Weed Control in *Zea mays* L.

by

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Field experiments were conducted for two years in two locations to investigate the use of atrazine, atrazine combinations, and other chemicals for weed control in forage corn.

No advantage was gained in 1968 by adding MCPA, Buctril M, or Banvel 3 to three rates of atrazine. Post-emergence atrazine alone produced forage yields which were as high as any treatment combination.

In 1969, no chemical in combination with 1 pound atrazine gave as satisfactory weed control and silage yield as did 2 pounds of atrazine alone. However, several combinations with 1 pound atrazine/acre applied pre-emergence tended to yield more corn dry matter than did the pre-emergence treatment of atrazine alone at 1 pound. Pre-emergence application of atrazine at Glenlea and post-emergence application of atrazine at Portage la Prairie resulted in the highest stover yields. Treatments not including atrazine gave poor weed control and low forage yields.

When atrazine was applied post-emergence at 1 and 2 pounds per acre, residues could be detected in the soil at the 0-2, 2-4, and 4-6 inch levels, using an oat bioassay.

Bioassay results suggested that if 1 pound of atrazine per acre was applied in a 12-inch band (36-inch row spacing), thorough mixing of the upper 2 inches of soil was sufficient to grow oats. Similar banding of 2 pounds of atrazine per acre required thorough mixing of the upper 6

inches of soil to grow oats. When an overall application of either 1 or 2 pounds atrazine per acre was made, thorough mixing of the upper 6 inches of soil was not sufficient to grow oats.

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Introduction

Grain and silage, *Zea mays* L., production in Manitoba has fluctuated greatly in the past 4 decades. From a high of 100,000 acres of grain corn in 1942, production has dropped to an average of 4,200 acres during the past 10 years. Silage corn production peaked in 1940 with 74,000 acres and has remained relatively stable during the past decade with an average of 34,300 acres.

The Manitoba Corn Committee has estimated a potential demand of 100,000 acres in 1970. According to this committee, the major limiting factor in corn production in Manitoba is inadequate weed control.

Cultivation procedures and chemicals used prior to the introduction of atrazine have given inconsistent weed control in corn.

Atrazine has given good weed control without injury to corn. Atrazine, however, under Manitoba conditions, persists in the soil, on occasion causing severe damage in susceptible crops grown the following year.

Experiments were conducted to find a chemical or chemical combination which would provide adequate weed control and eliminate the residue problem. Bioassays were conducted to determine the presence of atrazine residues in the soil.

Literature Review

Introduction

Weeds compete with corn for water, nutrients, and light. Bunting and Ludwig (1964) showed that this competition was most severe during the first 2-4 weeks after emergence of the corn. They showed that in a dry year competition for water was the most limiting factor, especially when weeds were not controlled. These results were substantiated by Staniforth (1969) who reported that green and yellow foxtail reduced yields of corn and sorghum by competing for moisture during July and August. Competition was most severe at crop densities giving optimum yields under weed-free conditions. Feltner, et al. (1969) showed that yellow foxtail competed with sorghum for soil nitrogen. The competitive influence of yellow foxtail increased with increasing rates of supplemental nitrogen.

In terms of actual yield reductions, Buchholtz and Doersch (1968) showed that weed growth reduced corn yields an average of 1.23 bushels/acre/100 pounds of dry weeds.

Efficient weed control is essential for successful corn production in Manitoba. Helgason and Clark (1968) suggest weeds can reduce yields more than any other single factor over which the farmer has control.

Cultural Control and Early Chemicals

Cultivation has long been a common means of weed control in corn, with varying degrees of success. Helgason and Clark (1968) suggest the use of a rotary hoe, spike-tooth harrow, and finger weeder until the corn is 6 inches tall, and the use of a row cultivator after this stage and until the corn reaches a height of 20 inches. Cultivation after

that time will cut off feeder roots, leading to lodging later in the season, and favoring the entrance of stalk-rotting organisms from the soil.

With the advent of 2,4-D and other chemicals, producers were encouraged by possibilities of overall weed control. Two,4-D and MCPA were extensively used in the early years of chemical control. F. W. Slife (1964) reported on the extensive use of 2,4-D in weed control in corn. Two,4-D was especially effective because corn was tolerant to this chemical in its early growth stages. Helgason and Clark (1968) stated that 2,4-D and MCPA did not control grasses. As a result, grassy weeds flourished. They recommended Banvel 3 for control of hard-to-kill broadleaf weeds and Avadex for wild oat control.

Linuron at 4 pounds/acre applied as a directed spray in a 12-inch band when the corn was 12-18 inches tall gave good weed control without injury to the corn (A. J. McNeur, 1964). Vengris (1966) indicated that linuron at 1.5 pounds/acre gave good overall post-emergence control, but damaged corn. He also stated that special equipment is necessary for post-emergence directed application to prevent corn injury.

Simazine and Atrazine as Corn Herbicides

The introduction of simazine and atrazine in the late fifties and early sixties appeared to give the farmer the answer for total weed control in corn.

Sivaji and Rao (1965) indicated that pre-emergence atrazine at 4-8 pounds/acre and simazine at 6-8 pounds/acre controlled broadleaf weeds and grasses while 2 pounds of either compound was sufficient to control the broadleaf weeds. More simazine than atrazine was required to obtain

equivalent grass control.

At lower rates, Sharma, et al. (1965) found simazine controlled annual weeds effectively. Higher rates, however, damaged corn.

Shear (1961) concluded that simazine and atrazine at similar rates gave higher corn yields than hoeing treatments. Only atrazine, however, gave season-long control of weeds.

Simazine showed good selectivity, but the results were not consistent, primarily due to its toxicity decreasing when soil moisture levels were reduced (Grover, 1966).

Staniforth and Lovely (1964) demonstrated that band applications of atrazine were equally effective to timely shallow cultivations in annual weed control. They showed that the increased yield of corn more than offset the cost of the applied atrazine. Compared to atrazine, they found the isooctyl ester of 2,4-D unsatisfactory.

Many workers (Shear, Buchholtz, Courson, Hinesly, et al.) have shown atrazine to be effective by itself, proving that corn production was possible through the use of atrazine. Weed control has varied from satisfactory to excellent, and corn yields have been high. The corn itself rarely showed phytotoxic effects. Both broadleaf and grassy weeds have been satisfactorily controlled with atrazine.

Shear (1961) applied atrazine at rates of 2-4 pounds/acre and found that treated plots remained nearly weed-free for the entire season. Stover yields were up to 32% higher on plots with no tillage.

Buchholtz (1963) found that atrazine was effective in controlling quackgrass (Agropyron repens L.), thus improving corn yields. A rate of 2 pounds/acre was generally sufficient to obtain satisfactory results.

He found the earliest treatments applied to undisturbed soil were most effective.

Courson (1965) found no differences in corn yields between control achieved by atrazine and conventional tillage. He demonstrated excellent control with 3 pounds atrazine/acre when at least 3/4-inch rain fell within 15 days after treatment.

Hinesly, et al. (1967) compared atrazine with cultivation for weed control in corn. They found atrazine effective 20 times out of 21 trials. In these cases, atrazine was at least as good or better than cultivation in control of weeds. On soils with good tilth they suggested that there was no advantage to additional cultivation while on soils that tended to crust a combination of atrazine and cultivation might prove to be effective in increasing corn yields.

Not all weed control experiments with atrazine have had positive results. Stephens (1962) found no apparent reduction in weed growth through the use of atrazine. However, a lack of sufficient soil moisture was blamed for this failure of atrazine activation.

Application Methods for Atrazine

Atrazine has given effective weed control in either pre-or post-emergence applications.

Vengris (1963) found pre-emergence atrazine at 1 pound/acre gave good weed control for 3-4 weeks after sowing. This rate was economical as subsequent weed growth didn't reduce yields. However, he also indicated that post-emergence applications were equal to pre-emergence treatments when weed seedlings were less than 1 inch tall.

Bunting and Ludwig (1964) reported that atrazine completely pre-

vented weed growth when applied before emergence of the corn. Alley and Chamberlain (1964) also showed that atrazine at 1 and 2 pounds/acre gave complete control of all weeds when applied to soil prior to emergence.

Knake, et al. (1965) reported that corn yields with row cultivation and with broadcast pre-emergence atrazine were almost identical on a wide variety of soil types over a 3-year period.

McNeur (1964) claimed that atrazine at 6-8 pounds/acre applied in 12-inch bands along the row gave good control of hard-to-kill barnyard grass (Echinochloa crusgalli (L.) Beauv.) when applied to grass 1-2 inches in height. The corn was not injured at this high rate and the residual action of the herbicide killed later emerging weeds. McNeur also stated that these rates would damage succeeding crops.

When applied post-emergence atrazine is generally combined with a non-herbicidal oil which is added to the spray mixture resulting in a more rapid weed kill (Jones and Anderson, 1964). Jones and Anderson (1964) also indicated that the oil mixtures gave better weed control at later stages of growth and with less herbicide than when water alone was used.

Atrazine Residues

Atrazine degrades slowly, allowing residues to remain in the soil for extended periods (Fink and Fletchall, Birk and Roadhouse, Peters, Frank, McGlamery and Slife).

Fink and Fletchall (1963) showed that 9 forage species were affected by residues of atrazine. Rates of 2-4 pounds/acre affected all crops whereas 1 pound did not affect tall fescue (Festuca elatior L.) and Korean lespedeza (Lespedeza stipulacea Maxim.). Of the crops tested

tall fescue was most resistant and timothy (Phleum pratense L.) most susceptible.

In later work, Fink and Fletchall (1969) reported that top growth of soybeans was not affected by 5 pounds/acre or less of atrazine, but bean yields were reduced. After 2 years of treatment with 2.5 and 5 pounds atrazine/acre, substantial reductions in yield of soybean forage occurred.

Peters (1966) reported that there was no injury to alfalfa (Medicago sativa L.) and/or oats (Avena sativa L.) where treatment was limited to 2 pounds atrazine applied pre-emergence. Where this rate was supplemented in 2 successive corn crops by use of 2 pounds before ploughing, (6 pounds in total), both oats and alfalfa were injured. The use of either 4 pounds pre-emergence or 4 pounds before ploughing gave injury to alfalfa and oats after only a single application.

Frank (1966) reported on atrazine residues and their effect on subsequent sugar beet crops. He found that damage to beets and loss of yield was correlated with the time, the rate, and the method of application, as well as the time of ploughing between the corn and sugar beet crop. Pre-emergence atrazine at 1.5 pounds caused no injury, but 2 pounds caused appreciable damage. Ploughing in autumn reduced pre-emergence damage, but did not affect post-emergence treatments. With post-emergence banding, there was damage at 2 pounds, but not at 1.5 pounds/acre. When beets were the second crop after atrazine treatment, injury was correlated with rate alone. After 2 successive years of atrazine, damage resulted even from 1.5 pounds banded. Granular formulations persisted longer than wettable powders.

Soils with high organic matter and/or high clay content tend to adsorb atrazine. McGlamery and Slife (1966) showed that adsorption of atrazine on soil increased as pH decreased, but that adsorption was affected only slightly by temperature and concentration. Desorption of atrazine was greater with increasing temperature and pH. Adsorption was reversible and desorption was nearly complete. Adsorption on the humic acid increased as temperature increased and pH decreased. They found little desorption of atrazine from the humic acid.

Birk and Roadhouse (1964) showed that at the end of the first growing season 90% of the residual atrazine was present in the 0-2 inch layer. Courson (1965) indicated that most atrazine residues were concentrated in the top 6 inches of soil in the first year and were at non-phytotoxic levels the following year. He suggested that banding the chemical as well as using proper crop rotations may give less residual damage.

Shimabukuro and Linck (1967) found that oats were especially sensitive to atrazine residue damage. This sensitivity accounts for the use of oats as a bioassay plant for atrazine residues.

Atrazine in Combination with Other Herbicides

Atrazine has frequently been combined with other chemicals in an attempt to achieve a broader spectrum of weed control at low rates of atrazine as well as to reduce residue problems.

Triplett (1966) indicated that no one chemical was satisfactory for all weeds in corn, thus making combinations necessary; the particular combination depending upon the weed growth in the crop. He combined atrazine with 2,4-D, amitrole, picloram, paraquat, dicamba, and

dalapon, thereby achieving broader control.

Colby and Harris (1966) obtained good weed control with a combination of atrazine and prometryne.

Methods and Materials

Field trials were conducted in 1968 and 1969 at the Glenlea Research Farm, Faculty of Agriculture, University of Manitoba (Glenlea) and at the Elm River Research Farm near Portage la Prairie (Portage).

The corn hybrid, Morden 67, was seeded in both locations in 1968 and at Portage in 1969. Northrup King KN2 was seeded at Glenlea in 1969. The corn was planted at an average depth of 1-2 inches and at a population of 20,000 to 24,000 plants/acre.

The chemicals applied in 1968 in both locations are listed in Table 1. All applications were post-emergence.

Table 1. Applications at Glenlea and Portage (1968).

Herbicide	Rate
Atrazine	0 (Weedy check)
Atrazine	½ pound
Atrazine	1 pound
Atrazine	2 pounds
Atrazine + Buctril M	0 (Weedy check)
Atrazine + Buctril M	½ pound + ½ pound
Atrazine + Buctril M	1 pound + ½ pound
Atrazine + Buctril M	2 pounds + ½ pound
Atrazine + MCPA	0 (Weedy check)
Atrazine + MCPA	½ pound + ½ pound
Atrazine + MCPA	1 pound + ½ pound
Atrazine + MCPA	2 pounds + ½ pound
Atrazine + Banvel 3	0 (Weedy check)
Atrazine + Banvel 3	½ pound + ½ pound
Atrazine + Banvel 3	1 pound + ½ pound
Atrazine + Banvel 3	2 pounds + ½ pound

The experimental design was a modified complete block using 4 blocks and 8 replications (Figure 1).

Figure 1. Diagram of 2 replications used in 1968 chemical trials[1].

Atrazine (A)[2]				A + MCPA				A + Bictril M				A + Banvel 3			
½	1	2	Ch[2]	½	1	2	Ch	½	1	2	Ch	½	1	2	Ch

A + Buctril M				A + Banvel 3				A + MCPA				A			
½	1	2	Ch	½	1	2	Ch	½	1	2	Ch	½	1	2	Ch

[1] Numbers in plots refer to pounds of atrazine.

[2] A refers to atrazine and Ch to weedy checks.

In 1969, the experimental design was a randomized complete block with 4 replications. Table 2 lists treatments in both locations, the last 5 of which were not applied at Portage.

All chemicals were tank-mixed at the site at a total spray volume of 19 gallons/acre. A bicycle-wheel sprayer was used in all trials with a pressure of 35 pounds/square inch. Modified corn oil (product of Shell Canada) was applied at 1.5 gallons/acre in all post-emergence atrazine treatments. Table 2 of the appendix indicates wind speed and direction in each experiment. Corn height at time of post-emergence spraying was 3-5 inches while weeds ranged from 0-3 inches.

Table 2. Applications at Glenlea and Portage (1969)[1].

Treatment	Rate	Application	Code
Atrazine	2 pounds	Pre-emerge	A-2# pre-E
Atrazine	1 pound	Pre-emerge	A-1# pre-E
Atrazine	2 pounds	Post-emerge	A-2# post-E
Atrazine	1 pound	Post-emerge	A-1# post-E
Sutan	3.3 pints	Pre-plant	Sutan-3.3 pints
Sutan	4.5 pints	Pre-plant	Sutan-4.5 pints
Atrazine + Sutan	1 pound + 3.3 pints	Pre-plant	A + Sutan-3.3 pints
Londax	7.5 pounds actual	Pre-emerge	Londax-7.5#
Londax	10 pounds actual	Pre-emerge	Londax-10#
Atrazine + Prometryne	1 pound + 1 pound	Pre-emerge	A + Prometryne-1#
Linuron	1.5 pounds	Pre-emerge	Linuron-1.5#
Atrazine + Linuron	1 pound + 1 pound	Pre-emerge	A + Linuron-1#
Atrazine + Linuron	1 pound + 1.5 pounds	Pre-emerge	A + Linuron-1.5#
Banvel D	1.5 pounds	Pre-emerge	Banvel D-0.5#
Atrazine + Banvel D	1 pound + 0.5 pounds	Pre-emerge	A + Banvel D-0.5#
Lasso	2 pounds	Pre-emerge	Lasso-2#
Lasso	3 pounds	Pre-emerge	Lasso-3#
Atrazine + Lasso	1 pound + 2 pounds	Pre-emerge	A + Lasso-2#
Ramrod	4 pounds	Pre-emerge	Ramrod-4#
Ramrod	6 pounds	Pre-emerge	Ramrod-6#
Atrazine + Ramrod	1 pound + 3 pounds	Pre-emerge	A + Ramrod-3#
Weeded check	-	-	Weeded check
Weedy check	-	-	Weedy check
Banvel D	1 pound	Pre-emerge	Banvel D-1#
Atrazine + Banvel 3	1 pound + 0.5 pounds	Pre-emerge	A + Banvel 3-0.5#
Banvel D + Ramrod	0.5 pounds + 3 pounds	Pre-emerge	Banvel D-0.5# + Ramrod-3#
Ametryne	1 pound	Pre-emerge	Ametryne-1#
Ametryne	2 pounds	Pre-emerge	Ametryne-2#

[1]Chemical names in Table 1 of appendix.

Visual observations of the effect of the chemicals were made. These were rated on a 0-10 scale, 0 being no control and 10 representing complete kill.*

Harvesting consisted of weighing fresh material cut from a 60 square foot area in 1968 and from a 120 square foot area in 1969. Representative samples from each plot were taken for dry matter analysis.

The soil at the Glenlea site had a 70% clay fraction and 2.5% organic matter while similar figures for the Portage location were 41% and 5.1% respectively.

Analysis of Data

Only differences significant at the 5% level of probability were considered meaningful in all experiments.

Experiment I. Atrazine alone and in combination with MCPA, Buctril M, and Banvel 3 for weed control in corn at Glenlea (1968).

The corn was planted on May 24 and fertilizer was side-banded at a rate of 75 pounds 11-48-0 and 156 pounds 33.5-0-0/acre as the corn was emerging.

Weeds present at the site included:

1) Wild mustard - *Sinapis arvensis* L.
2) Red-root pigweed - *Amaranthus retroflexus* L.
3) Wild buckwheat - *Polygonum convolvulus* L.
4) Great ragweed - *Ambrosia trifida* L.
5) Barnyard grass - *Echinochloa crusgalli* (L.) Beauv.
6) Wild oats - *Avena fatua* L.

*Fuller description of visual ratings given in Table 21 of Appendix.

Visual ratings of weed control were made on August 7 and 22.

Corn stover was harvested on September 11.

Experiment II. Atrazine alone and in combination with MCPA, Buctril M, and Banvel 3 for weed control in corn at Portage (1968).

Due to cutworm destruction of an earlier crop, corn was seeded on June 18. The fertilizing program consisted of broadcasting 100 pounds 33.5-0-0 before seeding and sidebanding 200 pounds 23-23-0 with the seed.

Weeds present in the area occupied by this experiment included the following:

1) Red-root pigweed - Amaranthus retroflexus L.
2) Wild buckwheat - Polygonum convolvulus L.
3) Lambsquarters - Chenopodium album L.
4) Wild mustard - Sinapis arvensis L.
5) Stinkweed - Thlaspi arvense L.
6) Green foxtail - Setaria viridis (L.) Beauv.
7) Barnyard grass - Echinochloa crusgalli (L.) Beauv.

Visual ratings of weed control were made on 3 occasions: July 22, August 7, and August 22. Corn forage was harvested on September 12.

Experiment III. Atrazine and other chemicals alone and in combination for weed control in corn at Glenlea (1969).

Seeding date of the corn was May 27, 2 days after the pre-plant incorporated Sutan treatments were applied. No fertilizer was applied in this test area.

Predominant weeds present were:

1) Wild oats - Avena fatua L.

2) Wild mustard - Sinapis arvensis L.

3) Green foxtail - Setaria viridis (L.) Beauv.

4) Barnyard grass - Echinochloa crusgalli (L.) Beauv.

Observations of the following weeds were also made:

5) Lambsquarters - Chenopodium album L.

6) Red goosefoot - Chenopodium rubrum L.

7) Oak-leaved goosefoot - Chenopodium glaucum L.

8) Hemp nettle - Galeopsis Tetrahit L.

9) Prostrate pigweed - Amaranthus graecizans L.

10) Red-root pigweed - Amaranthus retroflexus L.

11) Wild buckwheat - Polygonum convolvulus L.

12) Narrow-leaved dock - Rumex mexicanus Meisn.

13) Yellow marsh cress - Rorippa islandica (Oeder) Borbas

Visual observations of weed control were made on July 17 and August 11. Corn plant heights were recorded on August 26. Prior to harvesting, the number of ears/plant and their lengths were recorded (Appendix-Table 3).

The corn stover was harvested on September 11 and 12.

Experiment IV. Atrazine and other chemicals alone and in combination for weed control in corn at Portage (1969).

Corn was seeded on May 28. Fertilizer was sidebanded at a rate of 250 pounds 23-23-0/acre.

The predominant weeds present were:

1) Tame mustard - Sinapis alba L.

2) Wild oats - Avena fatua L.

3) Green foxtail - Setaria viridis (L.) Beauv.

The following weeds were also noted:

4) Wild mustard - Sinapis arvensis L.

5) Lambsquarters - Chenopodium album L.

6) Red-root pigweed - Amaranthus retroflexus L.

7) Wild buckwheat - Polygonum convolvulus L.

Corn plant heights were recorded on August 26. One week prior to harvest a record was made of the number of ears/plant and their lengths (Appendix-Table 4).

Harvesting date for the corn stover was September 11.

Experiment V. Greenhouse bioassay for atrazine residues.

Soil samples were taken from the Portage site on September 18, 1969, at 3 depths: 0-2 inches, 2-4 inches, and 4-6 inches. The 3 treatments represented were:

1) Hand-weeded check.

2) Atrazine at 1 pound/acre post-emergence with oil (A-1# post-E).

3) Atrazine at 2 pounds/acre post-emergence with oil (A-2# post-E).

The soil was dried at 55°C for 72 hours.

The experiment was set up in the greenhouse in a completely random design. Plastic pots were filled to a depth of 5 inches with soil from the respective plots. Fifteen seeds of Harmon oats were seeded in each pot. Pots were watered whenever soil displayed a cracked surface. Four replications were used. Light intensity was 750 foot-candles, the

temperature ranged from 68°F to 72°F, and a 16-hour light period was used.

An examination of oat plants was made 3 weeks after seeding.

The oat plants were harvested 4 weeks after seeding and dry weights were recorded.

Experiment VI. Growth chamber bioassay for atrazine residues.

This experiment was set up in a growth chamber. The design was the same as in Experiment V. Light intensity, however, was 2500 foot-candles in this location, and the temperature ranged from 60°F during the night to 70°F during the day. The light period was 16 hours/day.

An examination of oat plants was made 3 weeks after seeding.

The oat plants were harvested 4 weeks after seeding and dry weights were recorded.

Experiment VII. Growth chamber bioassay for atrazine residues in mixed soils and atrazine-diluted soils.

The same growth chamber and conditions were used as in Experiment VI.

The following treatments were established:

1) 0-6 inch check (Ch-6"). Equal weights from all 3 levels (0-2", 2-4", and 4-6") were used.
2) Intensive cultivation (mixing) to 6-inch depth; again equal weights of soil from all 3 levels were used.
   a) Atrazine - 1 pound (A1-6"-C where C is "cultivated").
   b) Atrazine - 2 pounds (A2-6"-C).

3) Treated and untreated soil was mixed in a 1:2 ratio to 6 inches to simulate banding.

a) Atrazine - 1 pound (A1-6"-B where B is "banded").

b) Atrazine - 2 pounds (A2-6"-B).

The remaining 4 groups of treatments involved using soil from successively lesser depths than the first 3 groups of treatments, thus simulating shallow field tillage.

4) 0-4 inch overall application.

a) Atrazine - 1 pound (A1-4"-C).

b) Atrazine - 2 pounds (A2-4"-C).

5) 0-4 inch depth, 1:2 mixing of treated and untreated soil.

a) Atrazine - 1 pound (A1-4"-B).

b) Atrazine - 2 pounds (A2-4"-B).

6) 0-2 inch overall application.

a) Atrazine - 1 pound (A1-2"-C).

b) Atrazine - 2 pounds (A2-2"-C).

7) 0-2 inch depth, 1:2 mixing of treated and untreated soil.

a) Atrazine - 1 pound (A1-2"-B).

b) Atrazine - 2 pounds (A2-2"-B).

Four replications of pots were set up in a completely random design.

The oat plants were again examined at the 3-week stage. Fresh weights were taken 4 weeks after seeding and dry weights were determined.

Results and Discussion

Experiment I. Atrazine alone and in combination with MCPA, Buctril M, and Banvel 3 for weed control in corn at Glenlea (1968).

Visual observations of the degree of weed control for both broadleaf and grassy weeds are given in Table 3.

Table 3. Degree of weed control in 1968 Glenlea trial.

Treatment Block	Pounds of Atrazine	Broadleaf Weeds	Grassy Weeds
Atrazine	0 (Check)	0	0
	½	0.5	0
	1	3.0	1.0
	2	6.5	3.5
Atrazine + Buctril M	0	0	0
	½	8.0	1.0
	1	9.0	2.0
	2	9.5	6.0
Atrazine + MCPA	0	0	0
	½	5.5	0
	1	7.5	1.5
	2	9.0	4.5
Atrazine + Banvel 3	0	0	0
	½	7.5	1.5
	1	8.5	3.5
	2	9.5	4.5

The ratings indicate that no treatment gave satisfactory control of grassy weeds. Buctril M, MCPA, and Banvel 3 in combination with atrazine (1 and 2 pounds/acre) gave satisfactory to very good control of broadleaf weeds. Plates 1 and 2 show 2 representative treatments, a weedy check and the combination of Buctril M and 2 pounds atrazine. Buctril M and Banvel 3 in association with $\frac{1}{2}$ pound of atrazine gave good control of broadleaf weeds whereas MCPA with $\frac{1}{2}$ pound atrazine did not give good broadleaf control.

Plate 1. Weedy check

Plate 2. Buctril M + 2 pounds atrazine

Mean stover yields are recorded in Table 4. Dry matter contents are listed in Table 5 of the appendix.

Table 4. Average corn stover yields in Glenlea chemical trial - 1969.

Treatment		Fresh Weights	Dry Weight
Block	Pounds of Atrazine	(tons/acre)	(tons/acre)
Atrazine	0	6.81	1.49
	½	9.31	1.99
	1	11.77	2.24
	2	14.77	2.74
Atrazine + Buctril M	0	7.29	1.21
	½	8.80	1.75
	1	11.02	2.16
	2	14.80	2.91
Atrazine + MCPA	0	7.22	1.41
	½	11.60	2.18
	1	12.36	2.37
	2	14.09	2.89
Atrazine + Banvel 3	0	7.86	1.32
	½	12.18	2.20
	1	13.14	2.48
	2	14.50	2.50

Statistical analyses were performed on the basis of both fresh and dry weight yields. Results of analysis of variance are shown in Tables 6-9 of the appendix.

No differences occur between treatments with equivalent atrazine content; i.e. the 1-pound atrazine treatment did not differ in stover yield from the 1-pound atrazine combinations with MCPA, Buctril M, and Banvel 3. Although some differences in weed control were evident, this observation was not further substantiated by corresponding yield differences.

Weed density at this location was high as seen in Plates 1 and 2. Increasing the rate of atrazine gave increased stover yield (Table 5).

Table 5. Mean tonnage fresh weight/acre, Glenlea - 1968[1].

Treatment Block	Fresh Weight
Weedy Checks	7.30 ± 1.31
Atrazine - $\frac{1}{2}$ pound	10.47 ± 1.49
Atrazine - 1 pound	12.07 ± 1.40
Atrazine - 2 pounds	14.54 ± 1.04

[1] 95% confidence limits.

Although the design of the experiment did not allow for statistical comparions between treatments in one particular block, Table 5 indicates a trend of increasing yields with increasing rates of atrazine regardless of which chemical, if any, is added.

Experiment II. Atrazine alone and in combination with MCPA, Buctril M, and Banvel 3 for weed control in corn at Portage (1968).

Visual observations of the degree of weed control are given in Table 6.

Table 6. Degree of weed control in 1968 Portage trial.

Treatment		Broadleaf Weeds	Grassy Weeds
Block	Pounds of Atrazine		
Atrazine	0	0	0
	½	3.7	1.3
	1	6.3	3.3
	2	8.0	6.0
Atrazine + Buctril M	0	0	0
	½	6.0	3.3
	1	8.3	5.7
	2	9.0	7.0
Atrazine + MCPA	0	0	0
	½	6.3	4.7
	1	7.7	6.3
	2	9.3	8.3
Atrazine + Banvel 3	0	0	0
	½	8.0	4.7
	1	9.7	5.7
	2	10.0	7.3

Fair to good control of grassy weeds was obtained only with the highest atrazine rate in combination with the 3 added chemicals. On the other hand, good control of broadleaf weeds was obtained with all

combinations at the 1- and 2-pound rates of atrazine, as well as with the combination of Banvel 3 and ½-pound atrazine.

Plates 3-5 illustrate degree of weed control and condition of corn in a representative group of treatments. Banvel plus 2 pounds atrazine (Plate 3) shows excellent weed control, but corn is somewhat stunted as compared to the weedy check (Plate 4) where corn is tall and healthy despite weed cover. Atrazine alone at the 2-pound rate (Plate 5) shows good broadleaf control, but green foxtail has not been eliminated.

Throughout the summer, much of the corn in the combination treatments showed chemical injury in the form of onion leaves (Plate 6). The corn in the atrazine treatments appeared healthier despite much higher weed densities. Corn stalks were generally thicker, the plants were taller, more tillered, and a darker green than in the combination treatments. By season end, however, the corn in the combination treatments did not differ in height from that in the plots treated with atrazine alone. Corn at season end varied only from 5.75 to 6.33 feet in height.

Stover yields over the 8 replications are recorded in Table 7. Dry matter is listed in Table 10 of the appendix.

Analysis of variance for both fresh and dry weights are given in Tables 11-13 of the appendix. The only comparisons made were those between treatments with a given constant rate of atrazine.

No yield increase was obtained by adding Buctril M, MCPA, or Banvel 3 to ½ pound atrazine. At the 1-pound rate all 3 added chemicals reduced dry matter production, but only Banvel 3 reduced the fresh weight compared to atrazine alone. At the 2-pound atrazine rate, MCPA, and

Plate 3. Banvel 3 + 2 pounds atrazine

Plate 4. Weedy check

Plate 5. Atrazine - 2 pounds

Plate 6. Onion leaves on corn

Table 7. Average corn stover yields at Portage - 1968.

Treatment Block	Pounds of Atrazine	Fresh Weights (tons/acre)	Dry Weights (tons/acre)
Atrazine	0	12.53	1.87
	½	12.25	2.07
	1	15.34	2.54
	2	14.54	1.82
Atrazine + Buctril M	0	11.55	1.65
	½	12.50	1.83
	1	12.90	1.86
	2	13.67	1.90
Atrazine + MCPA	0	12.12	1.97
	½	12.74	1.69
	1	12.47	1.87
	2	11.31	1.50
Atrazine + Banvel 3	0	13.23	2.05
	½	11.71	1.59
	1	12.01	1.80
	2	10.90	1.40

Banvel 3 reduced fresh and dry matter production.

The following table shows the mean tonnage of fresh weight/acre for each of the treatment blocks.

Table 8. Mean tonnage fresh weight/acre, Portage - 1968.

Treatment Block	Fresh Weight
Weedy Checks	12.36
Atrazine - $\frac{1}{2}$ pound	12.30
Atrazine - 1 pound	13.18
Atrazine - 2 pounds	12.61

The design of the experiment did not allow for statistical comparisons between treatments in any particular block. Table 8 indicates no increasing yields with increasing rates of atrazine.

Weed populations at the Portage location were considerably lower than at the Glenlea site. This fact may, in part, account for the high stover yields of the weedy check plots. Throughout the summer, the corn having received the treatments including the 3 chemicals added to atrazine showed signs of injury in the form of stunted plants as well as curled, and onion leaves. These injury symptoms may have been due to the relatively late application of the herbicides (4 weeks after seeding). The corn may have been too tall. This delay of one extra week was necessitated by the late emergence of the weeds. If the corn in these treatments had not been injured, it may have caught and bypassed the corn stand in the weedy checks. Even as it was, by the end of the season small size differences were evident between corn in the various treatments.

Experiment III. Atrazine and other chemicals alone and in combination for weed control in corn at Glenlea - 1969.

Visual observations of the degree of weed control and corn heights resulting from the particular chemical or combination of chemicals used in this location are shown in Table 9. Examination reveals that within one weed species column there are varying degrees of control by any one particular treatment. For example, Ramrod at 6 pounds/acre immediately follows Banvel D in the overall listings. However, while Banvel D shows satisfactory control of wild mustard, Ramrod shows negligible control of the same species. At the same time, Banvel D displays poor control of green foxtail and barnyard grass (B. grass) while Ramrod shows good control of these particular grassy species.

The weedy check (Plate 7) was severely infested with weeds. The combination of atrazine and Lasso (Plate 8) gave poor weed control, but stover yields remained high. Plates 9 and 10 represent control achieved with 2 pounds atrazine, pre- and post-emergence, respectively. Plates 11 and 12 show 2 treatment combinations giving good control of weeds.

Mean stover yields are recorded in Table 10. Table 14 of the appendix records dry matter contents.

In general, there appears to be a degree of correlation between visible weed control and height of corn plants with resulting stover yields, although some unpredictable results occurred as well. For example, while weed control with 2 pounds post-emergence atrazine was second only to the hand-weeded check in weed control, fresh weight of this same treatment, was only fifth in final stover yield. On the other hand, the combination of atrazine and Lasso was twelfth in control ratings, yet this

Table 9. Degree of weed control and corn height in Glenlea treatments - 1969.

Treatment	Wild Oats	Wild Mustard	Foxtail + B. grass	Others	Mean Control	Corn Height (in feet)
Weeded check	10.0	10.0	10.0	10.0	10.00	6.13
A-2# post-E	10.0	10.0	9.0	10.0	9.75	5.56
A + Sutan-3.3 pints	9.0	10.0	7.0	8.0	8.50	5.25
A-2# pre-E	7.5	9.5	7.0	8.0	8.00	6.00
A + Linuron-1.5#	8.0	8.5	7.0	7.0	7.63	5.56
A-1# post-E	7.0	9.0	3.0	8.0	6.75	5.50
A + Linuron-1#	4.0	8.5	7.0	7.0	6.63	4.56
A + Prometryne-1#	5.0	5.5	6.0	7.0	5.88	5.38
A + Banvel 3-0.5#	5.0	7.0	3.0	8.0	5.75	4.69
Linuron-1.5#	4.0	7.0	7.0	5.0	5.75	4.25
A + Lasso-2#	5.5	5.0	7.0	4.5	5.25	5.88
Banvel D-1#	3.0	7.0	3.0	5.5	4.63	4.38
Ramrod-6#	5.0	2.0	8.5	2.0	4.38	4.81
Londax-7.5#	3.0	3.0	7.0	4.0	4.25	4.94
Banvel D-0.5# + Ramrod-3#	2.5	2.0	6.5	5.0	4.00	5.81
Lasso-2#	3.0	4.0	5.0	3.0	3.75	3.63
Ramrod-4#	2.0	4.0	7.0	1.0	3.50	4.06
A + Ramrod-3#	3.0	4.0	3.0	3.5	3.38	4.69
Londax-10#	1.0	4.0	5.0	2.0	3.00	5.00
Lasso-3#	2.0	2.5	2.5	4.5	2.88	4.56
A-1# pre-E	2.0	4.0	2.0	2.0	2.50	4.13
Ametryne-2#	1.5	2.0	4.0	2.5	2.50	4.56
Banvel D-0.5#	1.0	4.0	1.0	3.5	2.38	2.50
Sutan-4.5 pints	2.0	1.0	1.0	0	1.00	2.88
Sutan-3.3 pints	1.5	0	1.0	0	0.63	2.75
Ametryne-1#	0	0	0	0	0	3.69
Weedy check	0	0	0	0	0	2.19

Plate 7. Weedy Check

Plate 8. Atrazine + Lasso

Plate 9. Atrazine - 2 pounds pre-emergence

Plate 10. Atrazine - 2 pounds post-emergence

Plate 11. Atrazine + Sutan

Plate 12. Atrazine + 1.5 pounds Linuron

treatment gave stoveryield which was equivalent to that of the weeded check.

Analysis of variance for fresh and dry weight is recorded in Table 15 of the appendix.

Only atrazine at 2 pounds/acre applied pre-emergence and the atrazine-Lasso combination gave corn stover yields which were equivalent to the weeded check treatment. Similarly, the low rate of ametryne, Banvel D at the lowest rate, and both rates of Sutan produced stover yields equivalent to the weedy check. The remainder of the treatments fell into an intermediate zone between the 2 extremes.

It is noteworthy that the only treatment giving the desired weed

Table 10. Mean stover yields (tons/acre) at Glenlea - 1969.

Treatments	Fresh Weight	Dry Weight
A-2# pre-E	13.98 a	3.61 a
Weeded check	14.62 a	3.13 a
A + Lasso-2#	14.46 a	2.73 a
A + Ramrod-3#	10.16	2.54
A + Linuron-1.5#	13.35 a	2.50
Banvel D-0.5# + Ramrod-3#	11.45 a	2.44
A-1# post-E	11.82 a	2.41
A + Sutan-3.3 pints	11.14 a	2.36
A-2# post-E	12.28 a	2.25
Londax-10#	8.77	2.21
Ramrod-6#	9.57	2.18
A + Banvel D-0.5#	11.02 a	2.04
A + Banvel 3-0.5#	10.99 a	1.96
A + Prometryne-1#	10.11	1.91
Ametryne-2#	7.66	1.76
Banvel D-1#	8.67	1.76
A-1# pre-E	6.68 b	1.70
A + Linuron-1#	9.60	1.64
Londax-7.5#	8.78	1.62
Lasso-3#	8.48	1.30
Linuron-1.5#	6.88 b	1.27
Lasso-2#	6.55 b	1.19
Ramrod-4#	6.66 b	1.17
Ametryne-1#	6.59 b	1.13 b
Banvel D-0.5#	4.41 b	0.81 b
Sutan-4.5 pints	4.15 b	0.69 b
Sutan-3.3 pints	3.78 b	0.60 b
Weedy check	2.92 b	0.58 b

a Treatments not differing from weeded check, using LSD.
b Treatments not differing from weedy check, using LSD.

control as well as a yield of stover which was equivalent to that of the weeded check was atrazine by itself at the 2-pound rate applied pre-emergence. The only other treatment giving the desired high yield of stover was the atrazine-Lasso combination; this treatment, however, left many weeds for seed.

Experiment IV. Atrazine and other chemicals alone and in combination for weed control in corn at Portage - 1969.

Visual observations of the degree of weed control and corn height are recorded in Table 11.

An examination of this table shows that within one weed species column there are varying degrees of control by any one particular chemical treatment. For example, the combination of atrazine and 1.5 pounds of linuron gave satisfactory to excellent control of the mustards and green foxtail, but negligible control of wild oats.

The weedy check (Plate 13) shows the weed infestation at the site. Atrazine at 2 pounds/acre applied post-emergence (Plate 14) shows near-perfect weed control and good corn stand while (Plate 15) shows poorer control of weeds resulting from pre-emergence application of 2 pounds atrazine. Plate 16 shows fair weed control and good corn stand achieved with 1 pound atrazine applied post-emergence.

Mean stover yields are recorded in Table 12. Table 16 of the appendix records dry matter contents.

Analysis of variance for fresh and dry weights is recorded in Table 17 of the appendix.

Only atrazine at 2 pounds applied post-emergence gave a corn stover yield equal to the yield of the weeded check. Falling slightly below

Table 11. Degree of weed control and corn height in Portage treatments - 1969.

Treatment	Wild Oats	Mustard	Green Foxtail	Others	Mean Control	Corn Height (in feet)
Weeded check	10.00	10.00	10.00	10.00	10.00	6.38
A-2# post-E	8.25	10.00	8.75	10.00	9.25	6.38
A-1# post-E	5.75	9.75	6.00	9.50	7.75	5.81
A + Linuron-1.5#	2.25	7.00	9.00	8.50	6.69	4.31
A-2# pre-E	3.50	5.00	4.50	5.25	4.56	3.94
A + Linuron-1#	2.75	3.00	6.50	4.25	4.13	3.31
Londax-10#	0	3.75	5.00	1.25	2.50	2.63
Linuron-1.5#	0.25	3.00	3.25	1.00	1.88	1.50
A + Prometryne-1#	0.50	0.50	4.00	1.00	1.50	2.81
A + Sutan-3.3 pints	0.25	2.75	1.25	1.25	1.38	3.19
A + Lasso-2#	0.25	1.75	1.50	0.50	1.00	2.88
A + Banvel D-0.5#	0	1.50	0.50	1.00	0.75	2.69
Londax-7.5#	0	0.75	1.00	0.25	0.50	1.50
Ramrod-6#	0	0.75	0.50	0	0.31	1.63
Sutan-4.5 pints	0	1.25	0	0	0.31	1.50
A + Ramrod-3#	0	1.00	0	0	0.25	2.13
Banvel D-1#	0	0.50	0	0	0.13	1.56
A-1# pre-E	0	0	0.25	0	0.06	2.19
Ramrod-4#	0	0	0.25	0	0.06	1.00
Lasso-3#	0	0	0	0	0	2.00
Lasso-2#	0	0	0	0	0	1.50
Sutan-3.3 pints	0	0	0	0	0	1.44
Weedy check	0	0	0	0	0	1.25

Plate 13. Weedy check

Plate 14. Atrazine - 2 pounds post-emergence

Plate 15. Atrazine - 2 pounds pre-emergence

Plate 16. Atrazine - 1 pound post-emergence

Table 12. Mean stover yields (tons/acre) at Portage - 1969.

Treatment	Fresh Weight	Dry Weight
Weeded check	15.10 a	3.73 a
A-2# post-E	13.86 a	3.63 a
A-1# post-E	10.81	3.23
A + Linuron-1.5#	5.13	1.52
A-2# pre-E	3.85	1.02
A + Sutan-3.3 pints	3.06	0.72
A + Banvel D-0.5#	2.17	0.57
A + Linuron-1#	2.61	0.57
A + Prometryne-1#	2.26	0.50
A + Lasso-2#	2.18	0.47 b
A-1# pre-E	1.61 b	0.35 b
Londax-10#	1.74 b	0.34 b
Sutan-4.5 pints	1.14 b	0.31 b
A + Ramrod-3#	1.54 b	0.31 b
Linuron-1.5#	1.28 b	0.30 b
Lasso-3#	1.40 b	0.26 b
Banvel D-1#	1.23 b	0.26 b
Londax-7.5#	1.07 b	0.24 b
Sutan-3.3 pints	1.11 b	0.22 b
Lasso-2#	1.15 b	0.21 b
Ramrod-4#	0.87 b	0.20 b
Ramrod-6#	0.94 b	0.19 b
Weedy check	0.81 b	0.16 b

a Treatments not differing from weeded check, using LSD.

b Treatments not differing from weedy check, using LSD.

the limits imposed by the LSD is the 1-pound post-emergence application of atrazine. On the other hand, some 13 treatments failed to differ from the weedy check in stover yield. The remaining treatments fall into an intermediate zone.

Experiment V. Greenhouse bioassay for atrazine residues.

Oat emergence was noted 4 days after seeding. By the fifth day, 90% of the seedlings had emerged. Emergence appeared normal in all pots. No physiological abnormalities appeared in any of the oat plants until 8-10 days after seeding. At that time, plants in the atrazine-2 pounds, 0-2 inch treatment showed a reduction in growth rate as compared to the check. Other treatments displaying slight growth depression were: atrazine-2 pounds, 2-4 inch and atrzine-1 pound, 0-2 inch.

The condition of the oat plants 3 weeks after seeding and their dry weights 4 weeks after seeding were recorded (Table 13).

Analysis of variance for dry weights is recorded in Table 18 of the appendix.

Oats grown in the atrazine-1 pound, 0-2 inch treatment had a lower dry weight yield than the check. Severe yield depression occurred in the atrazine-2 pound, 0-2 inch treatment.

Results at the 2-4 inch soil depth indicate that reduction in dry weight of oats occurred only at the 2 pound rate of atrazine.

No differences were detected between treatments at 4-6 inch soil layer.

The results of this experiment indicate that the atrazine has

Table 13. Condition of oats at 3 weeks and dry weights at 9 weeks - Greenhouse.

Treatment	Rate (lb/A)	Soil depth (inches)	Height (inches)	Leaf stage	Condition	Dry weight (grams)
Check	-	0-2	9-10	2½-3	Etiolated, some broken leaves.	0.45 a
Atrazine	1	0-2	5-6	2	30% broken leaves, weak.	0.28
Atrazine	2	0-2	4-5	2	Severe breakage and chlorosis.	0.13
Check	-	2-4	11	2½-3	Healthy.	0.55 a
Atrazine	1	2-4	8-10	2	20% bent leaves.	0.50 a
Atrazine	2	2-4	7	2-2½	Weak, 50% broken leaves.	0.42
Check	-	4-6	8	2½-3	Spindly, 30% broken leaves.	0.48 a
Atrazine	1	4-6	8	2½-3	Spindly, 30% broken leaves.	0.60
Atrazine	2	4-6	8	2½-3	Spindly, 30% broken leaves	0.48 a

a - Treatments not differing from respective checks, according to $LSD_{.05}$.

reached the 4-inch depth at the 2-pound rate while the 1-pound treatment has penetrated only to the 2-inch depth. Oats can be severely injured at high atrazine rates and shallow soil depths.

Experiment VI. Growth chamber bioassay for atrazine residues.

Oat emergence was noted 4 days after seeding. By the fifth day 50% of the seedlings had emerged. Emergence was normal; no physiological abnormalities occurring until 8-10 days after seeding. A reduced growth rated of plants in the atrazine-2 pound, 0-2 inch treatment was noted. Slight growth depression was also noted in the atrazine-2 pound, 2-4 inch and atrazine-1 pound, 0-2 inch treatments.

Condition of oat plants 3 weeks after seeding and their dry weights 4 weeks after seeding were recorded (Table 14).

Plate 17 illustrates the effect of the 2-pound rate of atrazine on the oats. Atrazine residue effects were noted in atrazine-2 pound, 0-2 inch (A2,0-2), atrazine-1 pound, 0-2 inch (A1,0-2), and atrazine-2 pound, 2-4 inch (A2,2-4) treatments. No differences were noted between the the check (Ch,0-2) and the atrazine-1 pound, 2-4 inch (A1,2-4) treatment.

Analysis of variance for dry weights is recorded in Table 19 of the appendix.

The dry weight of oats from the 0-2 inch layer was severely depressed at both the 1 and 2 pound rates of atrazine.

Yield depression in the 2-4 inch layer occurred only at the 2-pound rate of atrazine.

Results from the 4-6 inch layer indicate that atrazine reached the

Table 14. Condition of oats at 3 weeks and dry weights at 4 weeks - Growth Chamber.

Treatment	Rate (lb/A)	Soil depth (inches)	Height (inches)	Leaf stage	Condition	Dry weight (grams)
Check	-	0-2	6	2½-3	Healthy.	0.58 a
Atrazine	1	0-2	6	2½-3	Dark leaves, wilted.	0.32
Atrazine	2	0-2	4	2	Broken leaves, chlorotic.	0.12
Check	-	2-4	6-7	2½-3	Healthy.	0.64 a
Atrazine	1	2-4	6-7	2½-3	Healthy.	0.62 a
Atrazine	2	2-4	6	2½-3	Slight leaf bending.	0.47
Check	-	4-6	6	2½-3	Healthy.	0.71 a
Atrazine	1	4-6	6	2½-3	Healthy.	0.59
Atrazine	2	4-6	6	2½-3	Healthy.	0.53

a - Treatments not differing from respective checks, according to $LSD_{.05}$.

Plate 17. Effect of Atrazine on oat seedlings.

Ch,0-2 A1,0-2 A2,0-2 A1,2-4 A2,2-4

6-inch layer with the 2-pound treatment.

The results of this experiment indicate that the atrazine has reached the 6-inch soil level at both concentrations (1 and 2 pounds/acre). Oats grown in treated soil can be severely injured, especially at shallow soil depths and higher atrazine rates.

Experiment VII. Growth chamber bioassay for atrazine residues in mixed soils and atrazine-diluted soils.

Oat emergence was noted 4 days after seeding. By the sixth day, all oats had emerged. Emergence and early growth appeared normal in all treatments until 9-10 days after seeding. At that time, plants in the A2-2"-C treatment gave indications of a reduced growth rate. By the sixteenth day after seeding, much yellowing and dying back of the leaf tips was noted in A2-2"-C. Plants in this treatment also appeared stunted in growth. At the same time (16 days after seeding), indications of physiological abnormalities were evident in A2-4"-C. No readily observable signs of injury occurred in any other treatment by this time.

Table 15 indicates condition of oat plants at 3 weeks and their dry weight at harvest (4 weeks after seeding).

Table 20 of the appendix records analysis of variance of dry weights.

As expected, the A2-2"-C treatment yielded the lowest amount of dry matter. Even intensive soil-mixing of the 2-pound overall application to 4 and 6 inches failed to alleviate the problem of atrazine residues.

The yield of the A1-2"-C treatment was also low while mixing of these 1-pound rates to 4 and 6 inches improved the yields slightly, but still left them lower than the check plants.

Table 15. Condition of oats at 3 weeks and dry weights at 4 weeks - Experiment VII.

Treatment	Plant Condition	Dry weight (grams)
A1-4"-B	Tall, sturdy, healthy.	1.10 a[1]
Ch-6"	Tall, sturdy, healthy.	1.00 ab
A2-6"-B	Tall, sturdy, healthy.	0.93 abc
A1-6"-B	Tall, sturdy, healthy.	0.93 abc
A1-2"-B	Tall, sturdy, healthy.	0.90 bcd
A1-6"-C	Tall, study, healthy.	0.80 cde
A1-4"-C	Tall, less sturdy than check, healthy color.	0.65 ef
A2-4"-B	Tall, sturdy, some chlorosis.	0.65 ef
A2-2"-B	Tall, less sturdy than check, healthy color.	0.53 fg
A1-2"-C	Slight growth retardation, weaker than check, chlorotic.	0.45 gh
A2-6"-C	Slightly shorter and less sturdy than check, healthy color.	0.33 hi
A2-4"-C	Shorter than check, weak, chlorotic.	0.20 ij
A2-2"-C	Severe growth depression and chlorosis, many dead plants.	0.13 j

[1]Treatments followed by the same letter fail to differ at the 5% level of probability, according to Tukey's w procedure.

Banding the chemical at the 2-pound rate with subsequent mixing of the soil to 2 and 4 inches (A2-2"-B and A2-4"-B, respectively) resulted in yields which were lower than that of the check. However, when banded and mixed thoroughly to the 6-inch level, no differences could be detected between atrazine treated soil and the check.

Simulated banding of the atrazine at the 1-pound rate at all 3 soil levels resulted in yields which did not differ from the yield of the check.

The results of this experiment indicate that cultivation alone is not sufficient to dilute atrazine to non-toxic levels. Banding of the herbicide with subsequent thorough tillage may dilute the atrazine to a concentration where it will not injure a crop of oats grown in the subsequent year.

Summary and Conclusions

Chemical Trials

The 1968 chemical trials show that there is no advantage to be gained by adding Buctril M, MCPA, or Banvel 3 to specific rates of atrazine. No differences were noted at the Glenlea site. At the Portage location, any differences noted represented treatments where atrazine by itself was better (in terms of stover yield) than either one or more of the combinations with atrazine.

The Glenlea trials indicated a definite trend of increasing forage yields with increasing rates of atrazine. The Glenlea results are not borne out by the Portage data where little difference in yield occurred between the varying atrazine rates. The Portage results agree with those of Alley and Chamberlain (1964) who found that rates of $\frac{1}{2}$ pound atrazine/acre were as effective as rates 2-4 times as high.

At Portage in 1969, the 2 post-emergence treatments of atrazine rated second and third in stoveryield to the hand-weeded check. The pre-emergence atrazine treatment gave lower stover yields and poor control of weeds. These results disagree with the conclusion of Bunting and Ludwig (1964) who showed that pre-emergence applications generally result in better control of weeds and higher corn yields.

At Glenlea, the 2 post-emergence atrazine applications appeared between the 2 pre-emergence treatments in stover yield. Weed control by all atrazine treatments at Glenlea ranged from good to excellent.

The combinations of atrazine plus other chemicals, except for atrazine plus Lasso at Glenlea, gave poor corn yields as compared to the weeded checks. Weed control with atrazine plus Lasso was questionable

at Glenlea and poor at Portage.

A comparison of pre-emergence combinations with 1 pound atrazine and the 1-pound pre-emergence atrazine treatment indicates that several treatments tended to yield more dry matter than the atrazine treatment alone. The combinations of atrazine with Ramrod, Sutan, Lasso, and 1.5 pounds linuron gave dry matter yields which tended to be higher than the pre-emergence application of atrazine alone.

The favorable results with atrazine are in agreement with the work of a number of authors (Shear, et al., Hinesly, et al., Courson), and in disagreement with the report of Triplett (1966) who claimed that combinations were necessary to obtain maximum weed control.

All treatments involving chemicals other than atrazine gave poor weed control and low corn stover yields.

Based on the results of these studies, atrazine is still the best weed killer of the chemicals and combinations of chemicals tested in these areas of the province of Manitoba. Although differing as to time of application in the 2 locations, atrazine at the 2-pound rate was as effective in controlling weeds and enhancing corn yields as was weeding the corn by hand. The combinations of 1 pound atrazine plus other chemicals did not, on the basis of this 2-year study, show promise for replacing higher rates of atrazine.

Residue-Bioassay Studies

When atrazine was applied post-emergence at 2 pounds/acre, residues could be detected in the soil at the 0-2, 2-4, and 4-6 inch levels (Experiment VI). When, however, atrazine was applied at 1 pound/acre, residues could be detected in only the 0-2 inch level of soil. Thus,

atrazine gave greater depression of oat growth at higher soil levels and higher atrazine rates. Although the winter season was excluded from the normal cycle, Experiments V and VI emphasize the fact that atrazine can create a residue problem at high rates. This conclusion differs from the work of Peters (1966) who reported no injury to oats from similar rates of atrazine.

Thorough mixing of the soil to 2, 4, and 6 inches was not sufficient to grow oats, thus suggesting that intensive cultivation is not enough to effectively dilute the atrazine in the soil.

When soil was mixed in a 1:2 ratio (treated to untreated), thus simmulating a 12-inch band application (36-inch row spacing), thorough mixing of the upper 2 inches of the 1-pound atrazine treated soil was sufficient to grow oats. Similar "banding" of 2 pounds atrazine/acre required thorough mixing of the upper 6 inches of soil to grow oats.

Unless other chemicals or combinations with lower rates of atrazine prove effective, practices such as banding and the seeding of non-susceptible crops in the rotation may be the only alternatives left to the Manitoba corn producer. This recommendation is in agreement with the suggestion made by Courson (1965).

Since even simulated banding of atrazine at 2 pounds gave residue problems to 4 inches, the producer may have to lower the atrazine rate and apply combinations of atrazine with chemicals such as Sutan, Ramrod, Lasso, or linuron to alleviate the residue problem. Banding may then provide the answer to the problem of residues as well as giving the desired weed control.

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APPENDIX

Table 1. Chemicals used in 1968 and 1969 trials.

Common Name	Chemical Name
Atrazine	2-chloro-4-ethylamino-6-isopropylamino-5-triazine.
MCPA	2-methyl-4-chlorophenoxyacetic acid.
Banvel 3	2,4-D PLUS Mecoprop 2-(methyl-4-chlorophenoxy) propionic acid PLUS Dicamba (2-methoxy-3,6-dichlorobenzoic acid).
Buctril M	Bromoxynil (3,5-dibromo-4-hydroxybenzonitrile) PLUS MCPA.
Linuron	3-(3,4-dichlorophenyl)-1-methoxy-1-methylurea.
Banvel D	2-methoxy-3,6-dichlorobenzoic acid.
Lasso	2-chloro-2,6-diethyl-N-(methoxymethyl) acetanilide.
Ramrod	2-chloro-N-isopropylacetanilide.
Ametryne	2-ethylamino-4-isopropylamino-6-methylmercapto-5-triazine.
Prometryne	2,4-bis (isopropylamino)-6-methylmercapto-5-triazine.
Londax	Linuron PLUS 2-chloro-N-isopropylacetanilide.
Sutan	5-ethyldiisobutylthiocarbamate.

Table 2. Wind speed and direction at spraying time.

Location and Time	Wind Speed (mph)	Cross Wind	Along Row
Glenlea, 1968, post-emergence	6-12		x
Portage, 1968, post-emergence	0		
Glenlea, 1969, pre-plant	1-3	x	
Glenlea, 1969, pre-emergence	3-8		x
Glenlea, 1969, post-emergence	0-2		x
Portage, 1969, pre-plant	3-7		x
Portage, 1969, pre-emergence	5-12		x
Portage, 1969, post-emergence	2-3	x	

Table 3. Glenlea corn cob number and length (1969).

Treatment	Cobs/plant	Cob length (inches)
A-1# post-E	1.2	9.6
Banvel D-0.5# + Ramrod-3#	1.2	9.0
Ramrod-4#	1.4	8.6
A + Linuron-1.5#	1.2	7.8
A-1# pre-E	1.2	7.8
Hand-weeded check	1.0	7.6
A + Ramrod-3#	1.4	7.6
A + Banvel 3-0.5#	1.0	7.4
A + Prometryne-1#	1.0	7.4
Banvel D-1#	1.2	7.2
A + Sutan-3.3 pints	1.0	7.0
A + Linuron-1#	1.2	6.8
Lasso-2#	1.0	6.8
A-2# post-E	1.2	6.6
Ramrod-6#	0.8	6.6
Linuron-1.5#	1.0	6.6
Lasso-3#	1.0	6.2
A-2# pre-E	1.2	6.2
A + Banvel D-0.5#	1.4	6.0
Londax-10#	0.4	5.4
Londax-7.5#	1.2	5.2
Sutan-3.3 pints	0.4	5.0
A + Lasso-2#	1.0	4.8
Banvel D-0.5#	0.6	4.4
Ametryne-2#	0.4	3.8
Sutan-4.5 pints	0.4	3.8
Ametryne-1#	0.4	3.6
Weedy check	0.2	2.4

Table 4. Portage corn cob number and length 1969.

Treatment	Cobs/plant	Cob length (inches)
A-2# post-E	1.6	11
A-2# pre-E	1.2	11
A + Banvel D-0.5#	1.4	10
Hand-weeded check	1.6	10
A-1# post-E	1.6	9
A + Linuron-1.5#	1.2	9
A + Linuron-1#	1.4	7
A + Sutan-3.3 pints	1.2	7
A-1# pre-E	1.2	6
Lasso-2#	1.0	6
Linuron-1.5#	1.0	5
Sutan-4.5 pints	0.8	5
Weedy check	0.8	5
Sutan-3.3 pints	0.8	5
Londax-10#	0.6	5
Londax-7.5#	0.6	5
A + Ramrod-3#	0.6	5
Lasso-3#	0.4	4
Ramrod-6#	0.6	4
A + Lasso-2#	1.0	4
A + Prometryne-1#	1.0	4
Ramrod-4#	0.4	4
Banvel D-1#	0.6	4

Table 5. Dry matter content (%) of corn in 1969 Glenlea chemical trial.

Treatment		
Block	Atrazine rate (bands)	% Dry matter
Atrazine	0	21.7
	½	21.4
	1	19.1
	2	18.5
Atrazine + Buctril M	0	16.7
	½	19.9
	1	19.6
	2	19.7
Atrazine + MCPA	0	19.5
	½	18.8
	1	19.2
	2	20.5
Atrazine + Banvel 3	0	16.8
	½	18.1
	1	18.9
	2	17.3

Table 6. ANOVA for weedy checks - Glenlea - 1968.

Fresh weights

Source	df	Sum of squares	Mean squares	F
Treatments	3	38.44	12.81	0.108 n.s.[1]
Blocks	7	893.07	127.58	1.071 n.s.
Error	21	2501.39	119.11	
Total	31	3432.90		

Dry weights

Treatments	3	2.63	0.88	0.208 n.s.
Blocks	7	31.48	4.50	1.069 n.s.
Error	21	88.36	4.21	
Total	31	122.47		

[1] Non-significant at .05 level of significance.

Table 7. ANOVA for $\frac{1}{2}$-pound atrazine treatments - Glenlea - 1968.

Fresh Weights

Source	df	Sum of squares	Mean squares	F
Treatments	3	563.79	187.93	1.037 n.s.
Blocks	7	132.81	18.97	0.105 n.s.
Error	21	3807.48	181.31	
Total	31	4505.08		

Dry weights

Treatments	3	8.80	2.93	0.413 n.s.
Blocks	7	5.29	0.76	0.106 n.s.
Error	21	149.19	7.10	
Total	31	163.28		

Table 8. ANOVA for 1-pound atrazine treatments - Glenlea - 1968.

Fresh weights

Source	df	Sum of squares	Mean squares	F
Treatments	3	164.72	54.91	0.315 n.s.
Blocks	7	131.84	18.83	0.108 n.s.
Error	21	3663.57	174.46	
Total	31	3960.13		

Dry weights

Treatments	3	4.11	1.37	0.213 n.s.
Blocks	7	4.97	0.71	0.111 n.s.
Error	21	134.79	6.42	
Total	31	143.87		

Table 9. ANOVA for 2-pound atrazine treatments - Glenlea - 1968.

Fresh Weights

Source	df	Sum of squares	Mean squares	F
Treatments	3	21.80	7.27	0.089 n.s.
Blocks	7	465.25	66.46	0.813 n.s.
Error	21	1716.98	81.76	
Total	31	2204.03		

Dry weights

Treatments	3	7.21	2.40	0.794 n.s.
Block	7	17.68	2.53	0.835 n.s.
Error	21	88.43	3.03	
Total	31	88.43		

Table 10. Dry matter content of corn in 1968 Portage chemical plots.

Treatment		
Block	Atrazine rate (bands)	% Dry matter
Atrazine	0	14.9
	½	16.9
	1	16.5
	2	12.5
Atrazine + Buctril M	0	14.3
	½	14.6
	1	14.4
	2	13.9
Atrazine + MCPA	0	16.3
	½	13.3
	1	15.0
	2	13.3
Atrazine + Banvel 3	0	15.5
	½	13.6
	1	15.0
	2	17.4

Table 11. ANOVA for weedy checks - Portage - 1968.

Fresh weights

Source	df	Sum of squares	Mean squares	F
Treatments	3	90.43	30.14	1.121 n.s.
Blocks	7	574.58	82.08	3.053*
Error	21	564.57	26.88	
Total	31	1229.58		

Dry weights

Source	df	Sum of squares	Mean squares	F
Treatments	3	5.41	1.80	2.700 n.s.
Blocks	7	13.55	1.94	2.900*
Error	21	14.02	0.67	
Total	31	32.98		

*Significant at the 5% level.

Table 12. ANOVA for $\frac{1}{2}$ pound atrazine treatments - Portage - 1968.

Fresh weights

Source	df	Sum of squares	Mean squares	F
Treatments	3	35.95	11.98	0.255 n.s.
Blocks	7	285.54	40.79	0.869 n.s.
Error	21	985.52	46.93	
Total	31	1307.01		

Dry weights

Source	df	Sum of squares	Mean squares	F
Treatments	3	7.96	2.65	2.604 n.s.
Blocks	7	6.31	0.90	0.143 n.s.
Error	21	21.39	1.02	
Total	31	35.66		

Table 13. ANOVA for 1 pound atrazine treatments - Portage - 1968.

Fresh weights

Source	df	Sum of squares	Mean squares	F
Treatments	3	401.89	133.96	3.881*
Blocks	7	216.82	30.97	0.897 n.s.
Error	21	724.97	34.52	
Total	31	1343.68		

Dry weights

Treatments	3	22.07	7.36	9.027*
Block	7	4.93	0.70	0.864 n.s.
Error	21	17.12	0.82	
Total	31	44.12		

Table 14. ANOVA for 2 pound atrazine treatments - Portage - 1968.

Fresh weights

Source	df	Sum of squares	Mean squares	F
Treatments	3	574.13	191.38	7.265*
Blocks	7	328.08	46.87	1.867 n.s.
Error	21	527.09	25.10	
Total	31	1429.30		

Dry weights

Treatments	3	1.72	3.57	8.368*
Blocks	7	5.63	0.80	1.883 n.s.
Error	21	8.97	0.43	
Total	31	25.32		

Table 14. Dry matter content of corn in Glenlea chemical plots (1969).

Treatment	% Dry matter
A-2# pre-E	25.8
A-1# pre-E	25.5
Londax-10#	25.2
A + Ramrod-3#	25.0
Ametryne-2#	23.0
Ramrod-6#	22.8
Hand-weeded check	21.4
Banvel D-0.5# + Ramrod-3#	21.3
Lasso-3#	21.2
A + Sutan-3.3 pints	21.2
A-1# post-E	20.4
Banvel D-1#	20.3
Weedy check	20.0
A + Lasso-2#	18.9
A + Prometryne-1#	18.9
A + Linuron-1.5%	18.7
A + Banvel D-0.5#	18.5
Linuron-1.5#	18.4
Londax-7.5#	18.4
A-2# post-E	18.3
Banvel D-0.5#	18.3
Lasso-2#	18.1
A + Banvel 3-0.5#	17.8
Ramrod-4#	17.5
Ametryne-1#	17.2
A + Linuron-1#	17.1
Sutan-4.5 pints	16.7
Sutan-3.3 pints	15.8

Table 15. ANOVA for Glenlea chemical experiment (1969).

Fresh weights

Source	df	Sum of squares	Mean squares	F
Treatments	27	34453.65	1276.06	5.29*
Blocks	3	1904.54	634.85	2.63
Error	81	19525.93	241.06	
Total	111	55884.12		

Dry weights

Treatments	27	1855.01	68.70	14.63*
Blocks	3	520.66	173.55	36.96
Error	81	380.29	4.70	
Total	111	2755.96		

Table 16. Dry matter content of corn in Portage chemical plots (1969).

Treatment	% Dry matter
A-1# post-E	29.9
A + Linuron-1.5#	29.7
Sutan-4.5 pints	27.5
A-2# pre-E	26.4
A + Banvel D-0.5#	26.3
A-2# post-E	26.2
Hand-weeded check	24.7
Linuron-1.5#	23.5
A + Sutan-3.3 pints	23.4
Ramrod-4#	22.7
Londax-7.5#	22.2
A + Prometryne	22.0
A-1# pre-E	21.8
A + Linuron-1#	21.7
A + Lasso-2#	21.6
Banvel D-1#	21.2
Ramrod-6#	20.5
A + Ramrod-3#	20.0
Weedy check	20.0
Sutan-3.3 pints	19.5
Londax-10#	19.4
Lasso-3#	18.8
Lasso-2#	18.2

Table 17. ANOVA for Portage chemical experiment (1969).

Source	df	Sum of squares	Mean squares	F
Fresh weights				
Treatments	22	45162.98	2052.86	74.70*
Blocks	3	135.23	45.08	1.64
Error	66	1813.72	27.48	
Total	91	47111.93		
Dry weights				
Treatments	22	3306.10	150.28	104.36*
Blocks	3	9.81	3.27	2.27
Error	66	131.02	1.44	
Total	91	3446.93		

Table 18. ANOVA for greenhouse bioassay.

		Dry weights		
Source	df	Sum of squares	Mean squares	F
Treatments	8	0.667	0.083	29.79*
Error	27	0.075	0.003	
Total	35	0.742		

Table 19. ANOVA for growth chamber bioassay.

		Dry weights		
Source	df	Sum of squares	Mean squares	F
Treatments	8	1.069	0.134	34.26*
Error	27	0.106	0.004	
Total	35	1.175		

Table 20. ANOVA for atrazine bioassay (Experiment VII).

		Dry weights		
Source	df	Sum of squares	Mean squares	F
Treatments	12	4.80	9.400	66.67*
Error	39	0.24	0.006	
Total	51	5.04		

Table 21. Subjective interpretations (visual observations by plots) of weed control ratings used in all field experiments.

Rating	Degree of Control
0	No control
1	Very poor
2	Poor
3	Slight
4	Noticeable
5	Moderate
6	Fair
7	Good, satisfactory
8	Very good
9	Excellent
10	Complete kill