THE SELECTIVITY OF BROMOXYNIL OCTANOATE

IN CEREAL CROPS AND FLAX

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bromoxynil	3,5-dibromo-4-hydroxybenzonitrile
dicamba	2-methoxy-3, 6-dichlorobenzoic acid
dichlorprop	2-(2,4-dichlorophenoxy) propionic acid
ioxynil	3,5-diiodo-4-hydroxybenzonitrile
MCPA	2-methyl-4-chlorophenoxyacetic acid
MCPB	4-(2-methyl-4-chlorophenoxy) butyric acid
MCPP	2-(2-methyl-4-chlorophenoxy) propionic acid
picloram	4-amino-3,5,6-trichloropicolinic acid
2,4-D	2,4-dichlorophenoxyacetic acid
2,4-DB	4-(2,4-dichlorophenoxy) butyric acid

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ABSTRACT

THE SELECTIVITY OF BROMOXYNIL OCTANOATE IN
CEREAL CROPS AND FLAX

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A two year project was undertaken to study the potential usefulness of hydroxybenzonitrile herbicides for weed control in cereal crops and flax. The weed species studied were those generally considered resistant to the phenoxyacetic acid type herbicides.

The results of this study indicated that the n-octanoyl ester of bromoxynil was particularly well suited for the control of many serious weed problems, such as smartweeds and wild buckwheat.

Bromoxynil also appeared to have a high degree of crop safety to cereal crops and flax. Rates of twice the amount required for adequate weed control were applied with little or no damage to crop. Applications of bromoxynil and bromoxynil-MCPA mixtures to flax at eight different growth stages indicated favourable crop response at all stages.

Effective weed control was achieved by applications of 6 ounces per acre of bromoxynil. However it appeared that some weed species, particularly the smartweeds, became increasingly

resistant after the plants developed the fourth or fifth leaf.

In order to broaden the spectrum of weeds controlled, MCPA plus bromoxynil mixtures were tested. Crop response did not appear to be dependent to any measurable degree on the particular formulation of MCPA used.

Under conditions of dense weed infestations it appeared to be advantageous to increase the volume of diluent used.

Results from quality testing of wheat and flax suggested that bromoxynil alone, or in mixture, applied at recommended rates did not have any detrimental effect on crop quality.

INTRODUCTION

During the past twenty years, farmers of Western Canada have become increasingly aware of the importance of chemical weed control. This awareness has resulted in the widespread use of 2,4-D and MCPA for the control of many weeds in field crops. As a result, susceptible weeds such as wild mustard (*Sinapis arvense* L.), lamb's-quarters (*Chenopodium album* L.), ragweeds (*Ambrosia* spp.), and stinkweed (*Thalspi arvense* L.) are no longer the problem in crop production that they were two decades ago. However, the control of these weed species has permitted the semi-resistant weeds (often referred to as "hard to kill" weeds) such as wild buckwheat (*Polygonum convolvulus* L.), tartary buckwheat (*Fagopyrum tartaricum* L. Gaertn.) and smartweeds (*Polygonum* spp.) to increase in abundance and seriousness.

Approximately thirty-five million acres of farmland in Western Canada are infested with weeds not readily controlled by 2,4-D or MCPA, but which could readily be controlled by the use of recently developed herbicides such as picloram, dicamba or bromoxynil. However, the use of herbicides such as picloram and dicamba entails certain problems such as crop tolerance, soil residues and drift hazards.

Preliminary experiments have shown that bromoxynil may be particularly suited for the control of many serious weeds in cereal crops grown on the Canadian prairies. Bromoxynil is primarily a contact herbicide with some limited translocated action. Under field conditions the herbicide causes necrotic and blistered areas on the leaves of susceptible species, and finally the death of plants. There is some variation in the speed of action but many of the weeds are killed between two and seven days after application of the herbicide. Crop tolerance appears to be adequate for safe and selective weed control. There are no known soil residue or drift hazard problems. In view of this, bromoxynil appears to have definite advantages over other herbicides presently available for the control of "hard to kill" weeds.

A two-year study was initiated at the University of Manitoba in 1965 to obtain information on the effects of bromoxynil on cereal crops and flax grown under Manitoba conditions. In 1965, experiments were conducted to determine the selectivity of bromoxynil and herbicidal mixtures containing bromoxynil in wheat, oats and barley. In 1966, major emphasis was placed on the effect of bromoxynil on flax. The efficacy of bromoxynil and bromoxynil-MCPA mixtures in controlling "hard to kill" weeds was studied in both years.

Further tests were conducted to determine the effect of bromoxynil and bromoxynil-MCPA mixtures on seed quality in wheat (milling and baking characteristics) and on flax seed (oil content and iodine values).

REVIEW OF LITERATURE

Wild buckwheat (*Polygonum convolvulus* L.), tartary buckwheat (*Fagopyrum tartaricum* L. Gaertn.) and smartweeds (*Polygonum* spp.) constitute a major weed problem over a large portion of the cultivated acreage of Western Canada. Surveys have shown that 30,000,000 acres are infested with wild buckwheat, and 6,440,000 with green and pale smartweeds (1). Studies conducted by Friesen and Shebeski (18) in 1956 to 1958 showed that 98 percent of farm fields in Manitoba had wild buckwheat as part of the weed flora and 42 percent of the farm fields contained smartweeds.

Weed competition studies have demonstrated the inability of agricultural crops to compete successfully with the above-mentioned weeds. Competition studies were conducted by Nalewaja (41) with wild buckwheat in wheat and flax in North Dakota. His results demonstrated that 5 wild buckwheat plants per square foot caused an 11.6 percent loss in wheat yields, and 20 wild buckwheat plants per square foot resulted in a 27.5 percent loss. Similarly, 4 wild buckwheat plants per square foot in flax reduced the yield by 22.6 percent. The competitive effect of wild buckwheat has also been shown under field conditions. Friesen and Shebeski (18) found that an infestation of 47 wild buckwheat plants per square yard reduced wheat yields by 14.8 percent, and 172 wild buckwheat plants per square yard reduced wheat yields by 25.7 percent. Studies on the competition of wild buckwheat in oats and flax reported by

Forsberg (16) show that 15 plants per square foot are sufficient to reduce the yield of oats by 55 percent and that an infestation of 3 plants per square foot will reduce the yield of flax by 66 percent.

Martin and Rademacher (32) investigated the competitive effects of lady's-thumb (<u>Polygonum persicaria</u> L.) on flax and potatoes. Their results showed shoot growth of flax and potatoes reduced by 43 and 47 percent respectively, due to allelopathic influences of lady's-thumb.

Vanden Born and Corns (50) reported that tartary buckwheat infestations of 25, 50 and 100 plants per square yard reduced barley yields 7, 28 and 59 percent respectively.

<u>Phenoxy herbicides</u>

Considerable research has been directed towards improving the effectiveness of phenoxyacetic herbicides such as 2,4-D, MCPA, dichloroprop, MCPP, 2,4-DB, and MCPB for the control of wild buckwheat, tartary buckwheat and smartweeds. Results from this work are quite varied; however it is generally agreed that a single application of 2,4-D at 6 to 8 ounces per acre will not provide adequate control of these weeds. Forsberg (13) reported that fair control of wild buckwheat was achieved by 12 to 16 ounces per acre application of 2,4-D. However, at these heavier rates the yield of wheat was reduced. In a similar study he found that two 5 ounce per acre applications of 2,4-D spaced one week apart, resulted in 87 percent control of wild buckwheat, this being somewhat better than a single

10 ounce per acre rate (14). Other workers have found, however, that a double application is not necessarily more effective than a single application (of 2,4-D) for the control of wild buckwheat (5, 10, 28).

Corns and Vanden Born (10) investigated the possibility of using MCPA to control wild buckwheat. Their results show MCPA to be less effective than 2,4-D when compared at similar rates. A study conducted by Forsberg (13) comparing 2,4-D ester and MCPA ester showed MCPA to be even less effective than 2,4-D for the control of wild buckwheat. However its reaction on the yields of grain was not as severe as 2,4-D ester.

Similar experiments have been carried out on the smartweeds and tartary buckwheat. Results from these experiments indicate smartweeds are even more resistant to 2,4-D and MCPA than wild buckwheat. Siemens and Kusch (43) found an 8 ounce per acre application of MCPA amine resulted in only 19 percent control while 2,4-D amine at 12 ounces per acre was only slightly more effective. A summary prepared by McCurdy (35) in 1956 reports unsatisfactory control of smartweeds from applications of 2,4-D and MCPA products at rates up to 16 ounces per acre.

Ester formulations of 2,4-D applied at 8 ounces per acre on tartary buckwheat did little more than slightly stunt the plants while MCPA ester was even less effective than 2,4-D ester, and 2,4-D amine at 8 ounces per acre had no appreciable effect (19). Vanden Born and Corns (49) applied 2,4-D ester on tartary buckwheat at rates of 4, 8 and 12 ounces per acre, and achieved 45, 65 and 70 percent control respectively when the herbicide was applied during early growth stages.

Dichloroprop, 2,4-DB, MCPP and MCPB have also been evaluated for control of wild buckwheat, tartary buckwheat and smartweeds. Results have indicated that these chemicals offer no advantage over 2,4-D and MCPA when applied at similar rates (12, 13, 15, 20, 25, 48, 49).

Hydroxybenzonitrile herbicides

The first announcements of the discovery of the useful herbicidal properties of the salts of ioxynil and bromoxynil appeared simultaneously in October 1963, from Wain (54) and workers at May and Baker Limited (6). However it later became apparent that a third organization, Amchem Products, Incorporated, in the United States had independently been studying the interesting properties of ioxynil and bromoxynil (3, 23). Ioxynil generally showed more activity than bromoxynil and therefore received greater emphasis during the early period of investigations (46). However, from abstracts submitted to the National Weed Committee (Western Section) in 1964, it was concluded that bromoxynil was more effective under conditions found in Western Canada (24, 29, 46). It was shown that bromoxynil was very effective in controlling wild buckwheat, tartary buckwheat and smartweeds. However, some weed species such as the mustards (Cruciferae) and lamb's-quarters (Chenopodium album L.) are somewhat resistant to the herbicide (4, 36).

Subsequently the use of bromoxynil for control of wild buckwheat, green smartweed and tartary buckwheat was tested extensively. McConnell and Friesen (33) reported control of wild buckwheat and green smartweed at rates of 3 to 6 ounces per acre. Friesen (21) obtained complete control of green smartweed by using a 4 ounce per acre application. In a summary prepared by May & Baker Limited on the herbicidal activity of bromoxynil in field experiments, it is reported that tartary buckwheat was controlled by a 3 ounce per acre application of bromoxynil (4). It was also noted that certain weed species, particularly the smartweeds, became more resistant to the hydroxybenzonitriles with advancing age (4).

Due to the apparent resistance of several important weed species to bromoxynil, experiments were also conducted to investigate the possibility of using bromoxynil in mixture with phenoxyacetic herbicides, to increase the spectrum of weed control. Workers were also interested in studying the possible synergistic effects of phenoxyacetic herbicides on the efficacy of bromoxynil. Clarke reported 4 and 6 ounce per acre rates of bromoxynil reduced plant numbers of stinkweed (Thalspi arvense L.) and ball mustard (Neslia paniculata (L.) Desr.) 59 and 71 percent respectively, while bromoxynil plus MCPA applied at a rate of 4 ounces per acre each and 6 ounces per acre each, resulted in 91 and 97 percent control (7). In experiments conducted by Lobay (31), better control of wild buckwheat, tartary buckwheat and green smartweed was achieved by using a herbicidal mixture of bromoxynil and MCPA than by using bromoxynil alone. However other workers have not reported any increased activity with the addition of phenoxyacetic herbicides for the control of smartweeds and wild buckwheat (52, 53). Keys (30) concluded that the addition of phenoxy herbicides did not improve control of wild buckwheat when applied at the early growth stages; however when applied at later growth stages, control was improved by the addition of MCPA to bromoxynil.

The hydroxybenzonitriles are primarily contact herbicides with limited translocated action. Therefore adequate coverage of the plants by the herbicidal solution is necessary to achieve maximum control (4, 24). In a greenhouse experiment it was found that four times the amount of ioxynil was required to produce a given reduction in growth of a *Raphanus* leaf, when it was applied in a single droplet, than when it was applied in sixteen droplets (24).

Studies have been carried out to determine the effect of volume of diluent on the efficacy of this group of herbicides. Results from these experiments have been somewhat inconclusive. Research workers with Amchem Products Incorporated found the volume of diluent affected herbicidal activity significantly (17). Better weed control was observed as the amount of diluent increased from 3 gallons per acre to 100 gallons per acre. McConnell and Friesen (34) found that control of wild buckwheat and smartweeds was improved when a mixture of bromoxynil and MCPA at a rate of 3 ounces each per acre was applied in 20 gallons of water as compared to 5 gallons of water per acre. However, Terry and Wilson (46) concluded that there were no differences in herbicidal activity of bromoxynil or ioxynil when applied in 10 gallons as compared with 65 gallons of water per acre.

Studies have also been conducted to determine the effect of adding wetting agents or surfactants to the spray solution. Terry and Wilson (46) have shown that the addition of a wetting agent resulted in better weed control, especially of *Chenopodium* spp. and certain *Polygonum* spp. Work done by Stewart (17) showed increases in weed control by the addition of a surfactant.

Field trials published as abstracts in annual research reports of the National Weed Committee (Western Section) in 1965 and 1966 and papers published by research workers in England and the United States have established that bromoxynil and ioxynil alone and in mixture with phenoxyacetic herbicides may be used as selective herbicides for the control of wild buckwheat, tartary buckwheat and smartweed in cereal crops. The reports indicate a wide margin of crop safety. Terry and Wilson (46) found both ioxynil and bromoxynil could be safely applied on wheat, barley and oats at 2 to 4 times the rate necessary for weed control. An Amchem Products Incorporated technical service bulletin reports that ioxynil has been applied on cereal crops at rates as high as 4 pounds per acre without causing yield reductions (3). Bromoxynil has also been applied at rates several times higher than those required for weed control. These rates were applied on wheat, oats and barley from the two leaf stage until the early tillering stage without causing crop damage (4).

In 1965 two abstracts were published in the Research Report of the National Weed Committee (Western Section) reporting the use of bromoxynil and bromoxynil-MCPA mixtures on flax

(37, 38). No injury to the flax crop was observed. In 1966, many research workers in western Canada conducted similar experiments. Cook (9) reported some damage (scorching and delay in growth) to flax at one test site in Manitoba and Couckell (11) observed severe damage to flax in one test when bromoxynil was applied at 4, 6 and 12 ounces per acre. In both cases the herbicide was applied under conditions of high temperature and high humidity. These factors may have been responsible for the severe injury which occurred at these two sites. Other workers however, reported little or no injury to flax due to applications of bromoxynil and herbicidal mixtures containing bromoxynil (8, 39, 40, 44).

MATERIALS AND METHODS

Five projects were carried out to determine the response of wheat, oats, barley and flax to bromoxynil and bromoxynil-MCPA mixtures. The projects were as follows:

(a) Comparison of various herbicides for weed control in wheat, barley and flax.

(b) The efficiency of bromoxynil alone and in combination with various phenoxyacetic herbicides on oats, barley, wheat and flax.

(c) The effect of bromoxynil and bromoxynil-MCPA mixtures applied at various stages of crop growth.

(d) The effect of spray volume on the efficacy of bromoxynil alone and in mixture with MCPA.

(e) The effect of bromoxynil and bromoxynil-MCPA mixtures on seed quality of wheat and flax.

All experiments carried out on cereal crops were located on summerfallow land (Osborne clay soil) at the Glenlea Research Station. Experiments conducted on flax were located at the University of Manitoba on summerfallow land (Riverdale clay loam). To insure an adequate infestation of weeds at the University of Manitoba site, a mixture of weed seeds consisting mainly of smartweeds (_Polygonum_ spp.) and wild buckwheat (_Polygonum convolvulus_ L.) was broadcast over the area, in the late fall of 1965 and disced into the soil.

Field plots were seeded with a 6 foot pony press drill.

Each plot was 6 by 16 feet in size and accommodated 12 rows of crop spaced 6 inches apart. All herbicidal applications were made with a small plot precision sprayer delivering 5.5 imperial gallons per acre total solution at 45 p.s.i. (except where noted in project (d)). Visual assessment of crop injury and weed control were recorded on a 0-10 basis (0=no injury, 10=complete kill). A small plot harvester was used to harvest 30 square feet of crop from the centre of each plot at maturity. Yield data from each project was subjected to statistical analysis as outlined by Steel and Torrie (45).

(a) Comparison of various herbicides for weed control in wheat, barley and flax.

Pembina wheat was seeded on June 1 at a rate of 75 pounds per acre and Parkland barley on June 7 at a rate of 90 pounds per acre, both with 50 pounds per acre of 11-48-0 fertilizer drilled in with the seed in 1965. The following herbicides were applied on June 24 when wheat was in the early tillering stage and barley in the 2-3 leaf stage (rates in ounces per acre): bromoxynil ester, 8; K salt of bromoxynil, 4 and 8; bromoxynil + 2,4-D ester, 4+4 and 8+8; Na salt of ioxynil, 8; Na salt of ioxynil + 2,4-D ester, 4+4; Na salt of ioxynil + 2,4-D amine, 4+4; ioxynil amine, 4 and 8; ioxynil amine + 2,4-D amine, 4+4; dicamba + 2,4-D amine, $1\frac{1}{2}$+$4\frac{1}{2}$ and 2+6. Visual assessment of weed injury was made on two dates, June 29 and July 21, and crops were harvested August 25. The experimental design was a randomized block with 4 replicates.

Bolley flax was seeded at a rate of 35 pounds per acre May 11, 1966. The following herbicides were applied at two stages of crop growth (rates in ounces per acre): bromoxynil, 6, 8 and 12; bromoxynil + MCPA, 4+4, 6+6 and 8+8; Banvel 3, 8 (commercial mixture of dicamba + 2,4-D amine + MCPP, 1.8 + 5.0 + 1.2); Estaprop, 16 (commercial mixture (1:1) of 2,4-DP + 2,4-D ester); Picloram + MCPA amine, $\frac{1}{2}+7\frac{1}{2}$; 2,4-DP, 16; 2,4-D ester, 8; MCPA amine, 10. The first stage was sprayed on June 14 when the flax was 3 to 4 inches high. The second stage was sprayed on June 21, flax being 5 to 6 inches in height at this time. Crop and weed injury was assessed on July 15 and August 10. Flax was harvested on September 5. The experimental design was a split plot with 4 replicates, with stages of growth as main plots and chemical treatments as subplots.

(b) The efficiency of bromoxynil alone and in combination with various phenoxyacetic herbicides on oats, barley, wheat and flax.

Rodney oats and Parkland barley were seeded at a rate of 100 and 90 pounds per acre respectively, each with 50 pounds of 11-48-0 fertilizer, on June 7, 1965. Herbicidal sprays were applied on July 7, when the crop was in early tillering stage. Visual assessment of weed control was made on June 29 and July 21. Plots were harvested August 25. The experiments were designed as a randomized block with 3 replicates.

In 1966, Bolley flax was seeded at a rate of 35 pounds per acre and sprayed on June 17 when flax was 4 to 5 inches in height. Weed and crop injury was visually assessed on June 29 and again on July 21. Plots were harvested on August 30. Experimental design was a randomized block with 6 replicates.

Pembina wheat was seeded on May 28, 1966 at a rate of 75 pounds per acre. Herbicides were applied on July 11 when crop was in the shot blade stage of growth. Weed control was assessed on two dates, July 27 and August 11. Wheat was harvested September 6. Experimental design was a randomized block with 6 replicates.

(c) The effect of bromoxynil and bromoxynil-MCPA mixtures applied at various stages of crop growth.

Pembina wheat was seeded on June 1, 1965 at a rate of 75 pounds per acre. 11-48-0 fertilizer was drilled in with the seed at a rate of 50 pounds per acre. Herbicidal mixtures were applied at two stages of crop growth. The first stage was sprayed on June 29 when the wheat was in the 3-4 leaf stage. The second stage was treated on July 7 when crop was at the tillering stage. Weed control was visually assessed on June 29 and July 21 and crop was harvested on August 25. The experimental design used was a split plot with three replicates, with chemical treatment as main plots and stages of growth as subplots.

In 1966 Pembina wheat was seeded on May 28, at a rate of 75 pounds per acre. The dates of spray application and the stages of crop growth were as follows: June 15, 1-2 leaf; June 22, 2-3 leaf; July 11, shot blade; and July 19, heading. Weed control was visually assessed on July 27 and August 11.

Crop was harvested on September 6. The experimental design used was a split plot with 4 replicates with chemical treatments as main plots and stages of growth as subplots.

In 1966 an experiment was designed to study the effect of herbicides containing bromoxynil on flax at eight growth stages. Herbicides were to be applied at intervals of 5 days, however this schedule was at times interrupted due to adverse weather conditions. Bolley flax was seeded at a rate of 35 pounds per acre on May 11. Dates of spray application and stages of crop development were as follows: June 2, $\frac{3}{4}$ inch; June 8, $1\frac{1}{2}$ inches; June 13, 4 inches; June 17, 5 inches; June 21, 7 inches; June 25, 10 inches; June 30, early flowering. Visual assessment of weed control was made on July 15 and August 10. Plots were harvested on September 5. Experimental design was a split plot with 4 replicates with chemical treatments as main plots and stages of growth as subplots.

(d) The effect of spray volume on the efficacy of bromoxynil alone and in mixture with MCPA.

In this experiment, different volumes of diluent containing bromoxynil and bromoxynil plus MCPA mixtures were applied on flax heavily infested with smartweeds. Bolley flax was seeded May 11 at a rate of 35 pounds per acre. Plots were sprayed on June 21 when flax averaged 6 inches and smartweeds were in the 5 to 6 leaf stage. The application of the different volumes of diluent was achieved by using nozzles of different sizes and/or changing the speed of travel. Visual assessment of weed control was made on July 14 and August 10. Plots were harvested on September 5. The experimental design was a split plot with 4 replicates with chemical treatments as main plots and volumes as subplots.

(e) The effect of bromoxynil and bromoxynil-MCPA mixtures on seed quality of wheat and flax.

Grain samples of Pembina wheat were taken from harvested plots which had been treated with applications of bromoxynil and bromoxynil-MCPA mixtures at rates of 6 ounces and 4+4 ounces per acre. Herbicides had been applied at the 3-4 leaf stage in one experiment and at the 3-4 leaf and tillering stages of growth in the second experiment from which the samples were taken. These samples were bulked according to treatment and the experiment from which they were taken and milled in a Buhler laboratory mill. In each case a control sample from the appropriate check plots was also milled so that a comparison could be made. The moisture contents of grain samples were adjusted to a level at which optimum average flour yield could be obtained.

Crude protein was determined by the standard Kjeldahl procedure and flour color was measured with a Kent-Jones color meter (2). Bushel and 1000 kernel weights were also determined.

Farinograms were obtained for individual flour samples by the standard procedure (2). In baking trials, the standard pup loaves (100 g. flour) were prepared by the remix method (26). A standard formula was used throughout the baking trials so that under these particular conditions the results would be comparable.

The oil content and iodine values of the oil were determined on harvested samples of flax obtained from the dates of spraying test described in project (c). The oil content (percent dry weight) determinations were carried out according to a method outlined by Troëng (47). The oil collected from the seed samples was placed in an oil refractometer and the scale readings were taken at 35 Centigrade. Each reading was converted to the refractive index at 25 Centigrade by use of the tables included in the instruction booklet of the refractometer. The refractive index was then converted to the iodine number by the following formula:

Iodine Number (wijs) = 8584.97 n_D^{25} - 12,513.83

where n_D^{25} is the refractive index at 25 Centigrade (55).

Analysis of variance on iodine number was calculated using scale reading values which were then transformed to iodine numbers.

RESULTS AND DISCUSSION

(a) Comparison of various herbicides for weed control in wheat, barley and flax.

Considerable variation in the effectiveness of various herbicides included in these experiments were noted.

Results obtained from the wheat test indicate good weed control was achieved by the application of bromoxynil at a rate of 8 ounces per acre, bromoxynil plus 2,4-D ester at 4+4 and 8+8 ounces per acre and dicamba plus 2,4-D at rates of $1\frac{1}{2}+4\frac{1}{2}$ and 2+6 ounces per acre (Table 1). Somewhat less than satisfactory control was observed in those plots which were treated with the Na salt of ioxynil plus 2,4-D at 4+4 ounces, ioxynil amine at 8 ounces and the K salt of bromoxynil at 8 ounces per acre. The following applications resulted in completely unsatisfactory control: Na salt of ioxynil at 8 ounces, ioxynil amine at 4 ounces, ioxynil amine + 2,4-D amine at 4+4 and K salt of bromoxynil at 4 ounces per acre.

No injury to the wheat crop was observed. However wheat yields did differ significantly (Table 1, Appendix 1). In view of the fact that weed infestations in this test were relatively light, it appears that differences in yield were brought about primarily by an unfavourable crop response to the herbicidal application. In considering only those herbicides which gave adequate weed control, bromoxynil plus 2,4-D applied at a rate of 4+4 ounces per acre and dicamba plus 2,4-D ester at $1\frac{1}{2}+4\frac{1}{2}$ and 2+6 ounces per acre reduced wheat yields slightly but significantly as compared to bromoxynil alone applied at 8 ounces per acre. The application of bromoxynil plus 2,4-D at 8+8 ounces per acre resulted in a very significant reduction in yield.

Results obtained from the test on barley indicate that herbicidal activity was similar to that observed in the wheat experiment. Bromoxynil, bromoxynil plus 2,4-D, and dicamba plus 2,4-D again gave the most satisfactory control. Other treatments resulted in less than satisfactory control.

Yield results obtained from the barley test indicate a more favourable response to the herbicides which were applied. No significant differences in yield were observed with the exception of the weedy check (Table 2, Appendix 2).

The difference in crop response between the wheat and barley crops was likely due to either the difference in the stage of plant growth, or to inherent differences in resistance between barley and wheat.

Table 1. The effect of various herbicides on weed control and wheat yields, 1965.

Treatment Herbicide*	Rate oz./ac.	Weed Injury 0-10**	Wheat Yields bu./ac.	Duncan's Multiple Range Test***
Bromoxynil	8	9.5	46.0	a b
Bromoxynil + 2,4-D ester	4+4	7.7	42.7	b c
Bromoxynil + 2,4-D ester	8+8	9.5	37.4	d
K salt of bromoxynil	4	2.7	45.8	a b c
K salt of bromoxynil	8	7.0	48.4	a
Na salt of ioxynil	8	3.5	47.4	a b
Na salt of ioxynil+2,4-D ester	4+4	7.2	43.7	a b c
Na salt of ioxynil+2,4-D amine	4+4	5.2	40.5	c
Ioxynil amine	4	3.5	46.3	a b
Ioxynil amine	8	6.2	46.2	a b
Ioxynil amine + 2,4-D	4+4	4.7	46.4	a b
Dicamba + 2,4-D amine	$1\frac{1}{2}+4\frac{1}{2}$	8.7	42.9	b c
Dicamba + 2,4-D amine	2+6	9.5	42.7	b c
Check (weedy)	0	0.0	42.7	b c
Check (hand weeded)	0	10.0	45.9	a b

* Bromoxynil and ioxynil formulations supplied by Amchem Products, Incorporated.
** 0=no injury, 10=complete kill.
*** Means followed by the same letter are not significantly different at the 5% level of probability.

Table 2. The effects of various herbicides on weed control and barley yields, 1965.

Treatment: Herbicide*	Rate oz./ac.	Weed Injury 0-10**	Wheat Yields bu./ac.	Duncan's Multiple Range Test***
Bromoxynil	8	10.0	55.6	a
Bromoxynil + 2,4-D ester	4+4	8.5	53.6	a b
Bromoxynil + 2,4-D ester	8+8	9.5	55.4	a b
K salt of bromoxynil	4	5.0	56.7	a
K salt of bromoxynil	8	7.2	50.1	a b
Na salt of ioxynil	8	5.0	60.9	a
Na salt of ioxynil+2,4-D ester	4+4	7.2	59.2	a
Na salt of ioxynil+2,4-D amine	4+4	5.0	61.9	a
Ioxynil amine	4	3.7	57.4	a
Ioxynil amine	8	6.7	58.3	a
Ioxynil amine + 2,4-D	4+4	5.0	54.7	a b
Dicamba + 2,4-D amine	$1\frac{1}{2}+4\frac{1}{2}$	9.2	51.0	a b
Dicamba + 2,4-D amine	2+6	9.5	56.4	a
Check (weedy)	0	0.0	43.3	b
Check (hand weeded)	0	10.0	62.4	a

* Bromoxynil and ioxynil formulations supplied by Amchem Products, Incorporated.
** 0=no injury, 10=complete kill.
*** Means followed by the same letter are not significantly different at the 5% level of probability.

In 1966, bromoxynil, bromoxynil-MCPA mixtures and various other herbicides were applied on flax, heavily infested with smartweeds, at two stages of crop growth to compare crop response and weed control resulting from the application of these herbicides. Weed control ratings in the flax test show that applications of bromoxynil at rates of 8 and 12 ounces per acre, Banvel 3 at 8 ounces per acre and picloram plus MCPA at $\frac{1}{2}$+7$\frac{1}{2}$ ounces per acre all resulted in satisfactory weed control (Table 3). Bromoxynil and bromoxynil-MCPA applied at rates of 6 ounces and 4+4 ounces per acre respectively were not as effective as anticipated. This may have been due to the very heavy infestation of smartweeds, with the larger plants forming a partial canopy over the smaller plants. Since bromoxynil is a contact herbicide, good spray coverage would appear to be essential. The other herbicides used in this experiment did not give satisfactory weed control.

Crop injury in bromoxynil-treated plots was very light with rates of 12 ounces per acre causing only slight leaf tip burn (Table 3). Figure 1; A, B and C show plants taken from plots which had received an application of bromoxynil. At the highest rate, plant height has been reduced somewhat and it was noted that the diameter of the plant stems tended to be slightly less when compared with check plants. No delay in the time of flowering was noted in any of these plots.

Some injury was observed on those plots on which bromoxynil-MCPA mixtures were applied. This injury was in the form of slight delay in plant growth and slight "kinking" of the stems. Figure 1; D and Figure 2; A and B show plants taken from these plots. At the higher rates, the plants were observed to be somewhat shorter. At the highest rate the stems were thinner than those of the check plot. Some delay in flowering was noted on all plots which were sprayed with bromoxynil-MCPA mixtures.

Figure 2; C and D and Figure 3; A, B and C show crop damage which resulted from the application of Banvel 3; picloram plus MCPA; 2,4-D ester; MCPA amine and Estaprop at rates of 8 ounces, $\frac{1}{2}$+7$\frac{1}{2}$ ounces, 8 ounces, 10 ounces and 16 ounces per acre, respectively. Crop response was similar in all cases, in that the growing point of the plants was severely damaged. As a result, apical dominance was destroyed and the plants then produced new shoots from the axillary buds below the damaged area. Although each herbicide affected the plants in a similar way, the extent of damage was quite different between treatments. Flax response to estaprop and 2,4-DP was similar; this treatment resulted in the most severe injury observed in this test. Flowering was delayed two to three weeks. The least damage to the crop and least delay in flowering was observed on flax which was sprayed with 10 ounces of MCPA amine. When this herbicide was applied at the first stage of crop growth, flowering was delayed only two to three days. Applications made on the second stage of crop growth resulted in a delay of from 6 to 7 days. The extent of crop damage which resulted from the application of the other herbicides ranged from the slight amount caused by MCPA amine and the severe damage caused by 2,4-DP.

Severe damage to flax was observed from the application of Banvel 3 and picloram plus MCPA. However by harvest time, these plots had recovered sufficiently so that yields of flax obtained from these plots were not significantly lower than the yields obtained from plots which had been treated with bromoxynil and bromoxynil plus MCPA (which showed little or no injury) (Table 4).

The plots which received the other herbicidal treatments did not recover to the same extent, consequently the yields obtained from these plots were all significantly lower. Although crop yield was not significantly different between growth stages, yields tended to be lower when herbicides were applied at the later stage (Appendix 3).

The yields obtained from the hand weeded checks were quite high. This may have been due to the increased soil aeration brought about by the removal of the dense infestation of weeds. The harmful effects of weed competition on flax is clearly illustrated in Figure 3; D.

The results in these experiments indicate that wheat, barley and flax are quite tolerant to applications of bromoxynil and bromoxynil plus MCPA. These herbicides have quite a wide margin of crop safety over and above the rates required for adequate weed control. Although flax recovered fairly well from the damage which resulted from applications of Banvel 3 and picloram plus MCPA, these herbicides have such a small margin of crop safety that a great deal of care must be used when applying them.

Table 3. The effect of various herbicides applied at two stages of crop growth on weed control and crop injury on flax, 1966.

Treatment Herbicide*	Rate oz./ac.	Weed Injury Stage 1 0-10**	Weed Injury Stage 2 0-10**	Crop Injury Stage 1 0-10**	Crop Injury Stage 2 0-10**
Bromoxynil	6	7.3	6.0	0.0	0.0
Bromoxynil	8	7.9	8.3	0.0	0.0
Bromoxynil	12	8.4	8.3	.5	.5
Bromoxynil + MCPA	4+4	6.6	7.4	0.0	0.0
Bromoxynil + MCPA	6+6	7.8	7.5	1.5	1.5
Bromoxynil + MCPA	8+8	8.3	7.9	2.0	2.0
Banvel 3***	8	9.9	10.0	4.3	4.0
Picloram + MCPA	$\frac{1}{2}+7\frac{1}{2}$	9.0	10.0	2.0	3.5
Estaprop****	16	6.0	6.6	5.3	6.8
2,4-DP	16	5.6	5.5	5.0	7.0
2,4-D ester	8	5.9	6.0	3.8	4.0
MCPA amine	10	5.6	6.9	2.0	2.0
Check (weedy)	0	0.0	0.0	0.0	0.0
Check (hand weeded)	0	10.0	10.0	0.0	0.0
Average		7.0	7.4	1.8	2.2

* Herbicides containing bromoxynil supplied by May & Baker (Canada) Limited.

** 0=no injury, 10=complete kill.

*** Banvel 3 - a commercially prepared mixture of dicamba + 2,4-D + MCPP.

**** Estaprop - a commercially prepared mixture of 2,4-D + 2,4-DP.

Table 4. The effect of various herbicides applied at two stages of crop growth on flax yield, 1966.

Treatment Herbicide*	Rate oz./ac.	Crop Yield Stage 1 bu./ac.	Crop Yield Stage 2 bu./ac.	Average bu./ac.	Duncan's Multiple Range Test**
Bromoxynil	6	37.7	33.8	35.8	b
Bromoxynil	8	36.5	35.3	35.9	b
Bromoxynil	12	37.0	35.3	36.1	a b
Bromoxynil + MCPA	4+4	34.0	31.6	32.8	b c
Bromoxynil + MCPA	6+6	34.5	32.7	33.6	b c
Bromoxynil + MCPA	8+8	34.7	31.1	32.9	b c
Banvel 3***	8	34.4	30.1	32.2	b c
Picloram + MCPA	½+7½	35.7	35.7	35.7	b
Estaprop****	16	24.7	22.3	23.5	d e
2,4-DP	16	19.9	16.1	18.0	f
2,4-D ester	8	29.2	26.8	28.0	c d
MCPA amine	10	26.8	29.3	28.0	c d
Check (weedy)	0	19.7	21.2	21.5	e
Check (hand weeded)	0	42.1	42.0	42.0	a
Average		31.9	30.4		

* Herbicides containing bromoxynil supplied by May & Baker (Canada) Limited.

** Means followed by the same letter are not significantly different at the 5% level of probability.

*** Banvel 3 - a commercially prepared mixture of dicamba + 2,4-D + MCPP.

**** Estaprop - a commercially prepared mixture of 2,4-D + 2,4-DP.

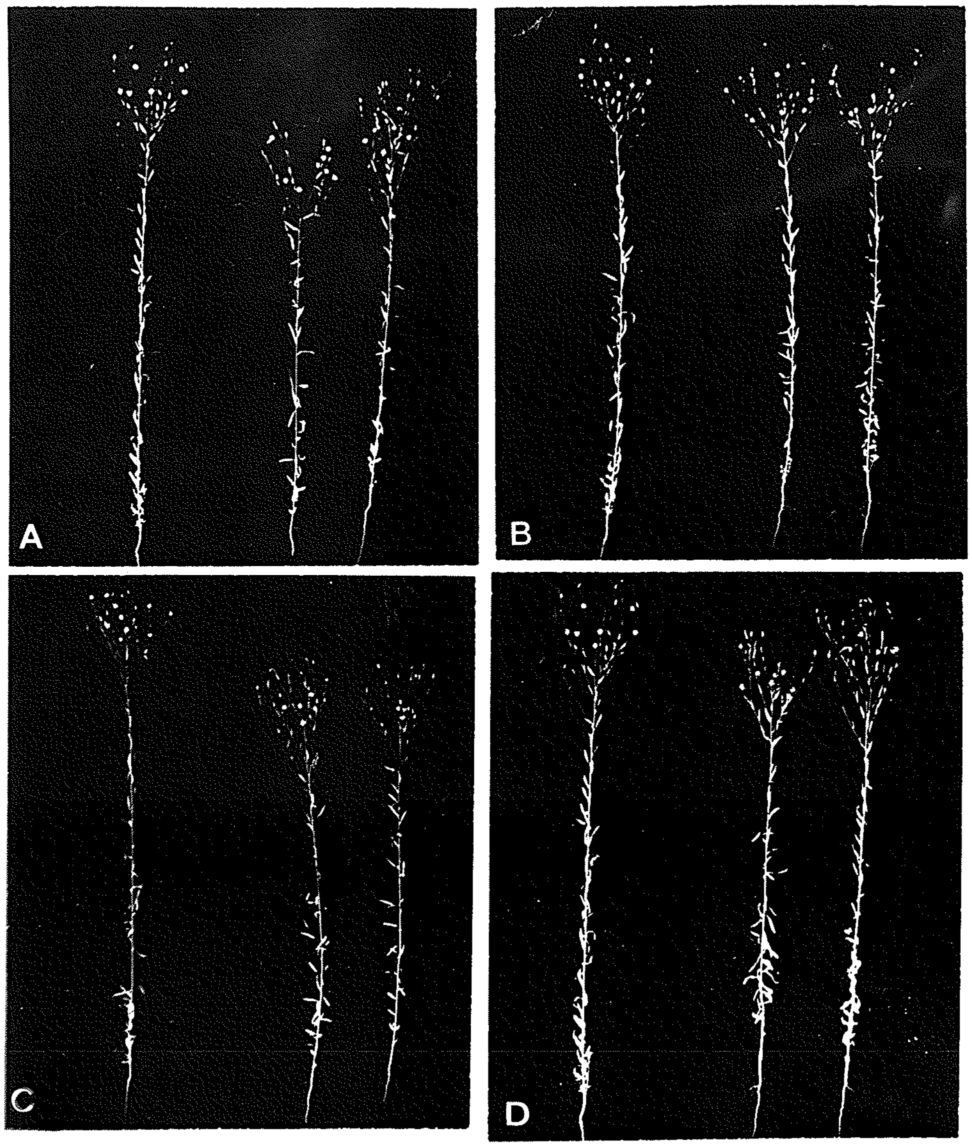

Figure 1. The effect of various herbicides on flax plants. Check plant at left.

A. Bromoxynil at 6 ounces per acre.

B. Bromoxynil at 8 ounces per acre.

C. Bromoxynil at 12 ounces per acre.

D. Bromoxynil-MCPA mixture at 4+4 ounces per acre.

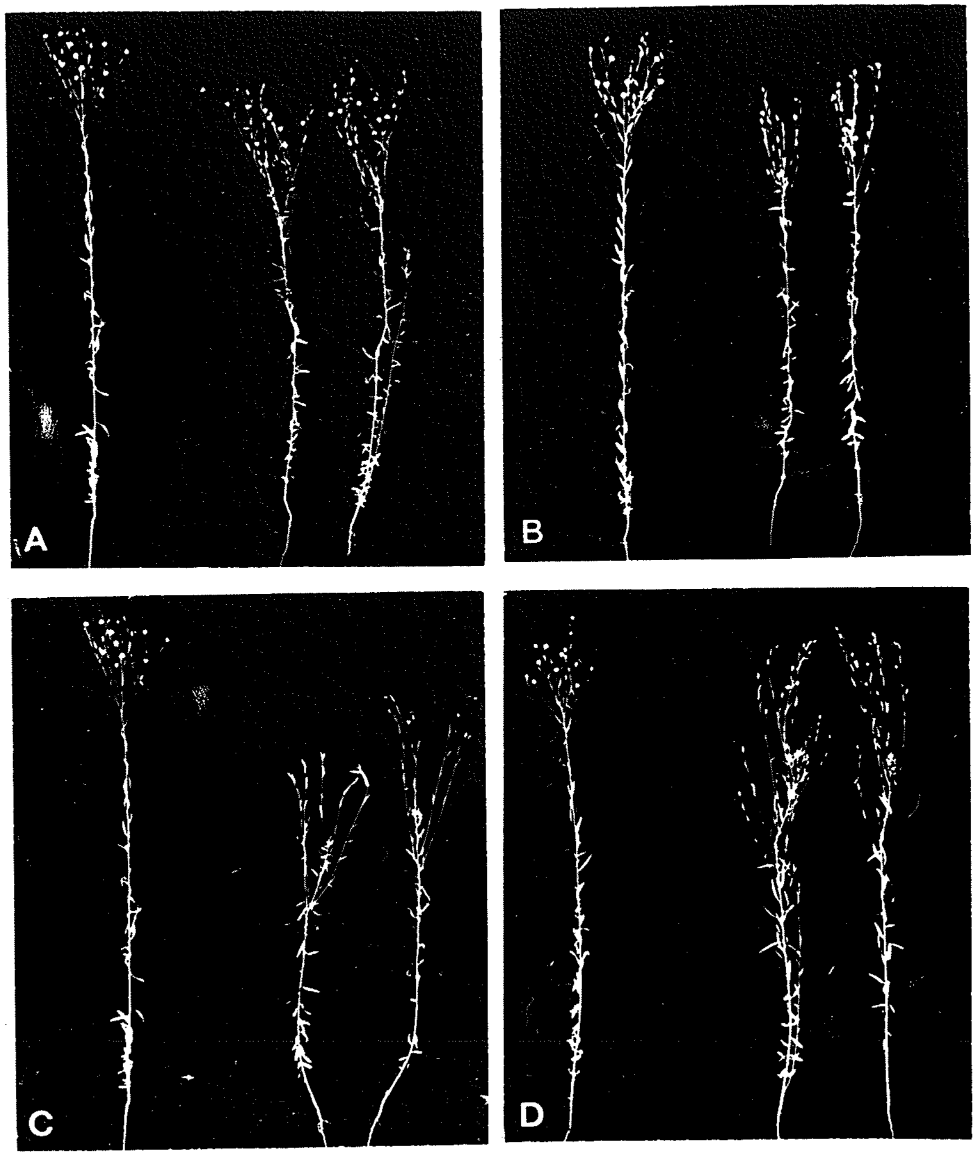

Figure 2. The effect of various herbicides on flax plants. Check plant at left.

A. Bromoxynil-MCPA mixture at 6+6 ounces per acre.

B. Bromoxynil-MCPA mixture at 8+8 ounces per acre.

C. Banvel 3 (dicamba + 2,4-D + MCPP) at 8 ounces per acre.

D. Picloram + MCPA at 8 ounces per acre.

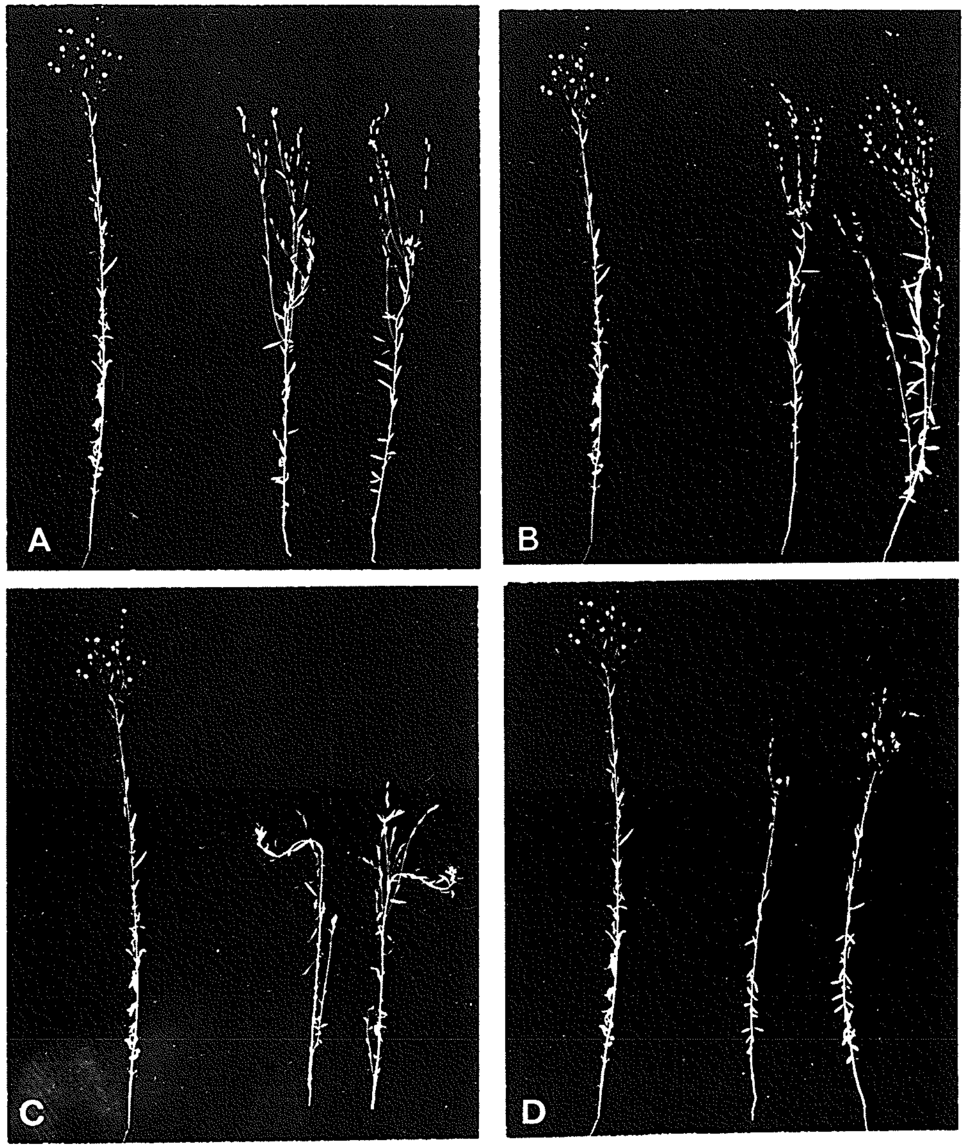

Figure 3. The effect of various herbicides on flax plants. Check plant at left.

A. 2,4-D ester at 8 ounces per acre.

B. MCPA amine at 10 ounces per acre.

C. Estaprop (2,4-D + 2,4-DP) at 16 ounces per acre.

D. Effect of weed competition.

(b) The efficiency of bromoxynil alone and in combination with various phenoxyacetic herbicides on oats, barley, wheat and flax.

In 1965, this project was carried out on oats and barley which contained a light infestation of wild buckwheat and wild mustard. Good control of these weeds was obtained as a result of treatment with bromoxynil at 4, 6 and 8 ounce per acre and bromoxynil-MCPA mixtures at 4+4 and 6+6 ounces per acre (Tables 5 and 6). Applications of bromoxynil plus MCPA, and 2,4-D ester at rates of 3+3 and 6 ounces per acre respectively resulted in somewhat less control.

Statistical analysis of yield data obtained from these plots did not show any significant differences in crop response to the treatments (Appendices 4 and 5). However the yield of oats appeared to be lower as a result of the application of 2,4-D ester.

In 1966 experiments were designed to study what effect different formulations of MCPA in mixture with bromoxynil might have on crop and weed response.

The plots were moderately to heavily infested with smartweeds and wild buckwheat. Results (Table 7) indicate satisfactory weed control with all herbicidal treatments except the bromoxynil plus iso-octyl ester of MCPA mixtures, at rates of 4+4 and 6+6 ounces per acre, and bromoxynil plus sodium salt of MCPA at 4+4 ounces per acre.

Crop injury was slight, but some delay in flowering was noted particularly in those plots receiving 2,4-D treatments.

Crop injury which resulted from the application of a mixture of 2,4-D and bromoxynil did not significantly reduce the yield of flax when compared to all other treatments (Table 7). Only the yield from the weedy check was significantly lower (Appendix 6).

Heavy rains delayed the application of herbicides on wheat in 1966. Consequently, by the time the plots could be sprayed the smartweeds, buckwheat, lamb's-quarters (*Chenopodium album* L.) and red-root pigweed (*Amaranthus retroflexus* L.) plants found in these plots were somewhat resistant to the herbicides due to their advanced stage of growth. As a result, weed control was somewhat less than expected (Table 8).

It is interesting to note that no crop injury was observed and that crop yields were not lowered significantly by any of these herbicidal treatments as a result of their application on the crop when it was in this late stage of development, the shot blade stage (Appendix 7).

These results indicate that crop response was not affected by the use of the different MCPA formulations which were tested in this project. However, weed response appeared somewhat dependent on the formulation of MCPA used.

Table 5. The effect of bromoxynil and bromoxynil-MCPA mixtures on weed control and on oat yields, 1965.

Treatment Herbicide*	Rate oz./ac.	Weed Injury 0-10**	Oat Yields bu./ac.
Bromoxynil + MCPA	3+3	6.0	87.6
Bromoxynil + MCPA	4+4	7.3	80.3
Bromoxynil + MCPA	6+6	8.6	82.5
Bromoxynil	4	8.0	83.9
Bromoxynil	6	9.3	84.7
Bromoxynil	8	9.0	87.5
2,4-D ester	6	5.0	70.2
Check (weedy)	0	0.0	88.2

* Bromoxynil and bromoxynil plus MCPA formulations supplied by May & Baker (Canada) Limited.

** 0=no injury, 10=complete kill.

Table 6. The effect of bromoxynil and bromoxynil-MCPA mixtures on weed control and on barley yields, 1965.

Treatment Herbicide*	Rate oz./ac.	Weed Injury 0-10**	Barley Yields bu./ac.
Bromoxynil + MCPA	3+3	5.0	47.9
Bromoxynil + MCPA	4+4	7.3	42.5
Bromoxynil + MCPA	6+6	9.3	45.9
Bromoxynil	4	7.5	54.7
Bromoxynil	6	9.3	46.2
Bromoxynil	8	9.3	51.8
2,4-D ester	6	5.3	57.1
Check (weedy)	0	0.0	53.5

* Bromoxynil and bromoxynil plus MCPA formulations supplied by May & Baker (Canada) Limited.

** 0=no injury, 10=complete kill.

Table 7. A comparison of the effect of different MCPA formulations in mixture with bromoxynil on weed injury, crop injury and crop yield on flax, 1966.

Treatment						
MCPA formulation	MCPA Rate oz/ac	Bromoxynil Rate oz/ac	Weed Injury 0-10**	Crop Injury 0-10**	Flax Yield bu/ac	Duncan's Multiple Range Test***
Mixed butyl ester*	4	4	8.0	0.8	23.1	a
Mixed butyl ester*	6	6	8.5	1.0	24.7	a
Butoxy ethanol ester*	4	4	7.4	0.8	25.8	a
Butoxy ethanol ester*	6	6	8.0	0.9	26.0	a
Iso-octyl ester*	4	4	5.8	1.3	20.1	a
Iso-octyl ester*	6	6	6.4	1.7	20.4	a
Sodium salt	4	4	5.4	0.8	21.0	a
Sodium salt	6	6	8.2	2.2	24.5	a
Amine salt	4	4	7.2	0.9	22.1	a
Amine salt	6	6	8.3	1.2	25.2	a
2,4-D ester	4	4	8.8	3.3	22.1	a
2,4-D ester	6	6	8.9	4.5	20.0	a
'Buctril' M****	4	4	7.3	0.8	24.0	a
'Buctril' M****	6	6	7.9	1.0	22.1	a
Check (weedy)	0	0	0.0	0.0	11.6	b
Check (hand weeded)	0	0	10.0	0.0	26.3	a

* Herbicidal mixtures supplied by Allied Chemical Services Limited.

** 0=no injury, 10=complete kill.

*** Means followed by the same letter are not significantly different at the 5% level of probability.

**** 'Buctril' M - a mixture of bromoxynil and iso-octyl ester of MCPA formulated by May & Baker Limited.

Table 8. A comparison of the effect of different MCPA formulations in mixture with bromoxynil on weed injury and crop yield on wheat, 1966.

Treatment				
MCPA formulation	MCPA Rate oz./ac.	Bromoxynil Rate oz./ac.	Weed Injury 0-10**	Wheat Yield bu./ac.
Mixed butyl ester*	4	4	6.8	28.1
Mixed butyl ester*	6	6	6.8	26.8
Butoxy ethanol ester*	4	4	7.4	27.2
Butoxy ethanol ester*	6	6	6.7	27.4
Iso-octyl ester*	4	4	6.3	24.3
Iso-octyl ester*	6	6	7.4	27.2
'Buctril' M***	4	4	6.5	28.8
'Buctril' M***	6	6	8.2	25.8
Check (weedy)	0	0	0.0	24.3
Check (hand weeded)	0	0	10.0	27.5

* Herbicidal mixtures supplied by Allied Chemical Services Limited.

** 0=no injury, 10=complete kill.

*** 'Buctril' M - a mixture of bromoxynil and ico-octyl ester of MCPA formulated by May & Baker Limited.

(c) The effect of bromoxynil and bromoxynil-MCPA mixtures applied at various stages of crop growth.

This project was designed to study crop response to herbicide applications made at different stages of crop development.

In 1965 results indicate effective weed control in wheat resulted from applications of bromoxynil at rates of 6 and 8 ounces per acre, and bromoxynil plus MCPA at rates of 4+4 and 6+6 ounces per acre (Table 9). The lower rates of these herbicides did not perform as effectively. 2,4-D ester applied at a rate of 6 ounces per acre resulted in unsatisfactory weed control.

The infestation of weeds in the plots was relatively light, hence competition was not an important factor in the experiment. Yields of wheat obtained from the various treatments did not differ significantly (Table 10, Appendix 8).

In 1966 a test was conducted to study the response of wheat to herbicides applied at very early or very late stages of crop development.

Results indicate quite poor weed control after the first date of spraying (Table 11). This was due to the fact that weeds found in these plots when they were assessed visually had germinated and grown after the herbicides had been applied. Weeds which had been present at the time of spraying were completely controlled. Poor control was observed on the last two spraying dates as a result of increased resistance in the weed species due to age.

Plots were moderately infested with smartweeds, buckwheat, lamb's-quarters and red root pigweed. Moisture was more than adequate throughout the growing season, therefore competition did not appear to be an important factor. Some leaf scorch was observed on those plots which received the higher rates of herbicides, however this did not appear to have any detrimental effect on plant growth as no significant yield differences were observed (Table 12, Appendix 9).

Table 9. The effect of bromoxynil and bromoxynil-MCPA mixtures on weed control in wheat, when applied at 2 stages of crop growth, 1965.

Treatment: Herbicide*	Treatment: Rate oz./ac.	Weed Injury: Stage 1 0-10**	Weed Injury: Stage 2 0-10**	Weed Injury: Average
Bromoxynil + MCPA	3+3	4.0	7.6	5.8
Bromoxynil + MCPA	4+4	7.6	8.3	7.9
Bromoxynil + MCPA	6+6	9.0	9.3	9.1
Bromoxynil	4	7.3	6.6	6.9
Bromoxynil	6	9.6	9.6	9.6
Bromoxynil	8	9.6	9.6	9.6
2,4-D ester	6	3.0	3.0	3.0
Check (weedy)	0	0	0	0
Average		6.2	6.6	

* Herbicides containing bromoxynil supplied by May & Baker (Canada) Limited.

** 0=no injury, 10=complete kill.

Table 10. The effect of bromoxynil and bromoxynil-MCPA mixtures on wheat yield, when applied at 2 stages of crop growth.

Treatment		Wheat Yields		
Herbicide*	Rate oz./ac.	Stage 1 bu./ac.	Stage 2 bu./ac.	Average
Bromoxynil + MCPA	3+3	39.0	40.0	39.5
Bromoxynil + MCPA	4+4	38.3	36.6	37.5
Bromoxynil + MCPA	6+6	35.7	37.9	36.8
Bromoxynil	4	37.9	40.2	39.1
Bromoxynil	6	37.2	36.0	36.6
Bromoxynil	8	43.0	36.6	39.8
2,4-D ester	6	36.6	32.2	34.4
Check (weedy)	0	37.4	37.3	37.3
Average		38.2	37.1	

* Herbicides containing bromoxynil supplied by May & Baker (Canada) Limited.

Table 11. The effect of bromoxynil and bromoxynil-MCPA mixtures on weed control when applied at various stages of crop growth on wheat, 1966.

Weed Control*

	Herbicide Treatment**				
	Bromoxynil		Bromoxynil + MCPA		
Stage of Growth	6 oz/ac	12 oz/ac	4+4 oz/ac	8+8 oz/ac	Average
1-2 leaf	5.7	4.2	6.3	5.7	5.5
2-3 leaf	9.7	9.8	9.8	10.0	9.8
Shot-blade	7.0	7.7	7.2	7.2	7.2
Heading	5.0	7.2	6.0	6.7	6.1
Check (weedy)	0.0	0.0	0.0	0.0	0.0
Check (weed free)	10.0	10.0	10.0	10.0	10.0
Average	6.2	6.5	6.5	6.6	

* 0=no injury, 10=complete kill.
** Herbicides supplied by Allied Chemical Services Limited.

Table 12. The effect of bromoxynil and bromoxynil-MCPA mixtures on the yield of wheat when applied at various stages of crop growth, 1966.

Wheat Yield*

	Herbicide Treatment**				
	Bromoxynil		Bromoxynil + MCPA		
Stage of Growth	6 oz/ac	12 oz/ac	4+4 oz/ac	8+8 oz/ac	Average
1-2 leaf	24.5	26.1	26.3	24.8	25.4
2-3 leaf	24.2	25.7	25.9	23.1	24.7
Shot-blade	27.3	22.5	22.5	23.4	23.9
Heading	27.0	24.2	26.2	22.3	24.9
Check (weedy)	19.7	21.2	23.4	27.3	22.9
Check (weed free)	23.9	20.5	25.9	27.8	24.5
Average	24.5	23.3	25.0	24.8	

* Bushels per acre.
** Herbicides supplied by Allied Chemical Services Limited.

The response of flax to applications of bromoxynil and bromoxynil-MCPA mixtures applied at various stages of crop growth was investigated in 1966. Weed seeds which had been broadcast the previous fall were already germinating when flax was seeded. As a result, a large percentage of these weeds emerged 5 to 6 days earlier than the flax. Therefore, when the flax plants had reached the five inch stage of growth, many of the smartweeds were in the 4-5 leaf stage. Results shown in Table 13 show that weed control was not as effective from this stage on. Smartweeds appear to become quite resistant to applications of bromoxynil after the 4-5 leaf stage of plant development. Unsatisfactory weed control was also observed after the second spraying date. This appears to have been due to cool dry conditions which prevailed at this time.

Yield results from these plots appear to show quite a variation in crop response to herbicides applied at various stages (Table 14, Appendix 10). However, when the average weed control is compared to the average yield at each date of spraying, a very definite positive correlation is show to exist (Figure 1). This suggests that significant yield differences are primarily due to the competitive effects of the weeds rather than differences in crop response at different stages of growth.

Results obtained from this project indicate that wheat and flax are quite tolerant to bromoxynil and bromoxynil-MCPA mixtures applied over a wide range of growth stages. These results also indicate the importance of applying the herbicides before the weeds have become resistant to the herbicides.

Table 13. The effect of bromoxynil and a bromoxynil-MCPA mixture on weed control when applied at various stages of growth on flax, 1966.

		Weed Injury*			
		Herbicidal Treatments**			
		Bromoxynil		Bromoxynil + MCPA	
Growth Stage of Flax	Time (Days post emergence)	4 oz/ac	8 oz/ac	4+4 oz/ac	Average
3/4 in.	9	9.4	9.8	8.4	9.2
1½ in.	15	3.0	8.0	7.0	6.0
4 in.	20	7.3	8.4	8.1	7.9
5 in.	24	7.0	6.8	5.8	6.5
7 in.	28	6.5	7.3	5.8	6.5
10 in.	32	6.8	7.8	6.4	7.0
Early flowering	37	3.0	3.0	3.0	3.0
Flowering	44	1.0	1.0	1.0	1.0
Check (weedy)		0	0	0	0
Check (hand weeded)		10.0	10.0	10.0	10.0
Average		5.4	6.2	5.5	

* 0=no injury, 10=complete kill.
** Herbicides supplied by May & Baker (Canada) Limited.

Table 14. The effect of bromoxynil and a bromoxynil-MCPA mixture on crop yield when applied at various stages of growth on flax, 1966.

Crop Yield*

Growth Stage of Flax	Time (Days post emergence)	Herbicidal Treatments** Bromoxynil 4 oz/ac	Bromoxynil 8 oz/ac	Bromoxynil + MCPA 4+4 oz/ac	Average	Duncan's Multiple Range Test***
3/4 in.	9	38.2	36.9	33.9	36.3	a b
$1\frac{1}{2}$ in.	15	21.8	31.6	29.9	27.7	c
4 in.	20	32.2	34.5	33.0	33.2	b c
5 in.	24	31.4	30.5	22.2	28.0	c
7 in.	28	32.9	27.6	22.1	27.5	c d
12 in.	32	31.8	23.5	28.7	28.1	c
Early flowering	37	30.4	26.0	22.6	26.3	c d e
Flowering	44	21.5	26.3	15.9	21.2	d e
Check (weedy)		17.9	20.6	22.3	20.2	e
Check (hand weeded)		41.6	39.7	42.2	41.1	a
Average		29.9	29.7	27.3		

* Bushels per acre.
** Herbicides supplied by May & Baker (Canada) Limited.
*** Means followed by the same letter are not significantly different at the 5% level of probability.

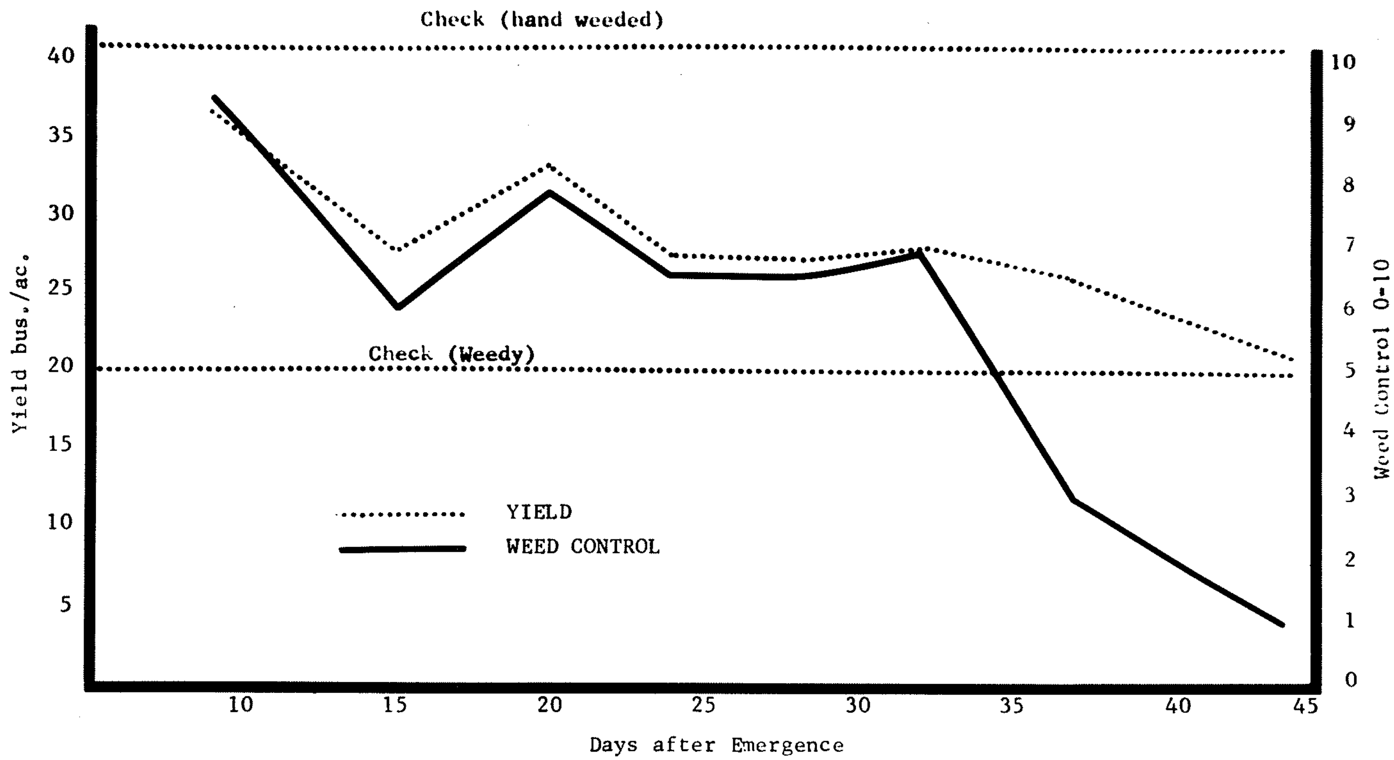

Figure 4. A comparison of the average weed control and average flax yield following applications of bromoxynil and bromoxynil-MCPA mixtures applied at various stages of crop growth.

(d) The effect of spray volume on the efficacy of bromoxynil alone and in mixture with MCPA.

The plots in this experiment were densely infested with smartweeds which were in the 5-6 leaf stage when the various rates of herbicides and diluents were applied.

Weed control in general was not as effective as would be expected under normal conditions (Table 15). Due to their advanced stage of development, the smartweed plants were becoming somewhat resistant to the herbicides which were applied. However, under even these adverse conditions a definite trend was observed; as the amount of diluent increased the efficiency of the herbicide increased. This was probably due to the more effective coverage of the plants as a result of the increased volume of diluent used.

Crop yields also increased as the volume of diluent increased (Table 16). Figure 2 shows a comparison of average weed control and average flax yield. It appears that increased yields were due to a reduction in competition of weeds which resulted from more efficient weed control when herbicides were applied in larger volumes of diluent. The only treatments which resulted in significantly lower yields were the weedy check and the 2 gallons per acre rate of diluent. No significant differences in yield were observed between the different rates of herbicides applied (Appendix 11).

The results indicate that under conditions such as encountered in this test, with the dense weed infestation and advanced stage of weed growth, it would be advantageous to increase the volume of diluent.

Table 15. The effect of diluent on efficiency of bromoxynil and bromoxynil-MCPA mixtures on weed control in flax, 1966.

Weed Control*

Volume of Diluent (Total solution) gal/ac	Bromoxynil** Rate 6 oz/ac	Bromoxynil** Rate 9 oz/ac	Bromoxynil + MCPA** Rate 4+4 oz/ac	Bromoxynil + MCPA** Rate 6+6 oz/ac	Average
2.0	5.6	4.3	5.3	6.1	5.3
3.7	5.1	5.8	5.0	5.9	5.5
5.5	6.4	7.5	5.5	7.4	6.7
9.0	6.5	7.9	7.1	7.8	7.3
14.0	7.9	8.5	7.4	6.8	7.7
22.0	8.6	9.1	6.4	9.1	8.3
Check (weedy)	0	0	0	0	0
Average	6.6	7.1	6.1	7.1	

* 0=no injury, 10=complete kill.
** Herbicides supplied by May & Baker (Canada) Limited.

Table 16. The effect of diluent on efficiency of bromoxynil and bromoxynil-MCPA mixtures on flax yield, 1966.

Flax Yield*

Volume of Diluent (Total solution) gal/ac	Bromoxynil** Rate 6 oz/ac	Bromoxynil** Rate 9 oz/ac	Bromoxynil + MCPA** Rate 4+4 oz/ac	Bromoxynil + MCPA** Rate 6+6 oz/ac	Average	Duncan's Multiple Range Test***
2.0	26.7	22.3	25.7	23.9	24.6	b
3.7	25.6	32.4	26.6	26.0	27.3	a b
5.5	28.7	34.4	22.3	33.1	29.5	a b
9.0	29.3	33.8	29.2	31.4	31.0	a
14.0	32.8	34.6	32.2	29.4	32.3	a
22.0	31.9	36.9	26.0	32.0	31.7	a
Check (weedy)	10.6	16.3	5.8	18.8	12.8	c
Average	26.5	30.0	23.8	27.8		

* Bushels per acre.
** Herbicides supplied by May & Baker (Canada) Limited.
*** Means followed by the same letter are not significantly different at the 5% level of probability.

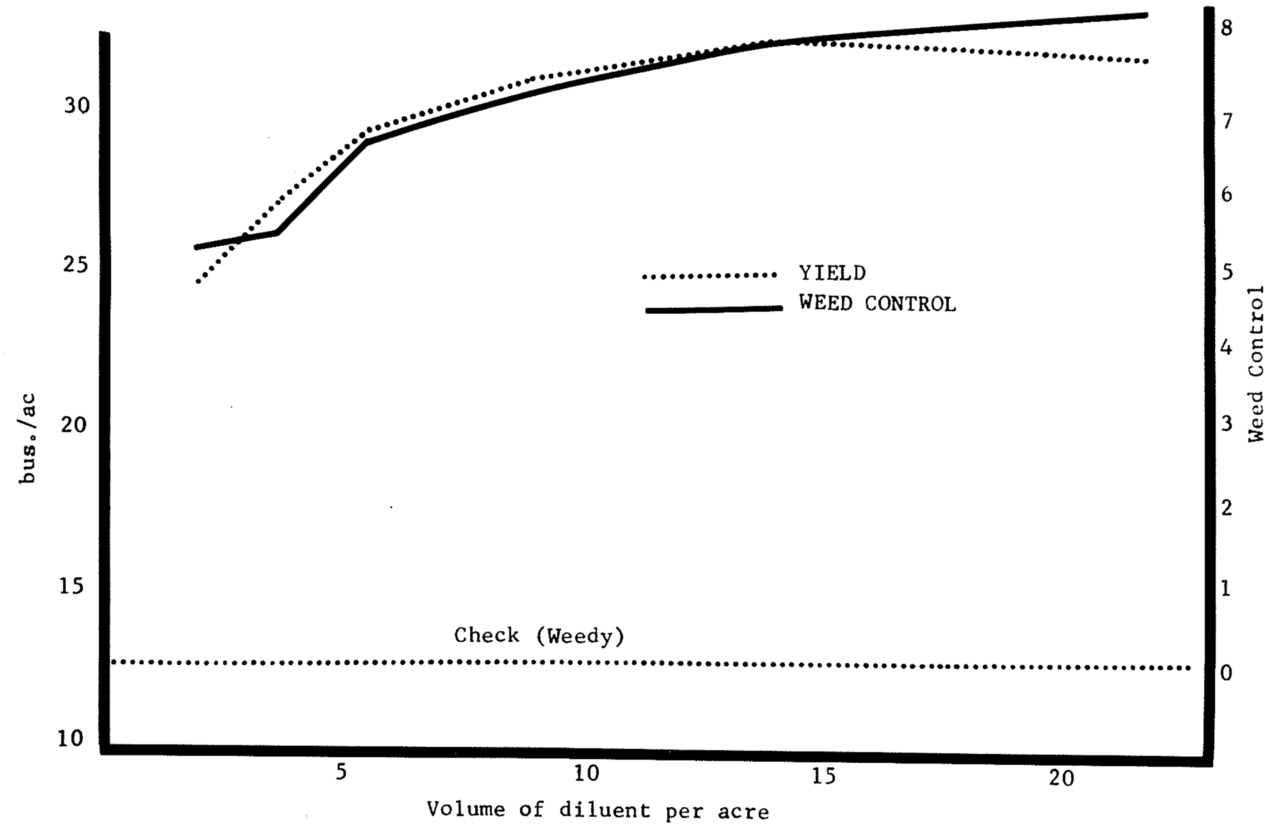

Figure 5. A comparison of the average weed control and average flax yield, following applications of bromoxynil and bromoxynil-MCPA mixtures applied in various volumes of diluent.

(e) The effect of bromoxynil and bromoxynil-MCPA mixtures on seed quality of wheat and flax.

Standard baking and milling tests were carried out on samples of wheat harvested from plots which had been treated with herbicides containing bromoxynil and samples taken from untreated checks. The results of these tests are summarized in Table 17. There appears to be no indication that the herbicide treatments had any adverse effect on either milling or baking quality.

Oil content values for flax seed show slight variations in the oil content of seed samples taken from plots which were treated with herbicides on different dates (Table 18). Statistical analysis shows only the oil content of the weedy check to be significantly lower (Appendix 12).

The iodine values presented in Table 19 are a measure of the degree of unsaturation of double bonds in the long chain fatty acids found in the oil of flaxseed. A high number of unsaturated double bonds indicates a rapidly drying oil. Consequently a high iodine number means high quality.

Results appear to indicate that iodine number of flax seed oil was not affected by herbicide treatments. Only the iodine value of the weedy check was significantly lower (Appendix 13).

The results of these experiments indicate that applications of bromoxynil and bromoxynil plus MCPA applied at recommended rates do not appear to have any significant effect on crop quality.

Table 17. The effect of bromoxynil and bromoxynil-MCPA mixtures on milling and baking quality of wheat.

	Bromoxynil* Rate 6 oz./ac.	Bromoxynil + MCPA* Rate 4+4 oz./ac.	Check
Wheat			
Yield, bu./ac.	38.6	37.7	38.4
Bushel weight, lb.	62.4	62.3	62.3
1000 kernel weight, gm.	28.0	28.3	28.1
Protein, %	12.5	12.5	12.2
Flour yield, % (total)	73.1	72.5	72.8
Flour			
Protein, %	11.4	11.4	11.2
Ash, %	.46	.48	.48
Color, units	.47	.48	.50
Baking absorption, %	54.7	55.2	54.9
Bread			
Loaf volume, c.c. (remix)	782.0	762.0	753.0
Farinogram			
Adsorption	58.7	59.2	58.7
Development time, min.	3.0	2.9	2.6
Mixing tolerance index	31.0	33.0	34.0

* Herbicides supplied by May & Baker (Canada) Limited.

Table 18. The effect of bromoxynil and a bromoxynil-MCPA mixture on oil content of flax seed when applied at various stages of crop growth.

Oil Content (%)

Growth Stages of Flax	Time (Days post emergence)	Herbicidal Treatments* Bromoxynil 4 oz/ac	Bromoxynil 8 oz/ac	Bromoxynil + MCPA 4+4 oz/ac	Average	Duncan's Multiple Range Test**
3/4 in.	9	43.0	42.8	42.6	42.8	a
$1\frac{1}{2}$ in.	15	41.9	42.2	42.7	42.3	a
4 in.	20	41.9	42.2	42.7	42.3	a
5 in.	24	43.2	42.8	43.2	43.1	a
7 in.	28	42.1	42.8	41.7	42.2	a
10 in.	32	42.5	42.6	42.4	42.5	a
Early flowering	37	42.8	42.3	42.6	42.6	a
Flowering	44	42.9	42.7	41.2	42.3	a
Check (weedy)		40.4	41.2	41.3	41.0	b
Check (hand weeded)		43.0	43.0	43.1	43.0	a
Average		42.4	42.5	42.4		

* Herbicides supplied by May & Baker (Canada) Limited.
** Means followed by the same letter are not significantly different at the 5% level of probability.

Table 19. The effect of bromoxynil and a bromoxynil-MCPA mixture on the iodine number of flax seed oil, when applied at various stages of crop growth, 1966.

Iodine Number

Growth Stages of Flax	Time (Days post emergence)	Herbicidal Treatments* Bromoxynil 4 oz/ac	Bromoxynil 8 oz/ac	Bromoxynil + MCPA 4+4 oz/ac	Average	Duncan's Multiple Range Test**
3/4 in.	9	192.9	191.4	192.4	192.2	a
1½ in.	15	191.9	190.4	192.4	191.5	a
4 in.	20	190.4	192.4	191.4	191.4	a
5 in.	24	192.9	192.4	190.4	191.9	a
7 in.	28	192.4	191.9	190.9	191.7	a
10 in.	32	192.9	192.9	191.9	192.5	a
Early flowering	37	191.4	191.4	190.9	191.2	a
Flowering	44	190.4	193.4	189.4	191.1	a
Check (weedy)		181.6	185.7	186.3	184.5	b
Check (hand weeded)		193.4	193.4	193.9	193.6	a
Average		191.9	191.5	190.9		

* Herbicides supplied by May & Baker (Canada) Limited.
** Means followed by the same letter are not significantly different at the 5% level of probability.

SUMMARY AND CONCLUSIONS

Weed species resistant to the phenoxyacetic herbicides have become increasingly important in Western Canada over the past 20 years. Therefore the need for a herbicide which will effectively and safely control these species has become of prime importance. In view of this, a two year project was undertaken at the University of Manitoba to study the potential usefulness of hydroxybenzonitriles as selective herbicides for the control of some "hard-to-kill" weeds in cereal crops and flax under Manitoba conditions.

The results of this study indicated that, of the hydrobenzonitriles tested, the n-octanoyl ester of bromoxynil, commonly referred to as bromoxynil, is particularly well suited for control of many serious weed problems, notably smartweeds and wild buckwheat, in cereal crops and flax in Manitoba.

Bromoxynil appears to have a high degree of safety to cereal crops such as wheat, oats and barley. Rates of twice the amount required for adequate weed control have been applied in this study, with little or no damage being observed on crops.

Applications of bromoxynil and bromoxynil plus MCPA to flax at eight different growth stages indicated favourable crop response at all stages. Yield differences observed appear to have been due to the competitive effect of weeds present in these plots rather than an unfavourable crop response to the herbicides.

In all experiments carried out in this project the effectiveness of bromoxynil for weed control was also evaluated. Results indicate that effective control may be achieved by applications of 6 ounces per acre of bromoxynil. However it appears that some weed species, particularly the smartweeds, become increasingly resistant after the plants develop the fourth or fifth leaf. Therefore, to achieve the most effective control, the herbicide should be applied before this stage of growth is reached. In order to broaden the spectrum of weeds controlled, MCPA plus bromoxynil mixtures have also been tested. Results appear to indicate that crop response was not dependent to any measurable degree on the particular formulation of MCPA used.

Under conditions where the weed population has not been excessive or the weeds have not become somewhat resistant due to age, the application of 5 gallons total solution of diluent has appeared to give satisfactory results. However under more adverse conditions, results indicate that volumes of 15 to 20 gallons per acre may give slightly better control.

Results from quality testing of wheat and flax suggest that bromoxynil alone or in mixture with MCPA applied at the recommended rates did not have any detrimental effect on crop quality.

As a result of the above mentioned study, as well as similar experiments carried out at other research stations in Western Canada, the Research and Appraisal Committee for the National Weed Committee (Western Section) in 1966 approved the use of bromoxynil ester at rates up to 8 ounces per acre, or bromoxynil-MCPA mixtures at rates up to 8+8 ounces per acre, on wheat, oats and barley from the 2-leaf through to the early flag leaf stage. In 1967 a mixture of bromoxynil and MCPA at a rate of 4+4 ounces per acre was approved for use on flax. However as flax appears to be less tolerant than cereals, the following statement accompanied the above recommendation. Severe injury has occasionally occurred from spraying when plants are under stress, e.g. in hot, humid weather. Spraying under these conditions should be avoided.

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APPENDIX

APPENDIX 1

Analysis of variance for the effect of various herbicides on wheat yields 1965.

Source of variation	d.f.	M.S.	F.
Replicates	3	11.32	
Treatments	14	33.76	3.13*
Error	42	10.79	
Total	59		

* Significant at the 5% level of probability.

C.V. (treatments) 13.5%

APPENDIX 2

Analysis of variance for effect of various herbicides on barley yields 1965.

Source of variation	d.f.	M.S.	F.
Replicates	3	91.86	
Treatments	14	127.00	2.275*
Error	42	55.82	
Total	59		

* Significant at the 5% level of probability.

C.V. (treatments) 13.5%

APPENDIX 3

Analysis of variance for the effect of various herbicides on the yield of flax 1966.

Source of variation	d.f.	M.S.	F.
Replicates	3	151.9	
Stages	1	66.34	1.49
Error 1	3	44.38	
Treatments	13	348.20	16.9*
Stages x treatments	13	10.83	0.526
Error 2	78	20.59	
Total	111		

* Significant at the 5% level of probability.

C.V. stages 21.38%
C.V. (treatments) 14.56%

APPENDIX 4

Analysis of variance for the effect of bromoxynil and bromoxynil plus MCPA on oat yields 1965.

Source of variation	d.f.	M.S.	F.
Replicates	2	590.32	
Treatments	7	104.27	0.57
Error	14	183.25	
Total	23		

C.V. (treatments) 16.3%

APPENDIX 5

Analysis of variance for the effect of bromoxynil and bromoxynil plus MCPA on barley yields 1965.

Source of variation	d.f.	M.S.	F.
Replicates	2	529.88	
Treatments	7	76.68	1.17
Error	14	65.66	
Total	23		

C.V. (treatments) 16.2%

APPENDIX 6

Analysis of variance for comparison of the effect of different MCPA formulations in mixture with bromoxynil on flax yields 1966.

Source of variation	d.f.	M.S.	F.
Replicates	5	85.72	
Treatments	15	78.03	3.28*
Error	75	23.77	
Total	95		

* Significant at the 5% level of probability.

C.V. (treatments) 21.7%

APPENDIX 7

Analysis of variance for the comparison of the effect of different MCPA formulations in mixture with bromoxynil on wheat yields 1966.

Source of variation	d.f.	M.S.	F.
Replicates	5	149.97	
Treatments	9	13.70	0.45
Error	45	30.01	
Total	59		

C.V. (treatments) 20.5%

APPENDIX 8

Analysis of variance for the effect of bromoxynil and bromoxynil plus MCPA mixtures on wheat yield when applied at 2 stages of growth.

Source of variation	d.f.	M.S.	F.
Replicates	2	54.45	
Stages	1	13.12	4.2
Error 1	2	3.12	
Treatments	7	19.20	2.2
Stages x treatments	7	14.46	1.7
Error 2	28	8.5	
Total	47		

C.V. (stages) 4.6%
C.V. (treatments) 7.7%

APPENDIX 9

Analysis of variance for the effect of bromoxynil and mixtures containing bromoxynil plus MCPA on yield of wheat when applied at various stages of crop growth 1966.

Source of variation	d.f.	M.S.	F.
Replicates	3	86.05	
Treatments	3	13.27	0.29
Error 1	9	11.75	
Stages	5	12.32	0.29
Stages x treatments	15	23.8	0.57
Error 2	60	41.40	
Total	95		

C.V. (stages) 26.3%
C.V. (treatments) 14.0%

APPENDIX 10

Analysis of variance for the effect of bromoxynil and a mixture of bromoxynil plus MCPA on crop yield when applied at various stages of crop growth on flax 1966.

Source of variation	d.f.	M.S.	F.
Replicates	3	269.28	
Treatments	2	88.42	1.5
Error 1	6	55.94	
Stages	9	491.4	9.3*
Stages x treatments	18	59.42	1.1
Error 2	81	52.56	
Total	119		

* Significant at the 5% level of probability.

C.V. (treatments) 25.8%
C.V. (stages) 25.0%

APPENDIX 11

Analysis of variance for the effect of volume of diluent on efficiency of bromoxynil and bromoxynil plus MCPA mixtures on flax yield 1966.

Source of variation	d.f.	M.S.	F.
Replicates	3	88.37	
Treatments	3	193.18	2.7
Error 1	9	69.75	
Volumes	6	741.1	15.6*
Volumes x treatments	18	40.06	0.84
Error 2	72	47.27	
Total	111		

* Significant at the 5% level of probability.

C.V. (treatments) 30.8%
C.V. (volumes) 25.4%

APPENDIX 12

Analysis of variance for effect of bromoxynil and a mixture of bromoxynil plus MCPA on oil content of flax seed when applied at various stages of crop growth 1966.

Source of variation	d.f.	M.S.	F.
Replicates	3	1.13	
Treatments	2	0.168	0.1
Error 1	6	1.53	
Stages	9	4.31	5.2*
Stages x treatments	18	0.85	1.0
Error 2	81	0.85	
Total	119		

* Significant at the 5% level of probability.

C.V. (treatments) 2.9%
C.V. (stages) 2.1%

APPENDIX 13

Analysis of variance for effect of bromoxynil and a mixture of bromoxynil plus MCPA on iodine values of flax seed oil when applied at various stages of crop growth.

Source of variation	d.f.	M.S.	F.
Replicates	3	0.28	
Treatments	2	0.14	0.2
Error 1	6	0.56	
Stages	9	2.73	6.8*
Stages x treatments	18	0.26	0.6
Error 2	81	0.39	
Total	119		

* Significant at the 5% level of probability.

C.V. (treatments) .9%
C.V. (stages) .8%