with diclofop and triallate. The lower yield increases on the plots treated with benzoylprop ethyl and difenzoquat were attributed to the later (three-to-five-leaf) stage of application.

The shallow incorporation of trifluralin did not significantly effect the wild oat population within the crop or the wild oat seed population in the soil as compared to the weedy check. The application of trifluralin showed the lowest yield increases over the weedy check, with significant yield increases occurring primarily on the plots treated with trifluralin under the yearly herbicide application scheme.

A crop yield advantage can be achieved through the application of wild oat herbicides. The reduction or elimination of a heavy wild oat infestation, however, requires a net yearly reduction in the viable wild oat seed population in the soil. Substantial yearly reductions in the number of wild oat seeds produced/ha are required to significantly reduce the viable wild oat seed population in the soil.

REFERENCES

Alex, J.F. 1965. Survey of weeds of cultivated land in the prairie provinces. Can. Agr. Res. Ltd. Regina, Sask.

Anderson, C.H. and A.M. Hennig. 1964. The effect of date of seeding and fertility level on yield of wheat, oats and barley in northwestern Alberta. Can. J. Pl. Sc. 44: 15-20.

Atwood, W.M. 1914. A physiological study of the germination of *Avena fatua*. Bot. Gaz. 57: 386-414.

Avery Jr., G.S. 1930. Comparative anatomy and morphology of embryos and seedlings of maize, oats and wheat. Bot. Gaz. 89: 1-39.

Baldwin, J.H. and R.J. Finch. 1976. The control of *A. fatua* in spring barley using post emergence herbicides. Proc. 13th Br. Weed Control Conf. pp. 31-38.

Baldwin, J. H. and D.B. Livingston. 1976. The control of *Avena fatua* in winter wheat by the use of post emergence herbicides applied at different timings. Proc. 13th Br. Weed Control Conf. pp. 25-30.

Banting, J.D. 1960. Control of weeds and woody plants. Wild oats - post emergence summary. Nat. Weed Committee (W.S.) pp. 45-46.

Banting, J.D. 1962. The dormancy behavior of *Avena fatua* L. in cultivated soil. Can. J. Pl. Sc. 42: 22-39.

Banting, J.D. 1966a. Studies on the persistence of *Avena fatua*. Can. J. Pl. Sc. 46: 129-140.

Banting, J.D. 1966b. Factors affecting the persistence of *Avena fatua*. Can. J. Pl. Sc. 46: 469-478.

Banting, J.D. 1967. Factors affecting the activity of diallate and triallate. Weed Res. 7: 302-315.

Banting, J.D. 1973. How wild oats grow. "Let's clean up on wild oats." Seminar. Proc., Action Proposals and Programs. Agric. Can. and United Grain Growers. pp 16-19.

Barber, D.D. 1976. The control of wild oats in ryegrass herbage seed crops. Proc. 13th Br. Weed Control Conf. pp. 1047-1051.

Bell, A.R. and J.D. Nalewaja. 1968a. Competition effects of wild oats in flax. Weed Sci. 16: 501-507.

Bell, A.R. and J.D. Nalewaja. 1968b. Competition of wild oats in wheat and barley. Weed Sci. 16: 505-508.

Bibbey, R.O. 1935. The influence of environment upon the germination of weed seeds. Sc. Agric. 16: 141-150.

Bibbey, R.O. 1948. Physiological studies of weed seed germination. Plant Physiol. 23: 467-484.

Black, M. 1959. Dormancy studies in seed of *Avena fatua*. I. The possibile role of germination inhibitors. Can. J. Bot. 37: 393-402.

Blackman, G.E. and W.G. Templeman. 1938. The nature of the competition between cereal crops and annual weeds. J. Agr. Sci. 28: 247-271.

Blackshaw, R.E. 1979. Environmental factors affecting green foxtail (Setaria viridis) competition in spring wheat. M.Sc. Thesis, University of Manitoba, Winnipeg, Manitoba.

Boyd, L. and G.S. Avery Jr. 1936. Grass seedling anatomy: The first internode of *Avena* and *Triticum*. Bot. Gaz. 97: 765-779.

Bowden, B.A. and G. Friesen. 1967. Competition of wild oats in wheat and flax. Weed Res. 7: 349-359.

Chancellor, R.J. 1964. Emergence of weed seedlings in the field and the effects of different frequencies of cultivation. Proc. 7th Br. Weed Control Conf. 2: 599-613.

Chancellor, R.J. and N.C.B. Peters. 1972. Germination periodicity, plant survival and seed production in populations of *Avena fatua* L. growing in spring barley. Proc. 11th. Br. Weed Control Conf. pp. 218-225.

Chancellor, R.J. and N.C.B. Peters. 1974. The time of onset of competition between wild oats (*Avena fatua* L.) and spring cereals. Weed Res. 14: 197-202.

Chepil, W.S. 1946. Germination of weed seeds I. Longevity, periodicity of germination and vitality of seeds in cultivated soil. Sci. Agric. 26: 307-346.

Chow, P.N.P. and R.D. Dryden. 1975. Control of wild oats in wheat with benzoylprop ethyl. Can. J. Pl. Sc. 55: 379-383.

Chow, P.N.P. 1976. Dinitroaniline herbicides for grassy weed control in rapeseed. Can. J. Pl. Sc. 56: 705-713.

Dew, D.A. 1972. An index of competition for estimating crop loss due to weeds. Can. J. Pl. Sc. 52: 921-927.

Faivre-Dupaigre. R. 1963. Experiments on the control of wild oats (*Avena fatua*) in spring barley crops. Weed Res. 3: 79-97.

Fay, P.K. and J.D. Nalewaja. 1977. The wild oat pilot project. A progress report of the first three seasons. Dept. of Agronomy, North Dakota State Univ. North Dakota.

Friesen, G. and L.H. Shebeski. 1960. Economic losses caused by weed competition in Manitoba grain fields. I. Weed species, their relative abundance and their effect on crop yields. Can. J. Pl. Sc. 40: 457-467.

Friesen, G. and L.H. Shebeski. 1961. The influence of temperature on the germination of wild oat seeds. Weeds 9: 634-638.

Friesen, H.A. 1961. Some factors affecting the control of wild oats with barban. Weeds 9: 185-194.

Friesen, H.A. 1974a. Identifying wild oats yield losses in Canada, Proc. Wild Oat Workshop, Las Vegas, Nevada. pp. 13-22.

Friesen, H.A. 1974b. Assessing cultural control methods in Canada. Proc. Wild Oat Workshop, Las Vegas, Nevada. pp. 30-39.

Friesen, H.A., J.D. Banting and D.R. Walker. 1962. The effect of placement and concentration of 2,3-DCDT on the selective control of wild oats in wheat. Can. J. Pl. Sc. 42: 91-104.

Friesen, H.A. and D.A. Dew. 1972. WL 17731 formulations mixed with other herbicides to control wild oats in wheat. Res. Rep. Can. Weed Comm. (W.S.) p. 328-329.

Friesen, H.A. and O.B. Litwin. 1975. Selective control of wild oats in barley with AC84777. Can. J. Pl. Sc. 55: 927-934.

Friesen, H.A., P.A. O'Sullivan and W.H. Vandenborn. 1976. Hoe 23408, a new selective herbicide for wild oat and green foxtail in wheat and barley. Can. J. Pl. Sc. 56: 567-578.

Godel, G.L. 1935. Relation between rate of seeding and yield of cereal crops in competition with weeds. Sc. Agric. 16: 165-168.

Hay, J.R. 1962. Experiments on the mechanism of induced dormancy in wild oats (*Avena fatua* L.) Can. J. Bot. 40: 191-202.

Hay, J.R. 1973. Wild oat herbicide recommendations. Let's clean up on wild oats. Seminar. Proc. Action Proposals and Programs. Agric. Can. and United Grain Growers Ltd. (1973).

Hill, B.D., E.H. Stobbe and B.L. Jones. 1978. Hydrolysis of the herbicide benzoylprop ethyl by wild oat esterase. Weed Res. 18:149-154.

Holroyd, J. 1964. The emergence and growth of *Avena fatua* from different depths in the soil. Proc. 7th Br. Weed Control Conf. 2: 621-623.

Honey, G.K. 1977. Wild oats cost more than you think. Country Guide, Mar. 1977.

Jeffcoat, B. and N. Harris. 1973. Selectivity and mode of action of ethyl (±)-2-(N-Benzoyl-3,4-dichloro-anilino) propionate in the control of *Avena fatua* in cereals. Pestic. Sci. 4:891-899.

Johnson, P.V. 1935. General preliminary studies on the physiology of delayed germination in *Avena fatua*. Can. J. Res. 13: 283-300.

Kock, W. 1967. Competition between crop plants and weeds. II. Effect of annual weeds on cereals. Weed Res. 7: 22-28.

Kock, W. 1968. Environmental factors affecting the germination of some annual grasses. Proc. 9th Br. Weed Control Conf. pp. 14-19.

Korven, N.A. 1960. Dates of seeding wheat for wild oat control. Res. Rep. Nat. Weed Comm. (Western Section). p. 26.

Manson, J.M. 1932. Weed survey of the prairie provinces. Nat. Res. Council Rep. #26, Ottawa, Canada.

McBeath, D.K., D.A. Dew and H.A. Friesen. 1970. Competition between barley and wild oats as affected by nitrogen, barban and time of seeding. Can. J. Pl. Sc. 50: 541-550.

Miller, S.D. and J.D. Nalewaja. 1975. Wild oat emergence and viability in the field. Agric. Exp. Sta. Publication, North Dakota State University, Fargo, North Dakota.

Miller, S.D. and J.D. Nalewaja. 1977. Wild oat seed in the soil as influenced by various crops. 34th Ann. Res. Rep. North Central Weed Control Conf. p. 12.

Molberg, E.S., H.A. Friesen, E.V. McCurdy and R.D. Dryden. 1964. Placement of di-allate and tri-allate for control of wild oats in wheat. Can. J. Pl. Sc. 44: 351-358.

Moyer, J.R. and R.D. Dryden. 1977. Effects of combined applications of triallate or trifluralin with solution nitrogen on wheat, wild oats and green foxtail. Can. J. Pl. Sc. 57: 479-484.

Naylor, J.M. and S. Jana. 1976. Genetic adaptation for seed dormancy in *Avena fatua*. Can. J. Bot. 54: 306-312.

Owino, M.G. 1977. Effect of dichlofop methyl on the growth and development of wheat, barley, wild oats and green foxtail. M.Sc. Thesis, University of Manitoba, Winnipeg, Manitoba.

Parker, C. 1963. Factors affecting the selectivity of 2,3-dichloroallyldiisopropylthiolcarbomate (di-allate) against *Avena* spp. in wheat and barley. Weed Res. 3: 259-276.

Parker, C. 1966. The importance of shoot entry in the action of herbicides applied to the soil. Weeds. 14: 117-121.

Pavlychenko, T.R. and J.B. Harrington. 1934. Competitive efficiency of weeds and cereal crops. Can. J. Res. 10: 77-93.

Pavlychenko, T.R. and J.B. Harrington. 1935. Root development of weeds and crops in competition under dry farming. Sc. Agric. 16: 151-160.

Pfeiffer, R.K. and H.M. Holmes. 1961. A study of the competition between barley and oats as influenced by barley seedrate, nitrogen level and barban treatment. Weed Res. 1: 5-18.

Prendeville, G.N., Y. Eshel, M.M. Schreiber, and G.F. Warren. 1967. Site of uptake of soil-applied herbicides. Weed Res. 7: 316-322.

Rahman, A. and R. Ashford. 1970. Selective action of trifluralin for control of green foxtail in wheat. Weed Sc. 18: 754-759.

Rahman, A. and R. Ashford. 1972a. Control of green foxtail in wheat with trifluralin. Weed Sc. 20: 23-27.

Rahman, A. and R. Ashford. 1972b. Trifluralin for green foxtail control in barley and flax. Weed Sc. 20: 160-162.

Roberts, H.A. and P.M. Feast. 1972. Fate of seeds of some annual weeds in different depths of cultivated and undisturbed soil. Weed Res. 12: 316-324.

Roebuck, J.F. and R.G. Hughes. 1972. Comparison of systems on control of *Avena fatua* in spring barley. Proc. 11th Br. Weed Control Conf. pp. 731-735.

Selman, M. 1968. The control of wild oats (*Avena fatua*) in continuous spring barley by triallate or late drilling. Proc. 9th Br. Weed Control Conf. pp. 84-88.

Sexsmith, J.J. and U.J. Pittman. 1962. Effect of nitrogen fertilizers on germination and stand of wild oats. Weeds 11: 99-101.

Sharma, M.P., D.K. McBeath and W.H. Vanderborn. 1976. Studies on the biology of wild oats. I. Dormancy, germination and emergence. Can. J. Pl. Sc. 56: 611-618.

Shimabukuro, R.W., W.C. Walsh and R.A. Hoerauf. 1976. The role of coleoptile on barban sensitivity between wild oats and wheat. Pest. Bio. and Phys. 6: 115-125.

Shuttleworth, C.T. 1972. Needed: A program for elimination of the wild oats problem. Minutes, Can. Weed Comm. pp. 22-30.

Stobbe, E.H. 1979. Tillage practices on the Canadian prairie. Outlook on Agric. 10: 21-26.

Stovell, F.R. and D.J. Bowler. 1972. Application of benzoylprop ethyl and the effect on yield of wheat. Proc. 11th Br. Weed Control Conf. pp. 276-280.

Sturko, A.R.W. 1978. Green foxtail (*Setaria viridis*) competition in semidwarf and normal height spring wheat. M.Sc. Thesis, University of Manitoba, Winnipeg, Manitoba.

Thurston, J.M. 1951. Some experiments and field observations on the germination of wild oat (*Avena fatua* L. and *A. ludoviciana* Dur) seeds in soil and the emergence of seedlings. Ann. Appl. Biol. 38: 812-832.

Thurston, J.M. 1961. The effect of depth of burying and frequency of cultivation on survival and germination of seeds of wild oats (*Avena fatua* L. and *A. ludoviciana* Dur.). Weed Res. 1: 19-31.

Thurston, J.M. 1962. The effect of competition from cereal crops on the germination and growth of *Avena fatua* L. in a naturally-infested field. Weed Res. 2: 192-207.

Thurston, J.M. 1966. Survival of seeds of wild oats (*Avena fatua* L. and *A. ludoviciana* Dur.) and charlock (*Sinapis arvensis* L.) in soil under Leys. Weed. Res. 6: 67-80.

Todd, B.G. and E.H. Stobbe. 1977. Selectivity of dichlofop methyl among wheat, barley, wild oat (*Avena fatua*) and green foxtail (*Seteria viridis*). Weed Sc. 25: 382-385.

Whybrew, J.E. 1964. The survival of wild oats (*Avena fatua*) under continuous spring barley growing. Proc. 7th Br. Weed Control Conf. 2: 614-620.

Williams, E.D. 1969. Effects of time of sowing of spring wheat and defoliation of *Agropyron repens* (L.) Beauv. on competition between them. Weed Res. 9: 241-250.

Wilson, B.J. 1972. Studies of the fate of *Avena fatua* seeds on cereal stubble, as influenced by autumn treatment. Proc. 11th Br. Weed Control Conf. pp. 242-247.

Wilson, B.J. and G.W. Cussans. 1972. The effect of autumn cultivations on the emergence of *Avena fatua* seedlings. Proc. 11th. Br. Weed Control Conf. pp. 234-241.

Wilson, B.J. and G.W. Cussans. 1975. A study of the population dynamics of *Avena fatua* L. as influenced by straw burning, seed shedding and cultivations. Weed Res. 15: 249-258.

Winfield, R.J. and J.B. Caldicott. 1975. Difenzoquat, 1,2-dimethyl-3,5-diphenylpyrazolium ion, a selective herbicide for the control of wild oats (*Avena* spp.) in wheat and barley. Pestic. Sc. 6: 297-303.

APPENDIX TABLE 1. Precipitation and temperature recorded at Carman Research Station, 1975

Date	May			June			July			August			September		
	Rain	Temperature		Rain	Temperature		Rain	Temperature		Rain	Temperature		Rain	Temperature	
	mm	Max (°C)	Min	mm	Max (°C)	Min	mm	Max (°C)	Min	mm	Max (°C)	Min	mm	Max (°C)	Min
1	1.5	6.7	0		22.2	2.8		26.2	12.8		24.4	18.9		20.6	11.1
2	T	10.0	0	9.9	21.1	6.1		27.2	14.4		23.9	13.3	16.5	15.0	2.8
3		13.3	2.8		17.8	6.7		28.3	12.2		24.4	13.3		21.7	7.2
4		13.3	1.1	3.0	16.1	6.7	0.7	28.9	14.4		22.8	10.6		20.6	8.3
5		16.7	0		13.3	7.2		30.6	16.1		22.8	7.8	1.5	20.0	7.8
6		20.6	3.3		17.8	6.1	T	30.0	15.6		27.8	7.8	0.2	20.0	5.6
7		20.6	5.6	1.2	21.7	3.3		28.3	16.1	18.8	27.8	10.6		16.7	9.4
8		22.2	2.2	1.7	18.9	11.7		23.9	8.9		26.1	15.6		18.9	- 0.6
9		24.4	2.2	13.9	14.4	11.1		21.1	11.7		24.4	12.2		22.2	3.9
10		25.0	4.4	1.2	18.9	11.1	T	22.2	5.0	9.1	26.7	10.6		18.3	8.9
11		16.1	3.3		22.2	6.7		20.6	9.4		26.1	14.4		10.6	2.2
12		23.3	0	T	27.8	8.9		29.4	8.3		22.8	14.4		13.9	- 0.6
13	6.3	23.9	9.4	0.7	23.3	11.1		31.7	15.0		25.6	10.6		22.2	- 0.6
14		13.3	2.2		18.9	10.6		32.2	15.6		20.0	12.2		28.3	5.0
15		23.3	- 1.1		21.7	7.8		33.9	17.2	1.5	23.9	5.0		17.2	7.2
16	3.8	28.3	7.2		21.7	6.1		32.2	18.3		21.1	5.6		22.8	0.6
17	4.0	22.2	8.9		22.8	11.1	8.1	28.3	19.4		18.3	6.1	12.7	25.0	5.6
18	3.0	24.4	4.4		26.1	7.2	10.4	27.2	16.7		16.7	2.2	2.0	16.1	12.8
19	1.7	22.2	10.6	1.5	23.9	15.0	3.8	23.9	15.0		17.8	8.9	3.5	10.6	4.4
20	5.5	13.3	6.7	3.3	30.6	15.6	0.7	26.1	13.3	0.7	16.1	6.1		12.2	5.6
21	T	8.9	1.7	7.6	24.4	13.9	1.0	26.1	15.0		18.9	11.7		16.1	- 1.1
22	4.5	16.7	1.7	16.5	18.9	13.9		28.9	14.4	1.7	23.3	12.8		22.2	2.8
23	7.6	21.7	5.0	1.2	26.7	11.1		28.9	11.7		31.7	14.4		16.1	5.0
24	0.7	24.4	9.4		27.2	11.1		28.9	12.8	11.6	26.1	15.0		20.6	2.2
25		17.2	9.4		29.4	11.1		30.0	13.9	4.0	20.6	12.2		25.6	7.2
26		18.9	6.7		27.8	20.6		27.2	18.3		17.8	8.3		25.6	3.9
27		22.2	5.6	34.2	28.9	10.0		31.3	11.1		22.2	3.9		19.4	3.3
28	0.2	22.2	4.4	0.2	27.2	15.6		35.0	17.2		27.8	8.3		14.4	5.6
29		17.8	6.7	3.8	28.3	16.7		34.4	17.8	4.0	20.6	13.9	2.0	17.2	4.4
30	0.7	17.2	3.9		29.4	13.6		35.6	21.7		27.2	11.1		9.4	3.3
31		17.8	5.0				8.3	26.7	19.4		26.7	15.0			
	49.0	18.9	3.9	100.5	22.8	10.6	33.2	28.3	14.4	51.8	23.3	10.6	38.6	18.9	5.0

APPENDIX TABLE 2. Precipitation and temperature recorded at Carman Research Station, 1976

Date	May Rain mm	May Max (°C)	May Min	June Rain mm	June Max (°C)	June Min	July Rain mm	July Max (°C)	July Min	August Rain mm	August Max (°C)	August Min	September Rain mm	September Max (°C)	September Min
1		7.2	- 0.6		28.3	11.7		26.7	8.9		25.6	7.8		17.8	6.1
2		6.7	- 2.8	1.3	31.1	13.6		27.2	8.9		27.8	7.8		26.1	3.9
3		13.3	- 5.6		30.6	16.1		26.7	9.4		31.7	8.9		22.8	8.9
4		21.7	1.7		31.1	16.7		28.9	11.1		21.7	16.7		24.4	3.3
5		6.7	- 3.3		25.6	8.9		31.1	13.3		22.2	6.1		35.6	11.1
6		8.9	- 6.1	3.6	29.4	15.6		28.3	16.7		27.2	4.4		37.2	10.0
7		18.3	- 5.6	3.3	21.7	16.1		28.3	11.7		31.1	7.2		23.9	16.1
8		22.8	4.4	0.8	21.7	11.7		27.8	13.3	7.8	24.4	16.1	1.2	16.7	7.8
9		28.3	7.8	4.6	24.4	11.1	5.1	30.6	16.1	1.3	20.6	11.7		21.7	3.3
10		15.6	4.4	0.3	30.0	13.3		23.9	18.3		28.3	13.3		28.9	7.8
11		21.7	- 0.6		31.4	11.7		21.1	11.1		25.0	11.7		31.1	7.2
12	3.6	18.3	3.9	22.1	25.0	15.6		24.4	9.4	4.3	19.4	13.9		27.8	13.3
13		22.2	5.0	2.0	18.3	12.8		25.0	13.9	T	23.9	14.4	3.0	9.4	7.8
14	5.3	19.4	6.7	1.5	16.7	11.7		27.8	13.3		25.0	9.4		13.3	6.1
15		21.7	10.0		16.7	8.9		28.3	11.1		24.4	7.8		26.7	1.1
16		18.9	4.4		18.9	3.3		24.4	9.4		27.2	8.3		26.7	4.4
17		17.8	- 1.7	27.7	13.3	10.6		25.0	8.3	T	28.2	9.4		32.8	12.8
18		27.8	7.2		21.1	4.4		30.0	12.8		31.1	13.3		27.8	13.9
19		24.4	7.2		26.1	10.6	0.3	31.1	18.3	T	31.7	16.7		16.7	7.8
20		22.2	4.4		30.6	12.2	18.8	29.4	11.1	6.9	33.3	17.2		21.1	3.3
21		21.1	5.6	1.3	15.6	14.4		25.6	7.8		28.3	12.2		17.2	- 1.7
22		25.0	1.1		25.6	8.9		26.7	16.1		29.4	8.9		12.2	2.2
23		25.0	1.1		28.9	15.0		27.8	10.6		37.2	12.8		15.6	- 4.4
24		25.0	0.0		22.2	15.6		27.8	7.8		28.9	17.2		12.2	- 1.7
25		27.2	8.9	2.0	22.8	11.7	5.8	28.3	16.7		28.3	17.2		16.7	- 2.8
26	1.0	21.7	18.4	1.0	20.6	11.7	T	27.8	11.7		30.6	15.0		15.6	3.3
27		21.1	3.3		23.3	8.3		30.0	11.1	4.3	18.9	13.3	1.0	24.4	- 3.3
28		25.0	3.9		20.6	7.8	0.5	25.6	6.7		15.6	5.6		25.0	3.9
29		27.2	7.2	11.4	22.8	10.6	T	23.3	13.9		24.4	3.3		26.1	2.2
30		28.9	9.4		25.6	9.4		20.0	11.1		28.9	7.2		31.1	7.2
31	0.5	28.3	10.0					25.0	5.6		19.4	7.2			
	10.4	20.6	3.5	82.9	24.0	11.6	30.5	26.9	11.7	24.6	28.6	10.7	5.2	21.9	6.3

APPENDIX TABLE 3. Precipitation and temperature recorded at Graysville Meterological Station, 1977

Date	May			June			July			August			September		
	Rain	Temp. °C		Rain	Temp. °C		Rain	Temp. °C		Rain	Temp. °C		Rain	Temp. °C	
	mm	Max.	Min.	mm	Max.	Min.	mm	Max.	Min.	mm	Max.	Min.	mm	Max.	Min.
1		15.6	1.7		16.7	12.8		24.4	10.0	.3	22.1	12.6	1.5	18.5	6.0
2	3.0	22.2	1.7		25.6	5.0	4.3	30.6	7.8	2.6	23.2	11.3		19.5	7.5
3	15.2	26.7	5.0		23.9	8.3		27.8	12.8	4.2	21.4	10.0	1.6	19.5	6.5
4	34.8	18.3	9.4	0.8	25.6	8.9	0.5	30.0	12.8		22.5	9.0	15.2	16.5	8.0
5	0.8	15.0	13.3	0.5	23.9	10.0	3.8	30.0	15.0		21.0	10.0	16.4	16.5	9.0
6		11.7	1.7		27.2	7.2		30.0	17.8	6.3	26.5	8.5		18.5	9.0
7		20.0	1.7		27.2	11.1		27.2	15.0	2.0	26.5	7.5	6.2	24.0	8.0
8		27.8	0.0		21.7	7.8		21.7	10.6		26.5	7.0	37.0	24.0	8.0
9		28.9	11.1		25.0	8.9		24.4	5.6	18.8	30.0	8.0		19.0	10.0
10		32.8	12.2	6.4	20.0	11.1	5.8	27.8	6.1	1.2	30.0	7.0		22.0	7.5
11		32.8	15.0	0.3	15.0	8.9	11.4	22.2	12.2		26.0	6.5		22.0	7.0
12		33.3	15.0	20.8	14.4	8.9		26.1	12.2	16.4	25.5	7.5	1.2	20.5	5.5
13	8.4	33.9	13.3		17.9	8.3	15.0	18.9	13.3		19.0	6.0		20.5	5.5
14	13.7	31.1	15.0		17.2	8.9		22.8	13.9		23.0	5.0		28.0	6.0
15		31.1	14.4	0.5	24.4	11.1		27.8	9.4		23.5	7.0		29.0	9.5
16		23.9	14.4		24.4	15.6	5.1	27.8	11.1	16.3	23.5	6.0		29.0	10.0
17	43.7	24.4	10.0	29.0	16.7	13.9	1.5	33.3	12.2		20.5	6.0		26.5	10.5
18	8.9	24.4	11.1	0.8	22.8	12.2		32.2	15.6		24.0	4.5		15.0	6.0
19	5.8	23.9	12.2	0.5	20.0	12.2		24.4	15.6	1.2	26.5	6.5		15.0	8.0
20		20.6	11.1		25.6	10.0		25.6	9.4		26.5	7.5	1.0	19.5	8.5
21		25.0	8.3		25.6	9.4		27.2	10.6		25.0	10.0		20.0	8.0
22		18.3	11.7		23.3	8.9		34.4	11.7		24.0	7.0	2.7	14.0	10.0
23		26.1	11.1	5.1	29.4	11.1	2.5	28.9	12.8		18.0	4.0	34.0	14.5	10.0
24		31.7	12.2		27.2	14.4		26.7	13.3		23.5	4.0	25.6	12.0	10.0
25		32.8	15.0	3.8	33.3	15.0		25.6	8.3	2.5	26.5	7.0	5.0	12.0	9.0
26	3.0	26.7	18.3		27.2	16.1		30.0	10.0		26.5	8.5		12.5	8.5
27	5.8	26.7	15.0	3.0	25.6	9.4		25.6	10.0	.6	22.5	7.5		16.5	7.5
28		24.4	15.0		24.4	10.0	1.8	29.4	12.8		22.0	10.0		16.5	5.0
29	0.5	26.7	9.4	1.5	25.0	8.9	11.2	24.4	6.3	15.6	23.5	4.0		16.0	1.5
30		25.6	15.6	2.3	17.8	10.6	5.1	23.3	9.4		23.0	5.0		15.5	1.5
31		26.7	13.9				5.3	24.4	11.2	12.6	22.0	9.5		15.5	1.0
	143.6	25.5	10.7	75.3	23.1	10.5	73.3	26.9	11.5	100.6	22.0	7.5	147.4	18.0	7.0