CHEMICAL SEEDBED PREPARATION FOR ZERO-TILLAGE CROP PRODUCTION

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"CHEMICAL SEEDBED PREPARATION FOR
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LARRY WILLIAM TAYLOR

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ABSTRACT

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Field trials were conducted under zero-tillage conditions to study broadspectrum annual weed control with applications of paraquat and glyphosate. Broadleaf herbicides were mixed with the paraquat and glyphosate treatments to find their impact on the effectiveness and cost for chemical seedbed preparation.

Excellent broadleaf annual weed control resulted when 0.28 kg/ha of bromoxynil was added to 0.42 kg/ha of paraquat. Excellent results were also obtained with 0.035 kg/ha of picloram, 0.14 kg/ha of dicamba or 0.28 kg/ha of bromoxynil in combination with 0.28 kg/ha of glyphosate. When broadleaf herbicides were not added, excellent broadspectrum annual weed control required 0.56 kg/ha of paraquat or 0.42 kg/ha of glyphosate.

The addition of broadleaf herbicides to 0.28 kg/ha of glyphosate was not necessary when wild oats or lamb's quarters were the only weed problem at seeding time. However, good control of wild mustard or wild buckwheat required the addition of 0.14 kg/ha of dicamba to 0.28 kg/ha of glyphosate. Paraquat at 0.28 kg/ha also gave very good control of wild mustard.

The addition of surfactant (0.5 per cent of spray solution) was found to increase the phytotoxicity of glyphosate mixtures to wild oats.

Experiments investigating the date of seeding under zero-tillage crop production showed that in general the yield of spring wheat (cv. Napayo) decreased as seeding date was delayed from May 3. However, yields obtained on the third seeding date (May 17) were greater than prior and subsequent seeding dates. These higher yields were attributed to improved moisture conditions at this seeding date.

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INTRODUCTION

Weeds can severely limit the success of crop production. The severity of this effect is dependent on the density and type of weed species as well as the associated management system. Today with decreased amounts of tillage accompanying crop production, chemical control of these undesirable species is increasingly necessary.

Zero-tillage has been proven to be a feasible concept under Manitoba conditions (Donaghy, 1973). In addition the herbicides paraquat and glyphosate have been reported to be well suited for broad-spectrum control of seedling annual weeds as the replacement for tillage prior to crop emergence (Nelson, 1975; Donaghy, 1973). Both paraquat and glyphosate are less active on annual broadleaf species than annual grasses. Nelson (1975) recommended that to increase the activity on broadleaf weeds the addition of specific broadleaf weed killers may be feasible. A study was initiated to determine the minimum concentrations of glyphosate or paraquat applied alone or in combination with broadleaf herbicides to most effectively control the annual weed problem. Experiments were conducted over various seeding dates to observe the effect of changing the stage and diversity of the weed populations at the time of spraying.

Recent studies have shown that at high calcium salt concentrations of the spray water the activity of glyphosate is reduced

(O'Sullivan, 1976). Experiments were conducted to determine if at low rates of glyphosate herbicidal activity was reduced due to high calcium salt concentration of the water source.

LITERATURE REVIEW

Many workers (Phillips, 1970; Donaghy, 1973; Arnott and Clement, 1966; Jeater and Laurie, 1966; Triplett and Lytle, 1972) have reported comparable yields obtained under zero-tillage crop production (zero-tillage) conditions as compared to normal cultivation. Donaghy (1973) showed that crops sown in an undisturbed seed bed had better germination and more uniformity than a crop seeded into tilled soil. Molberg (1969), and Arnott and Clement (1966) have reported reduced crop stands with zero-tillage relative to cultivated land but attribute this reduction to inadequate seeding equipment. In Manitoba Donaghy (1973) and Chinsuwan (1976) have reported successful zero-tillage seeding with a modified double disc press drill equipped with additional cutting coulters to cut trash and aid penetration into compacted soil.

Donaghy (1973) showed that the zero-tillage concept exerted profound effects on the population of annual weeds. He reported the reduction of many annual type weeds particularly those possessing a pronounced dormancy mechanism. Roberts and Dawkins (1967) reported that even though on cultivated land the number of viable seeds decreased faster than under zero-tillage, the amount of annual weed seedlings arising from those seeds was 7% from cultivated as compared to only 0.3% from zero-tillage land. Both workers (Roberts and Dawkins, 1967; Donaghy, 1973) attributed the reduction in seed germination to the elimination of seed trnasfer from deep in the soil to the germination zone. Kay and Owen (1970) reported that elimination of weeds by paraquat applications was more effective than when tillage was used since under tillage conditions weed seeds are placed under favorable germination conditions. Several researchers (Williams and Ross, 1970; Donaghy, 1973; Triplett and Lytle, 1972) reported a shift of weed populations from annual to perennial weeds because in the absence of tillage the underground propagules of perennial species were allowed to spread undisturbed. Darwent (1974a) reported good control of quack grass with tillage and crop competition. Darwent (1975a) also observed that more dense perennial weed infestations were experienced on zero-tillage plots in comparison to conventional cultivation. Effective chemical control of quack grass and Canada thistle has been reported with work done using glyphosate, paraquat and amitrole (Darwent, 1975c; Friesen, 1974; Sprankle, 1972).

Seeding Date

Donaghy (1973) recommended an evaluation of seeding and harvesting dates under zero-tillage due to differences in weed competition and crop response with zero-tillage as compared to conventional tillage production. Rahman and Ashford (1972) investigated green foxtail competition in wheat under a conventional tillage regime at various seeding dates. They found that competition occured at all three seeding dates, however, on the earliest date (May 6) the effects on wheat yield were insignificant. Sturko (1976) found that for both semidwarf (cv. Norquay) and normal stemmed (cv. Napayo) spring wheat, the competitive effects of green foxtail were more pronounced when seeding was delayed.

Bowden and Friesen (1967) found that their earliest seeding date (May 22) gave their best flax yield as it was affected by wild oat competition, this yield steadily decreased as the seeding date was delayed. They noted a trend of decreasing flax yield under weed free conditions as the seeding date was delayed but the trend was not as pronounced as when weeds were present. They suggested that wild oat competition occured even before crop emergence. Their conclusion is not in agreement with the work of Chancellor and Peters (1973) which indicated that wild oat competition did not occur before the four leaf stage of the crop, the exact stage depending on the density of the wild oat infestation.

Olson et al. (1941) studied the date of seeding of barley in Manitoba for three years and at four locations. They concluded that under usual environmental conditions early seeding (ie. as close to May 1 as possible) gave the best yields throughout most of Manitoba, except for the northern regions where seeding in the latter half of May gave the highest yields.

Work at the University of Manitoba (Buchannon, 1974) showed that the wheat varieties Pembina and Manitou yielded best when seeded in early May, however, these yields decreased as the seeding date was delayed. Conquest barley gave virtually equal yields, regardless of the date it was seeded between May 2 and June 6, whereas, the yield of Bonanza barley decreased dramatically as the seeding date was delayed beyond May 1.

Paraquat

Paraquat (1,1'-dimethyl-4;4'-bipyridylium-2A) is a nonvolatile fast acting contact herbicide the activity of which was first reported by Brian (1958). Paraquat is very readily inactivated by contact to the soil and, therefore, has no residual characteristics (Tu and Bollen, 1968).

The use of paraquat as a substitute for tillage is not new as success has been reported by Arnott et al. in 1966.

Slade (1966) observed that degradation of paraquat did not occur in the dark. He found that paraquat was degraded by photochemical decomposition on the surface of the leaf and not through metabolism by the plant.

Several workers (Donaghy, 1973; Appleby and Brenchley, 1968) have observed that seeds of annual grassy weeds laying on the soil surface were reduced in viability by application of paraquat. Tu and Bollen (1968) investigating the effect of paraquat on the microbial activities in the soil concluded that when paraquat was used as the label instructed, it had no deleterious effects on soil microorganisms and their activities important to soil fertility.

Paraquat is effective for controlling annual weeds, particularly annual grasses (Donaghy, 1973). Donaghy (1973) reported adequate control of annual grasses at 0.56 kg/ha and maximum control at 1.12 kg/ha. Using paraquat as a replacement for tillage in reduced tillage systems, Jeater and Laurie (1966) reported good broadspectrum weed control at 1.12 kg/ha.

Donaghy (1973) suggested mixing broadleaf herbicides with paraquat to increase the control spectrum and reported that paraquat plus diquat at 0.84 + 0.28 kg/ha, paraquat plus 2,4-D ester at 0.84 + 1.12 kg/ha, or bromoxynil and MCPA plus paraquat at 0.56 + 0.28 kg/ha could be utilized as a stale seedbed preparation.

Hughes and Cruikshank (1974) sprayed quack grass with rates of paraquat ranging from 0.56 to 3.36 kg/ha and reported inadequate quack grass control due to severe regrowth which followed the initial destruction of the foliage. Donaghy (1973) suggested that repeated burn off with several applications of this herbicide would be necessary to starve the underground storage organs of perennial weeds.

McKinlay _et al_. (1974) found that the phytotoxicity of low rates of paraquat (eg. 35 gm/ha) was improved if applied at low spray volumes such as 55 l/ha. These workers suggested that the low volume spraying provided more of a concentration gradient to the inside of the leaf and hence greater inward diffusive movement of the paraquat as compared to when large droplets are used. They also found that small droplets of approximately 100 μm containing paraquat were more effective than larger droplets and further observed that unlike the large droplets the small droplets produced little or no localized necrotic spots. Many other workers (Ennis and Williamson, 1968; McKinlay _et al_., 1972; Donaghy, 1973) reported similar findings. These workers are in agreement in that they felt that the smaller droplet sizes were more effective for two reasons 1) smaller droplets contact a larger leaf surface area hence facilitating greater penetration of the herbicide. Behrens (1957) directly substantiates this in his work which showed that if there was equal numbers of drops per unit leaf area then large and small drops were equally effective. 2) large droplets caused localized necrotic spots on leaves (physiological isolation) retarding inward movement of the paraquat and thus reducing the phytotoxicity.

Conflicting conclusions were reported by Douglas (1968) who showed that the optimal size droplet for paraquat was 400 - 500 μm, droplets larger or smaller than this size range had reduced activity. He also showed that smaller droplets applied under high humidity had increased activity as compared to applications made under low humidity. He concluded that for good uptake of paraquat a water bridge was necessary from the spray droplet to the leaf and therefore, the optimal size range or humid conditions provided the bridge necessary for an adequate length of time to facilitate total uptake.

Evans and Eckert (1965) found that additional surfactant increased the activity of paraquat but stated that the specific type of surfactant may vary with the plant target species.

Putnam and Ries (1968) noted that quack grass, which is difficult to wet, exhibited isolated necrotic spots when high rates of paraquat were applied with no additional surfactant. The addition of surfactant at 0.5% of the spray volume overcame this physiological isolation and increased the paraquat phytotoxicity to the quack grass.

Parker (1966) reported that the hardness of the water used as spray diluent affected paraquat activity. He compared tap and distilled water and showed that with increased calcium salt concentration paraquat activity decreased.

Bovey and Davis (1967) reported that the activity of paraquat was decreased by low temperatures and that rainfall ocurring within ten minutes of application also reduced the effectiviness of this herbicide.

Putnam and Ries (1968) observed that treatments applied in the evening were more effective than those applied in the morning. They suggested that paraquat which requires light and aerobic conditions for its manifestation moved in a non-toxic state into conductive cells in the absence of light. When aerobic conditions returned in the morning paraquat was activated within the plant resulting in a more efficient kill.

Glyphosate

Glyphosate [N-(phosphonomethyl) glycine] is a nonselective substituted glycine not having activity in the soil (Sprankle et al., 1975a). Sold under the trade name Roundup,[1] this foliar applied herbicide is formulated as an isopropylamine salt (Nelson, 1975). The usage of glyphosate was first reported by Baird et al. (1971) and at proposed rates gave excellent control of many perennial weeds. Sprankle et al. (1975a, b, c) showed that glyphosate was quickly inactivated in the soil because it was bound to the clay and organic matter through the phosphonic acid moiety. Sprankle et al. (1975b) found that with increased pH and/or phosphate level of the soil the inactivation of glyphosate was decreased. They suggested that the initial inactivation of glyphosate was a necessary prerequisite for the ensuing microbial degradation which readily followed. Sprankle et al. (1972) could show no soil residual glyphosate even when

[1]Monsanto Chemical Company

applied at 56.0 kg/ha.

Many workers (Freeman, 1975b; Nelson, 1975; Molberg, 1973) found that glyphosate is very effective on annual broadleaf and grassy weed species. Freeman (1975b) obtained good control of wild buckwheat, lady's thumb, lamb's quarters and red root pigweed with 0.56 kg/ha of glyphosate. Molberg (1973), however, felt that 0.56 kg/ha was not adequate for wild buckwheat control. Nelson (1975) investigating the retention of glyphosate suggested that 0.21 kg/ha, 0.14 kg/ha, 0.42 kg/ha and 0.28 - 0.48 kg/ha of glyphosate was required to control wild oats, green foxtail, wild buckwheat, and wild mustard respectively. Nelson (1975) also showed that these rates were more effective when additional surfactant (0.5% of spray volume) was utilized.

Sprankle (1975c) reported successful control of perennial weeds with glyphosate and attributed this success to rapid uptake and translocation of the active portion in sufficient quantities to kill the plant before metabolism could degrade it.

Corns and Egilsson (1974) reported that quack grass was best controlled with 1.68 - 2.80 kg/ha of glyphosate followed in one to fifteen days by a tillage operation. Darwent (1975c) reported good quack grass control with a similar dosage range (1.1 - 2.2 kg/ha), however, a tillage operation 3, 7, or 14 days after did not affect the performance of glyphosate.

When conducting experiments comparing plots under normal cultivation to zero-tillage plots, Darwent (1974c; 1975a, b) observed that the zero-tillage plots had denser quack grass infestations.

Friesen (1974) applied glyphosate to quack grass at the 8 cm stage in September and October. He noted that the low rates (0.56 and 1.12 kg/ha) gave much superior control when applied in September as compared to October. The higher rates (2.24 and 3.36 kg/ha) of glyphosate did not significantly differ with the month applied. He reported that all of the above treatments nearly tripled barley yields the following year.

Hughes and Cruikshank (1974) also investigated application rates of glyphosate and concluded that at least 1.68 kg/ha was needed for satisfactory control of quack grass.

Sprankle et al. (1975c) observed that glyphosate affected the target plant in the sites of highest metabolic activity. Darwent (1974c; 1975c) determined that the optimum stage of quack grass growth for glyphosate translocation to these sites and provide the best control was when the quack grass was in the shot blade stage.

Several workers (Friesen, 1974; Darwent, 1975b) found that the best time of year to control quack grass with glyphosate is in early fall (mid to late September). Sprankle et al. (1972) felt that they obtained maximum control of quack grass with a June application of glyphosate at 1.12 kg/ha followed in 30 days with 0.56 kg/ha.

Sprankle et al. (1975c) reported that additional surfactant hastened the uptake of glyphosate and hence the phytotoxicity to grassy weed species. Nelson (1975) similarly found that surfactant at 0.5% of the spray volume significantly increased glyphosate retention and phytotoxicity on grassy species but not broadleaf species.

Retention studies by Nelson (1975) further showed that glyphosate is most effective when applied at low spray volumes (e.g. 63 l/ha).

In tabled results, Monsanto have shown that the calcium salt concentration of the water used as the spray diluent had an effect on the activity of glyphosate (O'Sullivan, 1976). As the calcium salt concentration was increased, the activity of glyphosate was reduced, especially when applied at high water volumes.

MATERIALS and METHODS

Field Experiments Oak Bluff, 1975

Field experiments in 1975 (experiments 1 through 5) were conducted at Oak Bluff on a Red River Clay soil to study broad spectrum weed control in zero-tillage. Spring wheat (cv. Selkirk) was seeded on June 6 at a rate of 101 kg/ha into stubble land previously cropped to oats. The seeding operation was facilitated with model 620 International Harvester double disc press drill converted to a triple disc arrangement as shown in Figure 1.

Figure 1. Zero-tillage drill used for the seed placement operation.

The extra cutting coulter was added to aid penetration into a trashy surface, the double seeding discs then placed the seed about 6 cm deep in rows 15 cm apart. Fertilizer was drilled with the seed at a rate of 122 kg/ha of 11-48-0. Treatments were sprayed on June 12 with a compressed air push type bicycle sprayer at 5.6 Km/h delivering 55 l/ha at 245 kPa. The plots, 2 m x 6 m in size, were laid out in a randomized complete block experimental design having four replications.

Bulk density assessments (plant numbers/0.25 m^2 times the average plant height in cm) were taken on July 9. Visual rating assessments based on the 0-9 scale (Table 1) were taken on June 25 and again on September 2.

Experiment 1. Broadspectrum weed control in zero-tillage using Velpar, S15544 and dinoseb at Oak Bluff in 1975.

Herbicides were applied before the wheat emerged when the wild oats and wild mustard were in the 3-4 leaf stage and lady's thumb was in the four leaf stage. Quack grass was also present and at this time was 20-23 cm tall.

Experiment 2. Broadspectrum weed control in zero-tillage using paraquat in combination with bromoxynil, dicamba and Dowco 290 at Oak Bluff in 1975.

Herbicides were applied before the wheat emerged when the wild oats and wild mustard were in the 3-4 leaf stage and lady's thumb was in the 4-5 leaf stage.

Experiment 3. Broadspectrum weed control in zero-tillage using glyphosate in combination with Dowco 290, dicamba

TABLE 1. Visual rating scale

	Rating	Weed control	Crop tolerance
	0	No weed control	No crop tolerance (everything dead)
Not	1	Very slight evidence of weed control	Very slight crop tolerance
commercially	2	Slight evidence of weed control	Slight crop tolerance
acceptable	3	Very poor weed control	Very poor crop tolerance
range	4	Poor weed control	Poor crop tolerance
	5	Moderate weed control	Moderate crop tolerance
	6	Inadequate weed control	Inadequate crop tolerance
Commercially	7	Acceptable weed control	Acceptable crop tolerance
acceptable	8	Very good weed control	Very good crop tolerance
range	9	Complete weed control (all weeds dead)	Complete crop tolerance

and picloram at Oak Bluff in 1975.

Herbicides were applied before the wheat emerged when the wild oats were in the 4-5 leaf stage, wild mustard in the 3-4 leaf stage and lady's thumb in the 4-5 leaf stage.

Experiment 4. Broadspectrum weed control in zero-tillage using glyphosate in combination with bromoxynil + MCPA, and oxyfluorfen at Oak Bluff in 1975.

Herbicides were applied before the crop emerged when the wild oats were in the 4-5 leaf stage, wild mustard was in the 3-4 leaf stage and lady's thumb was in the 3-4 leaf stage.

Experiment 5. Quack grass control in zero-tillage using paraquat, and glyphosate alone and in combination with dicamba at Oak Bluff in 1975.

Herbicides were applied before the crop emerged and when the quack grass was 20-23 cm tall.

Field Experiments Graysville, 1975

Field experiments in 1975 (experiments 6 and 7) were conducted at Graysville on an Almassippi very fine sandy loam soil to study broadspectrum weed control in zero-tillage. Spring wheat (cv. Selkirk) was seeded on June 17 at a rate of 101 kg/ha into stubble land previously cropped to oats and not tilled since June of 1974. The seed placement operation was facilitated by the methods as outlined for Oak Bluff. A fertilizer mixture was drilled with the seed at a rate of 196 kg/ha of the equivalent of 25-30-0.

One week before seeding the quack grass was mowed to a 15 cm height to facilitate future spraying. Annual weeds, not having reached a 15 cm height, were left untouched. Herbicide applications were made June 23 using the same methods as described for Oak Bluff. The size and experimental design of the plots was also identical with those of Oak Bluff.

Bulk density assessments were taken on all plots on July 10 and visual ratings were made on July 2. Yield data was obtained on Oct. 2 by harvesting with a Hege 125 plot combine sampling 1.75 m X 6.0 m, drying this to 12% moisture and tabulating the result as grams of wheat per plot.

<u>Experiment 6</u>. Broadspectrum weed control in zero-tillage using glyphosate in combination with bromoxynil, nitrofen and oxyfluorfen at Graysville in 1975.

Herbicides were applied when the wild buckwheat and lady's thumb were in the 4-5 leaf stage and lamb's quarters was in the 5-6 leaf stage.

<u>Experiment 7</u>. Quack grass control in zero-tillage using paraquat and glyphosate alone and in combination with dicamba at Graysville in 1975.

Herbicides were applied when the quack grass was 15-18 cm tall. On Sept. 3 random 0.25 m^2 quadrants of vegetative samples of quack grass were extracted from each plot and dry weight determined for assessment purposes.

Field Experiments Carman Research Site, 1975

Field experiments in 1975 (experiments 8 through 11) were conducted at Carman on an Almassippi very fine sandy loam soil to study broadspectrum weed control in zero-tillage. Spring wheat (cv. Napayo) was seeded with a double disc press drill at a rate of 95 kg/ha into land previously cropped to oats. The site had been cultivated the previous fall, therefore, it was harrowed twice before seeding to level the resulting irregular surface yet not to disturb the subsoil. Fertilizer was drilled with the seed at a rate of 168 kg/ha of 11-48-0. Herbicide treatments were applied to the wild oats and wild mustard in the 3-4 leaf stage on May 26 with a compressed air push type bicycle sprayer by the procedures followed in Oak Bluff. Experimental design and plot size were also identical with that of Oak Bluff.

Visual rating assessments were made June 12 on wild oats and wild mustard control based on the 0-9 scale. On July 12 all four experiments received an overall application of Endaven at a rate of 1.12 kg/ha. The bicycle sprayer had a boom angled forward 45^{o} and delivering 55 l/ha at 310 kPa/cm^2. The wild oats were in various stages ranging from 4 leaf stage to heading.

Experiment 8. Broadspectrum weed control in zero-tillage with Velpar, S15544 and dinoseb at Carman in 1975.

Experiment 9. Broadspectrum weed control in zero-tillage with paraquat in combination with bromoxynil, dicamba and Dowco 290 at Carman in 1975.

Experiment 10. Broadspectrum weed control in zero-tillage with glyphosate in combination with Dowco 290, dicamba and picloram at Carman in 1975.

Experiment 11. Broadspectrum weed control in zero-tillage with glyphosate in combination with bromoxynil, nitrofen and oxyfluorfen at Carman in 1975.

Field experiments Carman Research Site 1976

Field experiments in 1976 (experiments 12 through 18b) were conducted at Carman on an Almassippi very fine sandy loam soil. Experiments 12, 13, 15, 17a and 17b were seeded to spring wheat (cv. Napayo) at a rate of 101 kg/ha with the triple disc zero-tillage drill. A fertilizer mixture was drilled with the seed at a rate of 157 kg/ha of the equivalent of 11-48-60. Herbicide application followed normal procedures to plots 2.5 m X 6 m in size and laid out in a randomized complete block experimental design having four replications. Experiments 17a and 17b were exceptions in that they had a split plot experimental design.

Visual rating, bulk density and yield evaluations were made periodically by the usual procedure as described previously.

Experiment 12. Broadspectrum weed control in zero-tillage using paraquat in combination with bromoxynil, dicamba and oxyfluorfen at Carman in 1976.

Spring wheat (cv. Napayo) was seeded on May 25 into stubble land previously cropped to wheat and not tilled since May of 1975.

Herbicide treatments were applied on May 27 to wild oats and lamb's quarters in the 6-7 leaf stage, wild mustard in the 5 leaf stage and wild buckwheat in the 3-4 leaf stage.

Bulk density assessments were made on June 3 and then plots were rated visually on June 8 and again on July 8.

Experiment 13. Broadspectrum weed control in zero-tillage using glyphosate in combination with bromoxynil, nitrofen dicamba and picloram at Carman in 1976.

Spring wheat (cv. Napayo) was seeded on May 25 into stubble land previously cropped to wheat and not tilled since May of 1975. Herbicide treatments were applied on May 27 to wild oats in the 5-6 leaf stage, lamb's quarters and wild mustard in the 6-7 leaf stage and wild buckwheat in the 4-5 leaf stage.

Bulk density assessments were made on June 2 then each plot visually rated on June 8 and again on July 7. Plots were harvested on August 26 by the procedures as outlined previously.

Experiment 14. Broadspectrum weed control in zero-tillage using glyphosate with additional surfactant in combination with bromoxynil, dicamba and picloram at Carman in 1976.

No crop was seeded in this experiment. The site was chosen for its uniform stand of weed populations. Wild oats in the 3-4 leaf stage and green foxtail and red root pigweed in the 4-5 leaf stage were sprayed with 110 l/ha on August 17. The plots were then rated visually on August 27 and the bulk densities determined on August 30.

Experiment 15. Broadspectrum weed control in zero-tillage using paraquat and glyphosate at Carman in 1976.

Spring wheat (cv. Napayo) was seeded on May 25 into stubble land previously cropped to faba beans and not tilled since May of 1975. Herbicide treatments were applied on May 27 to wild oats and lamb's quarters in the 6-7 leaf stage, wild mustard in the 5 leaf stage and wild buckwheat in the 3-4 leaf stage.

Bulk density assessments were made on June 2 and then each plot visually rated on June 10 and again on July 7. Plots were harvested on August 23 by the procedures as outlined previously.

Experiment 16. Broadspectrum weed control in zero-tillage using paraquat and glyphosate with additional surfactant at Carman in 1976.

No crop was seeded in this experiment. The site was chosen for its uniform stand of weed populations. Wild oats in the 3-4 leaf stage and green foxtail and red root pigweed in the 4-5 leaf stage were sprayed at 110 l/ha on August 17. The plots were then rated visually on August 27 and the bulk densities determined on August 30.

Experiment 17. The effect of the date of seeding and treatments of paraquat and glyphosate on weed populations in zero-tillage, a) no post-emergent treatments; b) with post-emergent applications of dichlofop methyl and MCPA.

Experiments 17a and 17b were laid out in a split plot experimental design having five dates of seeding as main plots and eight herbicide treatments as subplots replicated four times. Both experiments were seeded on the same predesignated dates with spring wheat (cv. Napayo) by the methods described, on stubble land previously cropped to wheat. Herbicides were applied within five days following the seeding operation and on the same date for both experiments 17a and 17b. Experiment 17a received no post-emergence herbicidal treatments, therefore, weed escapes and weed seeds germinating with the crop or later were still present to facilitate evaluation purposes. Experiment 17b received post-emergent treatments of dichlofop methyl at 1.12 kg/ha on June 16 and MCPA at 0.56 kg/ha on June 25.

May 3 Seeding Date. Herbicides were applied on May 6 to wild oats and wild buckwheat in the 1-2 leaf stage and wild mustard and lamb's quarters in the 2-3 leaf stage. The results were visually rated on May 27 for both experiments. Experiment 17b was visually rated again on June 22 whereas experiment 17a received a bulk density evaluation on July 12. Experiments 17a and 17b were harvested on August 18 and August 16 respectively.

May 10 Seeding Date. Herbicides were applied on May 11 to wild oats, wild mustard, lamb's quarters and wild buckwheat all in the 2-3 leaf stage. The results were visually rated on May 27 and May 28 for experiments 17a and 17b respectively. Experiment 17b was visually rated again on June 22 whereas experiment 17a received bulk density evaluation on July 14. Experiments 17a and 17b were harvested on August 18 and August 16 respectively.

May 17 Seeding Date. Herbicides were applied on May 19 to wild oats, wild mustard and wild buckwheat in the 3-4 leaf stage and lamb's quarters in the 4-5 leaf stage. The results were visually rated on May 27 for experiment 17a and May 28 for experiment 17b. Experiment 17b was visually rated again on June 22 whereas experiment 17a received a bulk density evaluation on July 14. Experiments 17a and 17b were harvested on August 18 and August 16 respectively.

May 24 Seeding Date. Herbicides were applied on May 27 to wild oats and wild mustard in the 3-4 leaf stage, lamb's quarters in the 6-7 leaf stage and wild buckwheat in the 4-5 leaf stage. The results were visually rated on June 3 for both experiments. Experiment 17b was visually rated again on June 24 whereas experiment 17a received a bulk density evaluation on July 14. Experiments 17a and 17b were harvested on August 23 and August 26 respectively.

May 31 Seeding Date. Herbicides were applied on June 1 to wild oats in the 4-6 leaf stage, wild mustard in the 4-5 leaf stage, lamb's quarters in the 6-7 leaf stage and wild buckwheat in the 8 - 10 leaf stage. The results were visually rated on June 8 for both experiments. Experiment 17b was visually rated again on June 24 whereas experiment 17a received a bulk density evaluation on July 14. Experiments 17a and 17b were harvested on August 23 and August 26 respectively.

Experiment 18. The effect of the hardness of water on the efficacy of glyphosate, a) with additional surfactant added to glyphosate; b) glyphosate with and without additional surfactant.

No crop was seeded in either experiment. The sites were chosen for the uniform stand of weed populations. Treatments consisted of two rates of glyphosate 0.14 and 0.28 kg/ha mixed with three classifications of water as spray diluent. The three classes of water; well water, tap water and distilled water were selected for their differences in degree of hardness. The properties of these three classes of water with respect to hardness were analyzed spectrochemically and the results depicted in Table 2. The above treatments were repeated within each experiment with "Calgon" a commercial water softener added to each at a rate of 2.5 g/l to reveal if softening the water had any effect on the activity of glyphosate. Additional surfactant (MON 0011) was also added to each treatment at a level of 0.5% of the total spray volume.

Experiment 18a was sprayed at 110 l/ha on June 28 when the wild oats were in the 2-3 leaf stage and wild mustard and wild buckwheat were in the 3-4 leaf stage. Bulk density assessments were made on July 7 and then visual ratings taken July 8.

Experiment 18b was sprayed at 110 l/ha on July 17 when the wild oats were in the 5-6 leaf stage, wild mustard was in the five leaf to flowering stage and green foxtail was in the 3-4 leaf stage. Visual ratings were made on July 27 and then bulk densities were determined on July 28.

Analysis of Variance

Experiments 17a and 17b were statistically analyzed using the split plot analysis for which their design was intended then using the standard error of difference to show statistical significance between treatments. All other experiments with the randomized complete block design were analyzed using Tukey's honestly significant difference at the 5% level (Snedecor and Cochran, 1976).

RESULTS and DISCUSSION

Experiment 1. Broadspectrum weed control in zero-tillage using Velpar, S15544 and dinoseb at Oak Bluff in 1975.

Weed control attained by several herbicide treatments is reported as visual ratings and crop bulk density assessments in Table 2.

Due to dense and patchy quack grass infestations crop evaluations made near the end of the season were very variable and none of the differences were significant at the 5% level.

Visual ratings of weed control showed that Velpar alone at all rates tested was inadequate for the control of wild oats and lady's thumb. Velpar gave satisfactory control of wild mustard at the highest rate (0.28 kg/ha) or when 2,4-D was added to either rate. Observations made during the season showed that all treatments containing Velpar had residual phytotoxicity to the wheat.

S15544 at both rates tested gave unsatisfactory control of all three weed species observed.

Dinoseb treatments (2.24 kg/ha and higher gave satisfactory results only for wild mustard control. The highest rate (6.71 kg/ha) was required for satisfactory wild oat control, however, at this rate severe phytotoxicity to the crop was noted.

The treatment glyphosate plus dicamba (0.28 + 0.14 kg/ha) gave good control of wild mustard and lady's thumb, whereas wild oat control

Table 2. Assessment of weed control using Velpar, S15544 and dinoseb

Treatment	Rate kg/ha	Crop Bulk[2] density	Visual rating[1] of weed control: Wild oats	Wild mustard	Lady's thumb
Weedy check		252	0	0	0
Velpar[3]	0.14	374	3	5	2
Velpar	0.28	8	4	7	1
Velpar + 2,4-D	0.14 + 0.56	331	4	8	7
Velpar + 2,4-D	0.28 + 0.56	220	5	8	5
S15544	3.36	247	4	4	3
S15544	4.48	104	4	3	2
Dinoseb	2.24	378	5	9	8
Dinoseb	4.48	495	6	8	5
Dinoseb	6.71	159	7	8	6
Glyphosate + Dicamba	0.28 + 0.14	261	6	8	8
Paraquat + Bromoxynil	0.28 + 0.28	588	8	8	5
Tukey's HSD (5%)		NS			

1. Visual ratings made June 25.
2. Crop bulk density taken July 9.
3. Spray applications made June 12.

was unsatisfactory. Unlike the above treatment paraquat + bromoxynil (0.28 + 0.28 kg/ha) gave unsatisfactory control only of lady's thumb.

Experiment 2. Broadspectrum weed control in zero-tillage using paraquat in combination with bromoxynil, dicamba and Dowco 290 at Oak Bluff in 1975.

Weed control attained by the several herbicide treatments is reported as visual ratings and crop bulk density assessments in Table 3.

The addition of bromoxynil plus MCPA to paraquat increased weed control of all three weed species, the effect of which was reflected in the relatively high crop yield. Paraquat when combined with oxyfluorfen gave better weed control as compared to paraquat alone. When in combination with the high rate (0.56 kg/ha) of oxyfluorfen a statistically significant yield reduction was noted. The addition of Dowco 290 to paraquat resulted in some enhancement of broadleaf weed control (wild mustard, lady's thumb) although yields were no better than paraquat alone. Similarly there was no higher yield when nitrofen (1.0 kg/ha) was added to 0.28 kg/ha of paraquat even though a substantial increase of wild oat, wild mustard and lady's thumb control was evident.

Experiment 3. Broadspectrum weed control in zero-tillage using glyphosate in combination with Dowco 290, dicamba and picloram at Oak Bluff in 1975.

Weed control attained by several herbicide treatments is reported as visual ratings and crop bulk density assessments in Table 4.

The visual ratings show that regardless of the mixture when

TABLE 3. Assessments of crop stand and weed control using glyphosate in combination with bromoxynil and MCPA, dicamba, oxyfluorfen and Dowco 290

		Crop stand		Visual ratings[1] of weed control		
Treatment	Rate kg/ha	Bulk[2] density	Visual rating	Wild oats	Wild mustard	Lady's thumb
Weedy check		245	9	0	0	0
Paraquat[3]	0.28	874	6	6	7	6
Paraquat	0.42	843	6	7	7	6
Paraquat + Bromoxynil and MCPA	0.28 + 0.28	1118	8	8	8	8
Paraquat + Bromoxynil and MCPA	0.42 + 0.28	1108	8	7	9	7
Paraquat + Dicamba	0.28 + 0.14	944	8	7	8	8
Paraquat + Dicamba	0.42 + 0.14	730	7	8	9	8
Paraquat + Oxyfluorfen	0.28 + 0.28	606	8	7	8	8
Paraquat + Oxyfluorfen	0.28 + 0.56	172	6	8	9	9
Paraquat + Dowco 290	0.28 + 0.14	916	6	6	7	7
Paraquat + Dowco 290	0.42 + 0.14	691	8	6	8	8
Paraquat + Nitrofen	0.28 + 1.0	884	7	8	8	8
TUKEY'S HSD (5%)		NS				

1. Visual ratings made June 25.
2. Crop bulk density taken July 9.
3. Spray applications made June 12.

TABLE 4. Assessments of crop stand and weed control using glyphosate in combination with Dowco 290, dicamba and picloram

Treatment	Rate kg/ha	Crop stand: Bulk[2] density	Crop stand: Visual rating	Visual ratings[1] of weed control: Wild oats	Visual ratings[1] of weed control: Wild mustard	Visual ratings[1] of weed control: Lady's thumb
Weedy check		1061	9	0	0	0
Glyphosate + Dowco 290[3]	0.14 + 0.14	1222	7	5	6	7
Glyphosate + Dowco 290	0.28 + 0.14	1020	8	7	7	8
Glyphosate + Dowco 290	0.42 + 0.14	1104	8	8	9	8
Glyphosate + Dicamba	0.14 + 0.14	880	6	6	8	8
Glyphosate + Dicamba	0.28 + 0.07	1090	8	8	9	8
Glyphosate + Dicamba	0.28 + 0.14	864	7	8	8	8
Glyphosate	0.42	1131	8	8	8	9
Glyphosate + Dicamba	0.42 + 0.14	989	8	8	9	9
Glyphosate + Picloram	0.14 + 0.035	670	7	5	5	6
Glyphosate + Picloram	0.28 + 0.035	1009	8	8	8	8
Glyphosate + Picloram	0.42 + 0.035	1083	8	8	9	9
TUKEY'S HSD (5%)		NS				

1. Visual ratings made June 25.
2. Crop bulk densities taken July 9.
3. Spray applications made June 12.

the glyphosate level is 0.14 kg/ha, inadequate weed control is generally the case. When glyphosate is applied at 0.42 kg/ha there was very good control of wild oats, wild mustard and lady's thumb and the addition of the broadleaf herbicides did not significantly improve this control. The addition of Dowco 290 (0.14 kg/ha), dicamba (0.07 kg/ha), or picloram (0.035 kg/ha) to 0.28 kg/ha of glyphosate gave very good weed control giving results similar to that attained by 0.42 kg/ha of glyphosate alone.

Experiment 4. Broadspectrum weed control in zero-tillage using glyphosate in combination with bromoxynil plus MCPA, nitrofen and oxyfluorfen at Oak Bluff in 1975.

Weed control attained by several herbicide treatments is reported as visual ratings and crop bulk density assessment in Table 5.

When glyphosate was applied in combination with bromoxynil and MCPA, wild oats, wild mustard and lady's thumb control was very good in all cases even when the rate of glyphosate was 0.14 kg/ha. When nitrofen (1.0 kg/ha) was in combination with glyphosate very good control of wild oats, wild mustard and lady's thumb occurred, however, wild oat control was unsatisfactory when the level of glyphosate was 0.14 kg/ha. The same observation was noted in mixtures with oxyfluorfen. Although excellent weed control was obtained using oxyfluorfen at 0.28 kg/ha, some injury to the crop was observed.

TABLE 5. Assessments of crop stand and weed control using glyphosate in combination with bromoxynil and MCPA, nitrofen and oxyfluorfen

Treatment	Rate kg/ha	Crop stand		Visual ratings[1] of weed control		
		Bulk[2] density	Visual ratings	Wild oats	Wild mustard	Lady's thumb
Weedy check		742	9	0	0	0
Glyphosate + Bromoxynil and MCPA	0.14 + 0.28	1055	8	7	9	9
Glyphosate + Bromoxynil and MCPA	0.28 + 0.14	719	7	7	9	9
Glyphosate + Bromoxynil and MCPA	0.28 + 0.28	1091	7	7	9	9
Glyphosate + Bromoxynil and MCPA	0.42 + 0.28	980	8	8	9	9
Glyphosate + Nitrofen	0.14 + 1.0	907	6	5	8	8
Glyphosate + Nitrofen	0.28 + 1.0	1448	8	7	8	8
Glyphosate + Nitrofen	0.42 + 1.0	1202	7	8	9	9
Glyphosate + Oxyfluorfen	0.14 + 0.28	792	6	6	8	8
Glyphosate + Oxyfluorfen	0.28 + 0.28	680	8	8	9	9
Glyphosate + Oxyfluorfen	0.42 + 0.28	960	8	8	9	9
Glyphosate	0.42	1260	8	8	9	9
TUKEY'S HSD (5%)		683				

1. Visual ratings made June 25.
2. Crop bulk density taken July 9.
3. Spray applications made June 12.

Experiment 5. Quack grass control in zero-tillage using paraquat, and glyphosate alone, and in combination with dicamba at Oak Bluff in 1975.

Due to the irregular distribution of the quack grass infestations, assessments made later in the season were extremely variable and therefore not valid. For this reason only one early assessment of quack grass control is presented. These results are reported as visual ratings in Table 6.

The results show that to obtain adequate control of quack grass with glyphosate, a rate of at least 1.12 kg/ha is required. Addition of dicamba (0.14 kg/ha) to glyphosate 0.42, 0.56 and 0.84 kg/ha) gave some improved phytotoxicity to the quack grass possibly because the surfactant supplied in the dicamba formulation aided penetration of the glyphosate. Paraquat applied at a rate of 1.12 kg/ha gave very good initial burn off of the quack grass, however, observations made later in the season showed that regrowth occurred much more in this treatment compared to the glyphosate treatments.

Experiment 6. Broadspectrum weed control in zero-tillage using glyphosate in combination with bromoxynil, nitrofen, and oxyfluorfen at Graysville in 1975.

Weed control attained by several herbicide treatments is reported as visual ratings and crop yield assessments in Table 7.

The wheat yield obtained with the glyphosate plus bromoxynil (0.42 + 0.28 kg/ha) treatment was significantly the best in the experiment. Initial weed control was very good at only 0.28 kg/ha of glyphosate

TABLE 6. Visual assessments of quack grass control using glyphosate, glyphosate plus dicamba, and paraquat

Treatments		Rate kg/ha	Visual rating[1] of quack grass control
1	Weedy check		0
2	Glyphosate[2]	0.84	5
3	Glyphosate	1.12	7
4	Glyphosate	1.68	8
5	Glyphosate + Dicamba	0.42 + 0.14	5
6	Glyphosate + Dicamba	0.56 + 0.14	5
7	Glyphosate + Dicamba	0.84 + 0.14	6
8	Paraquat	1.12	8

1. Visual ratings made June 25.
2. Spray applications made June 12.

TABLE 7. Assessments of crop yield and weed control using glyphosate in combination with bromoxynil, nitrofen and oxyfluorfen

		Crop stand		Visual ratings[1] of weed control		
Treatment	Rate kg/ha	Yield[2] kg/ha	Bulk[3] density	Wild buckwheat	Lamb's quarters	Lady's thumb
Weedy check		38	447	0	0	0
Glyphosate + Bromoxynil[4]	0.14 + 0.28	297	799	7	7	7
Glyphosate + Bromoxynil	0.28 + 0.14	365	807	6	7	8
Glyphosate + Bromoxynil	0.28 + 0.28	412	806	7	8	8
Glyphosate + Bromoxynil	0.42 + 0.28	925	1507	7	8	8
Glyphosate + Nitrofen	0.14 + 1.0	313	775	6	6	6
Glyphosate + Nitrofen	0.28 + 1.0	782	807	7	7	8
Glyphosate + Nitrofen	0.42 + 1.0	802	1109	7	7	8
Glyphosate + Oxyfluorfen	0.14 + 0.28	287	627	7	7	7
Glyphosate + Oxyfluorfen	0.28 + 0.28	298	633	8	7	8
Glyphosate + Oxyfluorfen	0.42 + 0.28	308	707	6	7	6
Glyphosate	0.42	795	1155	5	6	5
TUKEY'S HSD (5%)		130	174			

1. Visual ratings made July 2.
2. Crop yield taken October 2.
3. Bulk density taken July 10.
4. Spray applications made June 23.

when applied with 0.28 kg/ha of bromoxynil. Weed control trends from mixtures with nitrofen were similar to mixtures with bromoxynil in that significantly higher yields were obtained when the level of glyphosate was 0.42 kg/ha. Initial weed control was again very good even when the level of glyphosate was only 0.28 kg/ha. The control of wild buckwheat, lamb's quarters and lady's thumb from the oxyfluorfen mixtures was inconsistant but generally satisfactory. A significant depression of crop yield, however, resulted from the oxyfluorfen treatments as compared to glyphosate alone.

Experiment 7. Quack grass control in zero-tillage using paraquat, and glyphosate alone and in combination with dicamba at Graysville in 1975.

Quack grass control attained by the herbicide treatments is reported as crop yield, bulk density and visual rating assessments in Table 8.

The results show that satisfactory control of quack grass required at least 1.12 kg/ha of glyphosate. Significantly superior crop yield resulted from a 1.68 kg/ha treatment of glyphosate as compared to all other treatments. Addition of dicamba improved the phytotoxicity of the low rates (0.42, 0.56 and 0.84 kg/ha) of glyphosate to quack grass. A corresponding increase of crop yield, however, did not result. Quack grass control with paraquat at 1.12 kg/ha was very poor.

TABLE 8. Assessment of crop stand and quack grass control using glyphosate, glyphosate plus dicamba, and paraquat

Treatment	Rate kg/ha	Crop Stand		Quack Grass	
		Yield[1] kg/ha	Bulk[2] density	Bulk density	Visual[3] rating
Weedy Check		19	466	2906	0
Glyphosate[4]	0.84	246	800	395	4
Glyphosate	1.12	451	1016	144	7
Glyphosate	1.68	532	1453	23	8
Glyphosate + Dicamba	0.42 + 0.14	197	885	418	6
Glyphosate + Dicamba	0.56 + 0.14	235	916	272	7
Glyphosate + Dicamba	0.84 + 0.14	303	1419	215	7
Paraquat	1.12	143	477	1508	3
Tukey's HSD (5%)		77	183	127	

[1]Crop yield taken Oct. 2
[2]Bulk densities taken July 10
[3]Visual ratings July 2
[4]Spray applications made June 23

Experiment 8. Broadspectrum weed control in zero-tillage with Velpar, S15544 and dinoseb at Carman in 1975.

Weed control attained by several herbicide treatments is reported as visual rating assessments in Table 9.

All treatments containing Velpar gave poor general weed control and also were observed to be phytotoxic to the crop. S15544 also gave poor control of wild oats and wild mustard although acceptable wild mustard control occurred at 4.48 kg/ha. There was good control of wild mustard with dinoseb at 2.24 kg/ha, whereas, good control of wild oats required 6.71 kg/ha. At the latter rate of dinoseb, severe phytotoxicity was observed to occur to the wheat. Glyphosate plus dicamba (0.28 + 0.28 kg/ha) gave good control of both wild oats and wild mustard. Inadequate wild oat control was observed in the paraquat plus bromoxynil (0.28 + 0.28 kg/ha) treatment, however, wild mustard control was satisfactory. Unsatisfactory wild oat control was attributed to the fact that this weed was in an advanced stage when sprayed.

Experiment 9. Broadspectrum weed control in zero-tillage with paraquat in combination with bromoxynil, dicamba and Dowco 290 at Carman in 1975.

Weed control attained by several herbicide treatements is reported as visual rating assessments in Table 10.

The results show that paraquat alone at rates up to 0.42 kg/ha was inadequate for the control of wild oats or wild mustard. Addition of bromoxynil (0.14 kg/ha and higher) provided very good wild mustard

TABLE 9. Visual ratings of weed control using Velpar, S15544, and dinoseb

Treatment	Rate kg/ha	Visual ratings[1]	
		Wild oats	Wild mustard
Weedy check		0	0
Velpar[2]	0.14	4	4
Velpar	0.28	4	6
Velpar + 2,4-D	0.14 + 0.56	3	7
Velpar + 2,4-D	0.28 + 0.56	3	8
S15544	3.36	3	6
S15544	4.48	3	7
Dinoseb	2.24	3	7
Dinoseb	4.48	6	9
Dinoseb	6.71	7	9
Glyphosate + Dicamba	0.28 + 0.28	7	8
Paraquat + Bromoxynil	0.28 + 0.28	5	7

1. Visual ratings made June 12.
2. Spray applications made May 26.

TABLE 10. Visual ratings of weed control using paraquat in combination with bromoxynil, dicamba and Dowco 290

Treatment	Rate kg/ha	Visual ratings[1] Wild oats	Wild mustard
Weedy check		0	0
Paraquat[2]	0.28	4	3
Paraquat	0.42	5	4
Paraquat + Bromoxynil	0.42 + 0.28	6	7
Paraquat + Bromoxynil	0.42 + 0.14	6	8
Paraquat + Dicamba	0.28 + 0.14	6	7
Paraquat + Dicamba	0.42 + 0.14	7	8
Paraquat + Dicamba	0.28 + 0.28	8	8
Paraquat + Oxyfluorfen	0.28 + 0.56	8	9
Paraquat + Dowco 290	0.28 + 0.14	6	5
Paraquat + Dowco 290	0.42 + 0.14	5	5
Paraquat + Nitrofen	0.28 + 1.0	6	4

1. Visual ratings made June 12.
2. Spray applications made May 26.

control, however, wild oat control remained inadequate. Paraquat in combination with dicamba gave greatly enhanced activity on both weeds as compared to 0.28 or 0.42 kg/ha of paraquat alone. The best control was obtained when the level of dicamba was 0.28 kg/ha. Tank mixing paraquat with oxyfluorfen gave excellent control of both weeds but poor crop tolerance was observed throughout the season. Application of paraquat in combination with either Dowco 290 or nitrofen failed to improve wild oat or wild mustard control to an acceptable level.

Experiment 10. Broadspectrum weed control in zero-tillage with glyphosate in combination with Dowco 290, dicamba and picloram at Carman in 1975.

Weed control obtained by several herbicide treatments is reported as visual rating assessments in Table 11.

Glyphosate in combination with Dowco 290 (0.14 kg/ha) gave satisfactory wild oat and wild mustard control when the level of glyphosate was at least 0.28 kg/ha. The wild oat and wild mustard control obtained by this treatment was equal to that from 0.42 kg/ha of glyphosate alone. Dicamba at 0.07 kg/ha gave good control of wild mustard if combined with at least the 0.28 kg/ha of glyphosate required for good wild oat control. The addition of picloram (0.035 kg/ha) to glyphosate gave slightly better wild mustard control when combined with 0.42 kg/ha of glyphosate as compared to 0.42 kg/ha of glyphosate alone.

TABLE 11. Visual ratings of weed control using glyphosate in combination with Dowco 290, dicamba and picloram

Treatment	Rate kg/ha	Visual ratings[1] Wild oats	Wild mustard
Weedy check		0	0
Glyphosate + Dowco 290[2]	0.14 + 0.14	6	6
Glyphosate + Dowco 290	0.28 + 0.14	7	7
Glyphosate + Dowco 290	0.42 + 0.14	8	9
Glyphosate + Dicamba	0.14 + 0.14	5	7
Glyphosate + Dicamba	0.28 + 0.07	7	7
Glyphosate + Dicamba	0.28 + 0.14	7	8
Glyphosate	0.42	7	7
Glyphosate + Dicamba	0.42 + 0.14	8	9
Glyphosate + Picloram	0.14 + 0.035	6	6
Glyphosate + Picloram	0.28 + 0.035	6	6
Glyphosate + Picloram	0.42 + 0.035	7	8

1. Visual ratings made June 12.
2. Spray applications made May 26.

<u>Experiment 11</u>. Broadspectrum weed control in zero-tillage with glyphosate in combination with bromoxynil, nitrofen and oxyfluorfen at Carman in 1975.

Weed control attained by several herbicide treatments is reported as visual rating assessments in Table 12.

Glyphosate in combination with bromoxynil (0.14 kg/ha and higher) gave very good wild mustard control, however, adequate wild oat control required a level of 0.28 kg/ha of glyphosate mixed with 0.28 kg/ha of bromoxynil. Addition of 1.0 kg/ha of nitrofen to 0.42 kg/ha of glyphosate did not improve the effectiveness of 0.42 kg/ha of glyphosate alone to either wild oats or wild mustard. Tank mixing oxyfluorfen at 0.28 kg/ha with glyphosate at 0.14 kg/ha and higher gave very good control of the two monitored weeds. Observation of the plots throughout the season showed that a detrimental effect to the crop was evident in all cases where oxyfluorfen was applied.

<u>Experiment 12</u>. Broadspectrum weed control in zero-tillage using paraquat in combination with bromoxynil, dicamba and oxyfluorfen at Carman in 1976.

Weed control attained by several herbicide treatments applied in the spring (May 27) is reported as bulk density assessments in Table 13.

The results of wild oat control show that 0.28 kg/ha of paraquat gave unsatisfactory control. Addition of any of the three broadleaf herbicides: bromoxynil (0.28 kg/ha), dicamba (0.14 kg/ha) or oxyfluorfen (0.28 kg/ha) significantly improved the phytotoxicity to

TABLE 12. Visual ratings of weed control using glyphosate in combination with bromoxynil, nitrofen and oxyfluorfen

Treatment	Rate kg/ha	Visual ratings[1] Wild oats	Wild mustard
Weedy check		0	0
Glyphosate + Bromoxynil[2]	0.14 + 0.28	6	8
Glyphosate + Bromoxynil	0.28 + 0.14	6	8
Glyphosate + Bromoxynil	0.28 + 0.28	7	8
Glyphosate + Bromoxynil	0.42 + 0.28	8	8
Glyphosate + Nitrofen	0.14 + 1.0	6	6
Glyphosate + Nitrofen	0.28 + 1.0	7	8
Glyphosate + Nitrofen	0.42 + 1.0	7	8
Glyphosate + Oxyfluorfen	0.14 + 0.28	8	9
Glyphosate + Oxyfluorfen	0.28 + 0.28	8	8
Glyphosate + Oxyfluorfen	0.42 + 0.28	8	9
Glyphosate	0.42	7	8

1. Visual ratings made June 12.
2. Spray applications made May 26.

TABLE 13. Bulk density assessments of weed control using paraquat in combination with bromoxynil, dicamba and oxyfluorfen

Treatment	Rate kg/ha	Bulk densty evaluations[1]			
		Wild oats[2]	Wild mustard	Lamb's quarters[2]	Wild buckwheat
Weedy check		295	182	79	33
Paraquat[3]	0.28	108	15	10	21
Paraquat	0.42	37	5	3	19
Paraquat + Bromoxynil	0.28 + 0.28	54	2	2	4
Paraquat + Bromoxynil	0.42 + 0.28	13	13	0	1
Paraquat + Dicamba	0.28 + 0.14	45	18	4	13
Paraquat + Dicamba	0.42 + 0.14	37	4	0	21
Paraquat + Oxyfluorfen	0.28 + 0.28	17	15	4	15
Paraquat + Oxyfluorfen	0.28 + 0.42	75	8	5	9
Paraquat + Oxyfluorfen	0.28 + 0.56	10	16	1	14
TUKEY'S HSD (5%)		37	25	9	15

1. Bulk density taken June 3.
2. Weedy check was not included in statistical analysis.
3. Spray applications made May 27.

wild oats of the low rate (0.28 kg/ha) of paraquat to a level statistically equal to that attained by 0.42 kg/ha of paraquat alone. Addition of the above mentioned herbicides did not significantly improve the phytotoxicity of 0.42 kg/ha of paraquat alone to wild oats, wild mustard, or lamb's quarters. Lamb's quarters and wild mustard control was maximum with 0.28 kg/ha of paraquat alone and the addition of any of the three broadleaf herbicides did not significantly improve the control of these two weeds. Significantly superior wild buckwheat control was obtained only with the addition of 0.28 kg/ha of bromoxynil to either 0.28 or 0.42 kg/ha of paraquat as compared to 0.28 or 0.42 kg/ha of paraquat alone.

It is evident that 0.28 kg/ha of paraquat alone is not sufficient for broadspectrum control in zero-tillage. The addition of one of the above broadleaf herbicides is necessary at this low rate but not at 0.42 kg/ha of paraquat. Addition of specifically bromoxynil may be necessary if wild buckwheat is a problem.

Experiment 13. Broadspectrum weed control in zero-tillage using glyphosate in combination with bromoxynil, oxyfluorfen, dicamba and picloram at Carman in 1976.

Weed control attained by several herbicide treatments applied in the spring (May 25) is reported as crop yield and bulk density assessments in Table 14.

Excellent control of wild oats, wild mustard, lamb's quarters and wild buckwheat was obtained when 0.28 kg/ha of bromoxynil was in combination with 0.28 kg/ha and higher of glyphosate. Addition of oxyfluorfen (0.28 kg/ha) gave very good control of the four weed

TABLE 14. Crop yield and weed control assessments using glyphosate in combination with bromoxynil, oxyfluorfen, dicamba and picloram.

Treatment	Rate kg/ha	Crop yield kg/ha	Bulk density evaluations[2] Wild oats[3]	Wild mustard[3]	Lamb's quarters	Wild buckwheat
Weedy check		117	203	464	93	27
Glyphosate + Bromoxynil[4]	0.28 + 0.28	570	14	10	0	0
Glyphosate + Bromoxynil	0.42 + 0.28	454	3	2	0	2
Glyphosate + Oxyfluorfen	0.14 + 0.28	238	48	150	3	2
Glyphosate + Oxyfluorfen	0.28 + 0.28	542	20	24	14	3
Glyphosate + Oxyfluorfen	0.42 + 0.28	634	3	3	2	3
Glyphosate + Dicamba	0.14 + 0.14	264	23	39	5	8
Glyphosate + Dicamba	0.28 + 0.07	484	33	33	12	9
Glyphosate + Dicamba	0.28 + 0.14	527	39	18	2	3
Glyphosate + Picloram	0.28 + 0.035	489	33	7	2	6
Glyphosate + Picloram	0.42 + 0.035	564	3	4	5	1
Glyphosate	0.42	547	2	2	5	2
TUKEY'S HSD (5%)		254	26	29	9	10

1. Crop yield taken August 26.
2. Bulk density taken June 2.
3. Weedy check was not included in statistical analysis.
4. Spray applications made May 27.

species observed when combined with at least 0.28 kg/ha of glyphosate. A statistically significant increase in yield is shown when the rate of glyphosate is increased from 0.14 kg/ha to 0.28 kg/ha when in combination with oxyfluorfen (0.28 kg/ha). The yield of mixtures containing 0.14 kg/ha of dicamba were significantly improved when the rate of glyphosate was increased to 0.28 kg/ha from 0.14 kg/ha. The addition of 0.035 kg/ha of picloram gave very good broadleaf weed control (wild mustard, lamb's quarters, wild buckwheat) whereas an effect on wild oat control could not be observed.

No evidence is present to indicate that addition of any of the four broadleaf herbicides increased the activity of 0.42 kg/ha of glyphosate when compared to that rate of glyphosate alone.

Experiment 14. Broadspectrum weed control in zero-tillage using glyphosate with additional surfactant in combination with bromoxynil, dicamba and picloram at Carman in 1976.

Weed control attained by several herbicide treatments applied in late summer (August 17) is reported as bulk density assessments in Table 15. Due to rainfall encountered three hours after application the weed control was decreased from that expected.

Evidence shows that when bromoxynil (0.28 kg/ha), dicamba (0.14 kg/ha) or picloram (0.035 kg/ha) are mixed with glyphosate the rate of the latter herbicide must be at least 0.28 kg/ha for good general weed control. It is also apparent that when bromoxynil or picloram are added to 0.42 kg/ha of glyphosate no significance is shown indicating improved weed control compared to 0.42 kg/ha of glyphosate alone.

TABLE 15. Bulk density assessments of weed control using glyphosate with additional surfactant in combination with bromoxynil, dicamba and picloram

Treatment	Rate kg/ha	Bulk Density Evaluations[1]		
		Wild oats[2]	Green foxtail[2]	Red root pigweed[2]
Weedy check		1853	179	119
Glyphosate + Bromoxynil[3]	0.28 + 0.28	80	16	17
Glyphosate + Bromoxynil	0.42 + 0.28	47	5	2
Glyphosate + Bromoxynil[4]	0.28 + 0.28	105	19	16
Glyphosate + Dicamba[4]	0.14 + 0.14	667	26	31
Glyphosate + Dicamba[4]	0.28 + 0.07	235	10	4
Glyphosate + Dicamba	0.14 + 0.14	320	54	32
Glyphosate + Dicamba	0.28 + 0.07	135	38	13
Glyphosate + Dicamba	0.28 + 0.14	242	14	0
Glyphosate + Picloram	0.28 + 0.035	106	4	0
Glyphosate + Picloram	0.42 + 0.035	29	5	0
Glyphosate	0.42	25	8	0
TUKEY'S HSD (5%)		101	23	18

1. Bulk density taken August 30.
2. Weedy check was not included in statistical analysis.
3. Spray applications made August 17.
4. All treatments received additional surfactant <u>except</u> these.

The influence of additional surfactant (0.5% of spray volume) on the activity of the bromoxynil mixture although not statistically significant shows a trend which strongly suggests increased activity to wild oats, whereas, enhanced activity to green foxtail or red root pigweed is not apparent. The same observation is true with respect to the dicamba mixtures where statistical significance indicates increased control of wild oats with the addition of surfactant.

Experiment 15. Broadspectrum weed control in zero-tillage using paraquat and glyphosate at Carman in 1976.

Weed control attained by paraquat and glyphosate treatments applied in the spring (May 25) is reported as crop yield and weed bulk density assessments in Table 16.

Treatments of paraquat applied alone show that very good control of lamb's quarters and wild buckwheat occurred at 0.42 kg/ha, whereas, 0.56 kg/ha was required to adequately control wild oats and wild mustard. The relatively poor wild oat control can be partially explained by the fact that this weed was in an advanced stage when sprayed (6-7 leaf stage).

Weed control with glyphosate applied alone did not show significantly increased activity to wild oats, wild mustard or lamb's quarters at rates higher than 0.28 kg/ha of glyphosate. The trend of wild buckwheat control strongly suggests that for good control a rate of 0.56 kg/ha of glyphosate is required. It is important to note that direct comparison of paraquat vs. glyphosate showed that for wild oat control 0.28 and 0.42 kg/ha of glyphosate were significantly better than the equivalent rates of paraquat. Yield

TABLE 16. Crop yield and weed control using paraquat and glyphosate

Treatment	Rate kg/ha	Crop[2] yield kg/ha	Bulk density evaluation[1]			
			Wild oats	Wild mustard	Lamb's quarters	Wild buckwheat
Weedy check		96	164	69	6	24
Paraquat[3]	0.28	437	101	15	2	26
Paraquat	0.42	938	41	22	2	3
Paraquat	0.56	748	5	21	0	7
Paraquat	0.84	1208	23	7	0	0
Glyphosate	0.28	896	12	13	3	21
Glyphosate	0.42	864	8	23	4	15
Glyphosate	0.56	1004	5	19	0	5
Glyphosate	0.84	1187	0	4	0	3
TUKEY'S HSD (5%)		327	27	23	6	14

1. Bulk density taken June 23.
2. Crop yield taken August 23.
3. Spray applications made May 27.

comparisons show that 0.28 kg/ha of glyphosate was statistically better than the equivalent rate of paraquat, furthermore, no treatment gave significantly higher yields than this low rate (0.28 kg/ha) of glyphosate.

Experiment 16. Broadspectrum weed control in zero-tillage using paraquat and glyphosate with additional surfactant at Carman in 1976.

Weed control attained by paraquat and glyphosate treatments applied in late summer (August 17) is reported as bulk density assessments in Table 17. Due to rainfall encountered three hours after application the weed control of the glyphosate treatments was decreased from that expected. As the effectiveness of paraquat is not reduced in this manner direct comparison of paraquat vs. glyphosate is not valid.

The control of wild oats and red root pigweed was very good with a rate of paraquat at 0.28 kg/ha and higher. The highest rate of paraquat (0.84 kg/ha), however, was required to give good control of green foxtail possibly because this weed was in an advanced leaf stage (4-5 leaf stage) when sprayed.

Control of the grassy weeds (wild oats and green foxtail) was inadequate at all three tested rates of glyphosate when no additional surfactant was utilized. Similarly control of the aforementioned weeds was inadequate at 0.28 kg/ha of glyphosate when supplementary surfactant was utilized. These results were undoubtedly influenced by the rainfall occurance following herbicide application. Trends of wild oat and green foxtail control suggest that additional

TABLE 17. Weed control using treatments of paraquat, and glyphosate with additional surfactant

Treatment	Rate kg/ha	Bulk density evaluations[1] Wild oats	Green foxtail	Red root pigweed
Weedy check		237	201	47
Paraquat[2]	0.28	17	42	3
Paraquat	0.42	5	34	0
Paraquat	0.56	3	19	0
Paraquat	0.84	0	4	0
Glyphosate[3]	0.28	32	76	1
Glyphosate[3]	0.42	6	47	0
Glyphosate[3]	0.56	4	8	0
Glyphosate[3]	0.84	0	1	0
Glyphosate	0.28	19	132	4
Glyphosate	0.42	17	25	0
Glyphosate	0.56	15	10	0
TUKEY'S HSD (5%)		19	24	9

1. Bulk density taken August 30.
2. Spray applications made August 17.
3. Received additional surfactant.

surfactant (MON 0011 at 5% of spray solution) increased the activity of low rates of glyphosate on these weeds.

<u>Experiment 17</u>. The effect of the date of seeding and treatments of paraquat and glyphosate on weed populations in zero-tillage, a) with no post-emergence treatments.

<u>Wild Oat Control</u>. The results of the effect of seeding date and herbicide treatment on wild oat control is reported as bulk density assessments in Table 18. Due to experimental error of design and/or evaluation of the May 31 seeding date, the intial wild oat population (ie. the weedy check) was not as large as expected. For this reason wild oat control appears in the seeding date means to be better that it actually is when compared to the other dates. Wild oat control also is deceivingly good on May 17 because the first rain of the season which fell on May 13-15 induced the germination of the first flush of wild oats. This flush was sprayed in the early stages of growth on May 19 for the May 17 seeding date, whereas, the earlier seeding dates already received pre-emergence treatments. Disregarding the wild oat control of the May 17 and May 31 seeding dates for the above reasons cited it is apparent that as seeding date (spray date) is delayed wild oat control significantly decreases.

Analysis of the treatment means show statistical evidence that the best treatment for wild oat control prior to crop emergence was with glyphosate alone at 0.28 kg/ha and higher.

<u>Wild Mustard Control</u>. The results of the effect of seeding date and herbicide treatment on wild mustard control is reported as bulk

TABLE 18. Bulk density assessment of wild oat control as influenced by date of seeding and treatments of paraquat and glyphosate

Treatment	Rate kg/ha	Wild oat populations in bulk density units — Seeding dates: May 3	May 10	May 17	May 24	May 31	Overall treatment means
Weedy check		1202	1670	1803	5197	2254	2425
Paraquat	0.28	326	1054	433	1170	125	621
Paraquat	0.42	487	263	114	768	417	410
Glyphosate	0.28	293	565	240	100	21	244
Glyphosate	0.42	201	192	325	277	7	200
Glyphosate	0.84	362	256	448	60	12	227
Glyphosate + Dicamba	0.28 + 0.14	407	338	221	287	233	297
Paraquat + Bromoxynil	0.28 + 0.28	383	1650	178	268	296	555
Seeding date means		458	748	470	1016	420	622

STANDARD ERRORS OF DIFFERENCES (p = 0.05)
Between two seeding date means 49
Between two treatment means 54
Between two treatments within one seeding date 121
Between any two treatments in different seeding dates 123

density assessments in Table 19.

The control of wild mustard in zero-tillage as affected by seeding date (spray date) was found to be identical to that previously explained for wild oat control.

Statistical evidence in the treatment means show that for good control of wild mustard, paraquat was better when compared to equal rates of glyphosate. Paraquat applied at 0.28 kg/ha gave significantly better results than all glyphosate treatments except for 0.84 kg/ha. The addition of dicamba (0.14 kg/ha) significantly improved the wild mustard control of 0.28 kg/ha glyphosate, whereas, bromoxynil (0.28 kg/ha) did not increase the activity of that rate of paraquat on wild mustard.

Lamb's Quarters Control. The results of the effect of seeding date and herbicide treatment on lamb's quarters control is reported as visual assessments in Table 20. Due to a high coefficient of variability bulk density assessments were not statistically valid.

Visual ratings show that lamb's quarters control was very good on all dates even at the lowest rate (0.28 kg/ha) of glyphosate or paraquat.

Wild Buckwheat Control. The results of the effect of seeding date and herbicide treatment on wild buckwheat control is reported as bulk density assessments in Table 21.

The control of wild buckwheat as affected by seeding date (spray date) was found to be identical to that previously explained for wild oat control.

TABLE 19. Bulk density assessment of wild mustard control as influenced by date of seeding and treatments of paraquat and glyphosate

Treatment	Rate kg/ha	Wild mustard populations in bulk density units — Seeding dates: May 3	May 10	May 17	May 24	May 31	Overall treatments means
Weedy check		55	52	77	180	112	95
Paraquat	0.28	0	26	7	1	36	14
Paraquat	0.42	0	1	1	16	57	15
Glyphosate	0.28	0	10	12	13	120	31
Glyphosate	0.42	10	36	1	100	40	37
Glyphosate	0.84	3	26	0	43	21	18
Glyphosate + Dicamba	0.28 + 0.14	0	10	0	45	62	23
Paraquat + Bromoxynil	0.28 + 0.28	0	25	0	90	48	32
Seeding date means		8	23	12	61	62	33

STANDARD ERRORS OF DIFFERENCES ($p = 0.05$)
Between two seeding date means 4
Between two treatment means 6
Between two treatments within one seeding date 13
Between any two treatments in different seeding dates 13

TABLE 20. Visual ratings of lamb's quarters control as influenced by date of seeding and treatments of paraquat and glyphosate

Treatment	Rate kg/ha	Seeding dates				
		May 3	May 10	May 17	May 14	May 31
Weedy check		0	0	0	0	0
Paraquat	0.28	8	8	8	7	7
Paraquat	0.42	8	8	8	7	8
Glyphosate	0.28	8	8	8	8	8
Glyphosate	0.42	8	8	8	8	8
Glyphosate	0.84	9	8	8	8	8
Glyphosate + Dicamba	0.28 + 0.14	9	8	8	8	7
Paraquat + Bromoxynil	0.28 + 0.28	8	8	8	8	8

TABLE 21. Bulk density assessment of wild buckwheat control as influenced by date of seeding and treatments of paraquat and glyphosate

Treatment	Rate kg/ha	Wild buckwheat populations in bulk density units — Seeding dates: May 3	May 10	May 17	May 24	May 31	Overall treatments means
Weedy check		200	125	143	588	328	277
Paraquat	0.28	63	128	125	405	334	211
Paraquat	0.42	50	236	201	392	194	215
Glyphosate	0.28	46	147	4	41	82	64
Glyphosate	0.42	37	82	1	39	13	34
Glyphosate	0.84	37	31	2	2	6	16
Glyphosate + Dicamba	0.28 + 0.14	14	5	0	0	105	24
Paraquat + Bromoxynil	0.28 + 0.28	101	24	0	5	4	26
Seeding date means		68	97	59	184	133	108

STANDARD ERRORS OF DIFFERENCES ($p = 0.05$)
Between two seeding date means 18
Between two treatment means 16
Between two treatments within one seeding date 36
Between any two treatments in different seeding dates 38

Statistical evidence in the treatment means shows that to obtain good wild buckwheat control with glyphosate alone a rate of 0.42 kg/ha was required, unless, 0.14 kg/ha of dicamba was added to 0.28 kg/ha of glyphosate. Good wild buckwheat control with paraquat (0.28 kg/ha) required the addition of 0.28 kg/ha of bromoxynil.

Yield Results. The effect of seeding date and herbicide treatment on the yield of wheat is reported in Table 22.

When herbicides were not used (weedy check) the wheat yield decreased as the seeding date was delayed. Where herbicides were used, the seeding date giving the best wheat yield in 1976 was May 17. The significantly greater yields can be attributed to the first rain of the season which fell on May 13-15. This rain increased the moisture conditions and induced the germination of the major flush of weed seedlings. This flush of weeds was subsequently sprayed on May 19 (ie. in the May 17 seeding date). The new population of weed seedlings, however, affected previous seeding dates which had already received the pre-emergence treatments, whereas, later seeding dates were sprayed when the weeds were in advanced stages. Paraquat and glyphosate give optimum weed control under ideal moisture conditions and when weeds are in young stages. Comparitively low populations of wild oats, wild mustard and wild buckwheat in the May 17 seeding date support the above observations and the decreased amount of weed competition to the crop is reflected in significantly higher yields for the May 17 seeding date.

With the exception of the May 17 seeding date it is statistically significant that under no-till conditions, as seeding date is delayed

TABLE 22. Wheat yield as influenced by date of seeding and treatments of paraquat and glyphosate

Treatment	Rate kg/ha	Yield kg/ha Seeding dates					Treatment means
		May 3	May 10	May 17	May 24	May 31	
Weedy check		1052	747	678	366	88	586
Paraquat	0.28	1039	978	1310	671	674	934
Paraquat	0.42	942	1156	1304	782	876	1012
Glyphosate	0.28	944	950	1285	920	878	995
Glyphosate	0.42	1036	909	1329	1020	891	1037
Glyphosate	0.84	1028	1046	1495	978	1076	1125
Glyphosate + Dicamba	0.28 + 0.14	1363	1136	1352	931	795	1115
Paraquat + Bromoxynil	0.28 + 0.28	1021	1052	1216	830	913	1006
Seeding date means		1053	997	1246	812	774	976

STANDARD ERRORS OF DIFFERENCES ($p = 0.05$)
Between two seeding date means 52
Between two treatment means 57
Between two treatments within one seeding date 128
Between any two treatments in different seeding dates 131

from May 3, the yield of wheat is decreased.

Analysis of the treatment means show that when all dates are considered, the best treatments were glyphosate 0.84 kg/ha and glyphosate plus dicamba 0.28 + 0.14 kg/ha.

Experiment 17. The effect of the date of seeding and treatments of paraquat and glyphosate on weed populations in zero-tillage, b) with post-emergent treatments of dichlofop methyl and MCPA.

Wild Oat, Wild Mustard, Lamb's Quarters and Wild Buckwheat Control. Visual assessments of the effect of seeding date and herbicide treatment on the control of wild oats, wild mustard, lamb's quarters and wild buckwheat are reported in Tables 23, 24, 25, and 26 respectively.

Analysis of the initial weed control results show that all four weeds were adequately controlled by all herbicide treatments at all five seeding dates. The initial evaluations also show that paraquat at 0.28 and 0.42 kg/ha and glyphosate at 0.28 kg/ha did not give as good weed control as the other treatments. Late season evaluations showed that these treatments were inadequate for long lasting suppression of the four monitored weeds.

Yield Results. The results of the effect of seeding date and herbicide treatment on wheat yield is reported in Table 27.

As this experiment is essentially a repeat of experiment 17a, except for post-emergent applications of dichlofop methyl (1.12 kg/ha) and MCPA (0.56 kg/ha), it is understandable that yield trends are similar. Yields from the May 17 seeding date were again significantly

TABLE 23. Visual ratings of wild oat control as influenced by date of seeding and treatments of paraquat and glyphosate

		Seeding date									
		May 3		May 10		May 17		May 24		May 31	
		Evaluation date									
Treatment	Rate kg/ha	May 27	June 22	May 28	June 22	May 28	June 22	June 3	June 24	June 8	June 24
Weedy check		0	0	0	0	0	0	0	0	0	0
Paraquat	0.28	8	5	7	3	7	4	7	2	7	6
Paraquat	0.42	8	6	7	3	7	6	7	4	8	6
Glyphosate	0.28	8	6	7	3	7	7	7	6	7	6
Glyphosate	0.42	8	6	7	4	8	7	8	7	8	8
Glyphosate	0.84	8	8	8	6	8	8	8	8	8	8
Glyphosate + Dicamba	0.28 + 0.14	8	7	8	5	8	7	8	7	6	6
Paraquat + Bromoxynil	0.28 + 0.28	8	5	7	2	8	6	8	6	7	7

TABLE 24. Visual ratings of wild mustard control as influenced by date of seeding and treatments of paraquat and glyphosate

		Seeding date									
		May 3		May 10		May 17		May 24		May 31	
		Evaluation date									
Treatment	Rate kg/ha	May 27	June 22	May 28	June 22	May 28	June 22	June 3	June 24	June 8	June 24
Weedy check		0	0	0	0	0	0	0	0	0	0
Paraquat	0.28	7	4	7	3	7	3	6	2	8	3
Paraquat	0.42	8	7	7	3	8	6	7	4	7	6
Glyphosate	0.28	7	6	7	3	8	8	7	5	7	6
Glyphosate	0.42	7	6	8	5	8	8	8	8	7	7
Glyphosate	0.84	7	7	8	6	8	8	8	8	8	8
Glyphosate + Dicamba	0.28 + 0.14	8	8	8	7	8	8	7	8	7	7
Paraquat + Bromoxynil	0.28 + 0.28	7	6	8	6	8	8	8	8	8	8

TABLE 25. Visual ratings of lamb's quarters control as influenced by date of seeding and treatments of paraquat and glyphosate

		Seeding date									
		May 3		May 10		May 17		May 24		May 31	
		Evaluation date									
Treatment	Rate kg/ha	May 27	June 22	May 28	June 22	May 28	June 22	June 3	June 24	June 8	June 24
Weedy check		0	0	0	0	0	0	0	0	0	0
Paraquat	0.28	7	6	8	3	8	3	7	2	7	3
Paraquat	0.42	8	8	7	3	8	7	7	4	8	7
Glyphosate	0.28	7	7	7	4	8	8	8	6	6	6
Glyphosate	0.42	8	7	8	6	8	8	8	8	7	8
Glyphosate	0.84	8	8	8	7	8	8	8	8	8	8
Glyphosate + Dicamba	0.28 + 0.14	8	8	8	8	8	8	8	8	7	8
Paraquat + Bromoxynil	0.28 + 0.28	8	8	8	7	8	8	8	7	8	7

TABLE 26. Visual ratings of wild buckwheat control as influenced by date of seeding and treatments of paraquat and glyphosate

		Seeding date									
		May 3		May 10		May 17		May 24		May 31	
		Evaluation date									
Treatment	Rate kg/ha	May 27	June 22	May 28	June 22	May 28	June 22	June 3	June 24	June 8	June 24
Weedy check		0	0	0	0	0	0	0	0	0	0
Paraquat	0.28	7	5	7	2	7	3	7	2	7	3
Paraquat	0.42	8	8	7	3	8	7	7	4	7	5
Glyphosate	0.28	7	7	8	5	8	7	7	7	7	6
Glyphosate	0.42	7	8	8	6	8	8	8	8	8	8
Glyphosate	0.84	7	7	8	7	8	8	8	8	8	8
Glyphosate + Dicamba	0.28 + 0.14	8	8	8	8	8	8	7	7	7	8
Paraquat + Bromoxynil	0.28 + 0.28	8	7	8	7	8	8	8	7	9	8

TABLE 27. Wheat yield as influenced by date of seeding, treatments of paraquat and glyphosate, and post-emergent treatments

Treatment	Rate kg/ha	Yield kg/ha Seeding dates May 3	May 10	May 17	May 24	May 31	Overall treatment means
Weedy check		592	282	259	84	56	255
Paraquat	0.28	814	545	938	341	615	651
Paraquat	0.42	794	572	1299	560	735	792
Glyphosate	0.28	934	503	1365	777	708	858
Glyphosate	0.42	945	604	1775	879	914	1023
Glyphosate	0.84	789	698	1613	1071	850	1004
Glyphosate + Dicamba	0.28 + 0.14	994	737	1476	698	977	976
Paraquat + Bromoxynil	0.28 + 0.28	929	768	1070	596	774	827
Seeding date means		849	589	1224	626	703	798

STANDARD ERRORS OF DIFFERENCES (p = 0.05)
Between two seeding date means 128
Between two treatment means 68
Between two treatments within one seeding date 153
Between any two treatments in different seeding dates 192

better than all other dates, the reasons being the same as those cited for experiment 17a. Disregarding the May 17 seeding date, the seeding date means show that it is significantly better to seed as close to May 3 as possible when compared to the other dates. Due to the post-emergent treatments subsequent seeding dates (May 10, 24, 31) did not statistically differ with respect to yield.

Analysis of the treatment means shows similar results to experiment 17a. The best treatments included glyphosate at 0.42 kg/ha and higher and glyphosate plus dicamba at 0.28 + 0.14 kg/ha.

Experiment 18. The effect of the hardness of water on the efficacy of glyphosate, a) with additional surfactant added to glyphosate.

The effect of the hardness of water on glyphosate was tested using the control of wild oats, wild mustard and wild buckwheat as indicators and the results presented in Table 28.

In no case could it be shown that weed control varied with respect to the hardness of water. Each of the three sources of water provided statistically equal control of each of the three monitored weeds. The addition of a commercial water softener (Calgon) did not observably improve the phytotoxicity of glyphosate by overcoming the hardness factor.

Excellent wild oat control occurred and no significant differences could be shown between treatments indicating that 0.14 kg/ha of glyphsoate with additional surfactant was enough for excellent control. Wild mustard and wild buckwheat control also was good although trends strongly suggest that 0.28 kg/ha with additional surfactant is required.

TABLE 28. Weed control from glyphosate treatments as affected by water of different hardness.

Rate of glyphosate kg/ha	Source of water used as spray diluent	Bulk Density evaluations[1]		
		Wild oats	Wild mustard	Wild buckwheat
0		1568	1040	32
0.14	Tap water	8	20	12
0.28	Tap water	2	8	2
0.14	Well water	8	24	4
0.28	Well water	2	12	3
0.14	Distilled water	15	55	4
0.28	Distilled water	2	41	5
0.14	Tap water + softener	7	55	9
0.28	Tap water + softener	2	4	5
0.14	Well water + softener	10	57	17
0.28	Well water + softener	0	2	9
0.14	Distilled water + softener	6	56	11
0.28	Distilled water + softener	3	2	1
0	Tap water + softener	1423	1107	26
	TUKEY'S HSD (5%)	17	39	13

1. Bulk density taken July 7.
2. All treatments recieved additional surfactant.
3. Weedy check was not included in statistical analysis
4. Spray applications made June 28.

Experiment 18. The effect of the hardness of water on the efficacy of glyphosate, b) with and without additional surfactant.

The effect of hardness of water on glyphosate was tested using the control of wild oats, wild mustard and green foxtail as indicators and the results reported in Table 29.

As in experiment 18a it could not be shown that the hardness of water had a significant effect on the efficacy of glyphosate. Evidence similarly did not show that useage of a water softener had a beneficial effect when using a very hard water. Also similar to experiment 18a weed control observed indicated that 0.14 kg/ha of glyphosate with additional surfactant is adequate for wild oat control whereas trends suggest that 0.28 kg/ha of glyphosate with additional surfactant is necessary for the control of wild mustard and green foxtail.

Comparison of the two treatments lacking additional surfactant show that for excellent control of wild oats at low rates of glyphosate additional surfactant is not required. Additional surfactant was shown however to significantly improve the phytotoxicity of 0.14 kg/ha of glyphosate on wild mustard and green foxtail.

TABLE 29. Weed control from glyphosate treatments as affected by different water hardness and surfactant

Rate of glyphosate kg/ha	Source of water used as spray dilutent	Bulk density evaluations[1]		
		Wild oats	Wild mustard[2]	Green foxtail[2]
0		38	727	1562
0.14[3]	Tap water	2	3	5
0.28	Tap water	2	4	4
0.14	Well water	0	3	35
0.28	Well water	0	0	13
0.14	Distilled water	0	5	24
0.28	Distilled water	0	0	5
0.14	Tap water + softener	0	8	19
0.28	Tap water + softener	0	0	1
0.14	Well water + softener	0	21	17
0.28	Well water + softener	1	0	2
0.14	Distilled water + softener	0	19	35
0.28	Distilled water + softener	0	4	6
0.14	Tap water[4]	1	26	97
0.28	Tap water[4]	1	0	13
	TUKEY'S HSD (5%)	5	17	20

1. Bulk density taken July 28.
2. Weedy check was not included in statistical analysis.
3. Spray applications made July 17.
4. All treatments received additional surfactant <u>except</u> these.

GENERAL DISCUSSION and CONCLUSIONS

A summary of general weed control of each herbicide treatment as evaluated by the preceeding experiments is presented in Table 30.

Certain treatments were found to be unsatisfactory for pre-emergent (of the crop) weed control in zero-tillage due to residual phytotoxicity to the wheat. These treatments included all those containing Velpar at 0.14 kg/ha, dinoseb at 2.24 kg/ha or oxyfluorfen at 0.28 kg/ha.

Treatments found to be unsatisfactory due to inadequate general weed control included: paraquat applied alone at 0.28 kg/ha or when in combination with 0.14 kg/ha of Dowco 290. Inadequate weed control was also obtained using 0.14 kg/ha of glyphosate applied alone or when combined with 0.14 kg/ha of dicamba, 0.14 kg/ha of Dowco 290, 0.035 kg/ha of picloram or 1.0 kg/ha of nitrofen.

Adequate general weed control was obtained if at least 0.42 kg/ha of paraquat or 0.28 kg/ha of glyphosate was applied with no additional broadleaf herbicide. When additional broadleaf herbicides were added adequate weed control resulted if 0.28 kg/ha of paraquat was applied in combination with bromoxynil at 0.28 kg/ha, 0.14 kg/ha of dicamba, 1.0 kg/ha of nitrofen or 0.28 kg/ha of bromoxynil and MCPA. Glyphosate at 0.14 kg/ha provided adequate general weed control only if combined with 0.28 kg/ha of bromoxynil or bromoxynil plus MCPA. The addition

TABLE 30. Table of herbicide treatment performance

Treatment	Rate kg/ha	Experiment found in	Phytotoxicity to crop	General weed control
Paraquat	0.28	2, 9, 12, 15, 16, 17	None	Inadequate
Paraquat	0.42	2, 9, 12, 15, 16, 17	None	Adequate
	0.56	15, 16	None	Excellent
	0.84	15, 16	None	Excellent
Paraquat + Bromoxynil	0.28 + 0.28	9, 12, 17	None	Adequate
	0.42 + 0.28	9, 12	None	Excellent
Paraquat + Dicamba	0.28 + 0.14	2, 9, 12	None	Adequate
	0.42 + 0.14	2, 9, 12	None	Adequate
	0.28 + 0.28	9	None	Adequate
Paraquat + Dowco 290	0.28 + 0.14	9	None	Inadequate
	0.42 + 0.14	9	None	Adequate
Paraquat + Oxyfluorfen	0.23 + 0.28	2, 12	Slight	Inadequate
	0.28 + 0.42	12	Slight	Adequate
	0.28 + 0.56	2, 9, 12	Slight	Adequate
Paraquat + Nitrofen	0.28 + 1.0	9	None	Adequate
Paraquat + Bromoxynil and MCPA	0.28 + 0.28	2	None	Adequate
	0.42 + 0.28	2	None	Excellent
Velpar	0.14	1, 8	Slight	Inadequate
	0.28	1, 8	Severe	Inadequate
Velpar + 2,4-D	0.14 + 0.56	1. 8	Slight	Inadequate
	0.28 + 0.56	1, 8	Severe	Inadequate
S15544	3.36	1, 8	None	Inadequate
	4.48	1, 8	None	Inadequate
Dinoseb	2.24	1, 8	Slight	Inadequate
	4.48	1, 8	Slight	Inadequate
	6.71	1, 8	Severe	Adequate
Glyphosate	0.14	1, 8	None	Inadequate
	0.28	15, 16, 17, 18	None	Adequate
	0.42	4, 6, 11, 13, 14, 16, 17	None	Excellent
	0.56	15, 16	None	Excellent
	0.84	4, 15, 16, 17	None	Excellent
Glyphosate + Dicamba	0.14 + 0.14	3, 10, 13, 14	None	Inadequate
	0.28 + 0.07	3, 10, 13, 14	None	Adequate
	0.28 + 0.14	1, 3, 10, 13, 14	None	Excellent
	0.28 + 0.28	8	None	Excellent
	0.42 + 0.14	3, 10	None	Excellent
Glyphosate + Dowco 290	0.14 + 0.14	3, 10	None	Inadequate
	0.28 + 0.14	3, 10	None	Adequate
	0.42 + 0.14	3, 10	None	Excellent
Glyphosate + Picloram	0.14 + 0.035	3, 10	None	Inadequate
	0.28 + 0.035	3, 10, 13, 14	None	Excellent
	0.42 + 0.035	3, 10, 13, 14	None	Excellent
Glyphosate + Nitrofen	0.14 + 1.0	4, 6, 11	None	Inadequate
	0.28 + 1.0	4, 6, 11	None	Adequate
	0.42 + 1.0	4, 6, 11	None	Excellent
Glyphosate + Oxyfluorfen	0.14 + 0.28	4, 6, 11, 13	Slight	Adequate
	0.28 + 0.28	4, 6, 11, 13	Slight	Adequate
	0.42 + 0.28	4, 6, 11, 13	Slight	Excellent
Glyphosate + Bromoxynil	0.14 + 0.28	6, 11, 14	None	Adequate
	0.28 + 0.14	6, 11	None	Adequate
	0.28 + 0.28	1, 6, 11, 13, 14	None	Excellent
	0.42 + 0.28	6, 11, 13, 14	None	Excellent
Glyphosate + Bromoxynil and MCPA	0.14 + 0.28	4	None	Adequate
	0.28 + 0.14	4	None	Adequate
	0.28 + 0.28	4	None	Excellent
	0.42 + 0.28	4	None	Excellent

of dicamba at 0.07 kg/ha, Dowco 290 at 0.14 kg/ha, 1.0 kg/ha of nitrofen or 0.14 kg/ha of bromoxynil or bromoxynil plus MCPA did not improve the weed control of 0.28 kg/ha of glyphosate applied alone.

Treatments giving excellent general weed control recommended for useage in zero-tillage include 0.56 kg/ha of paraquat or 0.42 kg/ha of glyphosate applied without additional broadleaf herbicides. When additional broadleaf herbicides were added excellent general weed control was found with 0.42 kg/ha of paraquat in combination with 0.28 kg/ha of either bromoxynil or bromoxynil plus MCPA. Glyphosate at 0.28 kg/ha in combination with 0.14 kg/ha of dicamba, 0.035 kg/ha of picloram or 0.28 kg/ha of bromoxynil or bromoxynil plus MCPA also gave excellent weed control.

In experiments 14 and 16, it was found that the addition of a surfactant (MON 0011 at 0.5% of the final spray volume) increased the wild oat control of low rates (0.28 kg/ha) of glyphosate. This is in agreement with the findings of Nelson (1975).

Experiments 5 and 7 show that adequate quack grass control can be obtained with 1.12 kg/ha of glyphosate, however, for very good control a rate of 1.68 kg/ha glyphosate was required. The addition of dicamba at 0.14 kg/ha significantly increased the phytotoxicity of 0.84 kg/ha of glyphosate to quack grass. This increased control was attributed to the surfactant in the dicamba formulation aiding the penetration of glyphosate. Paraquat at 1.12 kg/ha was found to give very good initial burn off of the quack grass, however, observations taken later in the season showed that regrowth was severe, making this treatment inadequate for quack grass control.

It was found in experiment 17a that for wild oat control only, excellent results were obtained with glyphosate applied alone at 0.28 kg/ha. The addition of any of the broadleaf herbicides to the glyphosate did not increase the resulting wild oat control. For excellent control of wild mustard, however, the addition of 0.14 kg/ha of dicamba to 0.28 kg/ha of glyphosate was necessary unless a rate of 0.84 kg/ha of glyphosate alone was used. Paraquat at 0.28 kg/ha also gave excellent wild mustard control increased by the addition of 0.28 kg/ha of bromoxynil. Very good lamb's quarters control was achieved with the lowest rate (0.28 kg/ha) of paraquat or glyphosate applied alone. The addition of 0.14 kg/ha of dicamba to glyphosate at 0.28 kg/ha was required for good wild buckwheat control, whereas, if dicamba was not added, 0.42 kg/ha of glyphosate was required for similar control.

Seeding Date

It was shown that under normal environmental conditions the yield of wheat grown under zero-tillage decreases as seeding date is delayed. Wheat seeded on May 17 gave higher yields. However, these higher yields were attributed to improved moisture conditions at seeding time. This trend of yield decrease is attributed first of all, to the fact that wheat when seeded early has a more favorable maturity response to the growing season and higher yields normally occur. Secondly, because the wheat crop was established before the bulk of the weeds emerged, the wheat had a competitive advantage over the weed populations. This is evident in the May 3 seeding date of experiment 17a, where the yield from the weedy check is the same as that from those plots receiving herbicidal treatments. Thirdly, yields were greater from earlier seeding dates due to the more efficient weed control demonstrated by paraquat and glyphosate the earlier these herbicides are applied. Thus decrease of weed control with a delay of seeding date (spray date) was attributed to the fact that paraquat and glyphosate give less effective weed control if the leaf stage of the weed is increased.

In conclusion, the addition of some broadleaf herbicides increased the effectiveness of both paraquat and glyphosate for chemical seedbed preparation in zero-tillage. Comparative costs of the most effective treatments are given in Table 31. Where wild oats or volunteer grain is the major weed problem at seeding time, the most economical treatement was shown to be 0.28 kg/ha of glyphosate. If broadleaf weeds such as wild mustard and wild buckwheat are present at seeding time the addition of either picloram at 0.035 kg/ha or dicamba at 0.14 kg/ha to 0.28 kg/ha of glyphosate would be the most economically advisable.

TABLE 31. Comparative costs of the most effective treatments

Treatment	Rate kg/ha	General weed control	As of January 1977 cost $/ha
Paraquat	0.42	adequate	21.29
Paraquat	0.56	excellent	28.39
Paraquat + Bromoxynil	0.42 + 0.28	excellent	28.06
Glyphosate	0.28	adequate	12.71
Glyphosate	0.42	excellent	19.07
Glyphosate + Dicamba	0.28 + 0.14	excellent	15.81
Glyphosate + Picloram	0.28 + 0.035	excellent	14.43
Glyphosate + Bromoxynil	0.28 + 0.28	excellent	19.48

SUGGESTIONS FOR FURTHER STUDY

Additional studies on economical treatments for perennial weed control.

Investigate the shift of annual weed populations under zero-tillage.

Study the effect of trash cover and moisture retention on the date of seeding.

Investigate optimum rates and methods of nitrogen fertilizer application under zero-tillage conditions.

Investigate the influence of zero-tillage crop production on the incidence of various crop diseases.

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APPENDIX

APPENDIX TABLE 1. Visual ratings of weed control using paraquat in combination with bromoxynil, dicamba and oxyfluorfen

Treatment	Rate kg/ha	Visual ratings[1] Wild oats	Wild mustard	Lamb's quarters	Wild buckwheat
Weedy check		0	0	0	0
Paraquat[2]	0.28	7	7	7	6
Paraquat	0.42	8	8	7	7
Paraquat + Bromoxynil	0.28 + 0.28	7	8	8	8
Paraquat + Bromoxynil	0.42 + 0.28	8	8	8	8
Paraquat + Dicamba	0.28 + 0.14	7	7	8	6
Paraquat + Dicamba	0.42 + 0.14	8	7	8	7
Paraquat + Oxyfluorfen	0.28 + 0.28	8	8	8	7
Paraquat + Oxyfluorfen	0.28 + 0.42	7	7	7	7
Paraquat + Oxyfluorfen	0.28 + 0.56	8	8	8	8

1. Visual ratings taken June 8.
2. Spray applications made May 27.

APPENDIX TABLE 2. Visual ratings of weed control using paraquat in combination with bromoxynil, dicamba and oxyfluorfen

Treatment	Rate kg/ha	Visual ratings[1]			
		Wild oats	Wild mustard	Lamb's quarters	Wild buckwheat
Weedy check		0	0	0	0
Paraquat[2]	0.28	5	7	6	5
Paraquat	0.42	7	6	7	7
Paraquat + Bromoxynil	0.28 + 0.28	6	6	8	7
Paraquat + Bromoxynil	0.42 + 0.28	7	7	8	7
Paraquat + Dicamba	0.28 + 0.14	6	6	7	7
Paraquat + Dicamba	0.42 + 0.14	7	7	8	7
Paraquat + Oxyfluorfen	0.28 + 0.28	7	7	6	6
Paraquat + Oxyfluorfen	0.28 + 0.42	6	5	5	4
Paraquat + Oxyfluorfen	0.28 + 0.56	8	7	6	6

1. Visual ratings taken July 8.
2. Spray applications made May 27.

APPENDIX TABLE 3. Visual ratings of weed control from glyphosate in combination with bromoxynil, oxyfluorfen, dicamba and picloram

Treatment	Rate kg/ha	Visual ratings[1]			
		Wild oats	Wild mustard	Lamb's quarters	Wild buckwheat
Weedy check		0	0	0	0
Glyphosate + Bromoxynil[2]	0.28 + 0.28	8	8	8	8
Glyphosate + Bromoxynil	0.42 + 0.28	8	8	8	8
Glyphosate + Oxyfluorfen	0.14 + 0.28	7	6	6	8
Glyphosate + Oxyfluorfen	0.28 + 0.28	8	7	7	8
Glyphosate + Oxyfluorfen	0.42 + 0.28	8	8	8	8
Glyphosate + Dicamba	0.14 + 0.14	6	6	8	7
Glyphosate + Dicamba	0.28 + 0.07	7	8	8	8
Glyphosate + Dicamba	0.28 + 0.14	8	8	8	8
Glyphosate + Picloram	0.28 + 0.035	7	8	8	8
Glyphosate + Picloram	0.42 + 0.035	8	8	8	8
Glyphosate	0.42	8	8	8	8

1. Visual ratings made June 8.
2. Spray applications made May 27.

APPENDIX TABLE 4. Visual ratings of weed control from glyphosate in combination with bromoxynil, oxyfluorfen, dicamba and picloram

Treatment	Rate kg/ha	Visual ratings[1]			
		Wild oats	Wild mustard	Lamb's quarters	Wild buckwheat
Weedy check		0	0	0	0
Glyphosate + Bromoxynil[2]	0.28 + 0.28	7	7	7	7
Glyphosate + Bromoxynil	0.42 + 0.28	8	5	8	8
Glyphosate + Oxyfluorfen	0.14 + 0.28	6	7	5	6
Glyphosate + Oxyfluorfen	0.28 + 0.28	7	6	6	7
Glyphosate + Oxyfluorfen	0.42 + 0.28	8	6	8	8
Glyphosate + Dicamba	0.14 + 0.14	4	6	7	7
Glyphosate + Dicamba	0.28 + 0.07	7	7	7	7
Glyphosate + DIcamba	0.28 + 0.14	8	8	8	8
Glyphosate + Picloram	0.28 + 0.035	7	7	7	7
Glyphosate + Picloram	0.42 + 0.035	8	8	8	8
Glyphosate	0.42	8	7	7	7

1. Visual ratings made July 7.
2. Spray applications made May 27.

APPENDIX TABLE 5. Visual ratings of weed control from glyphosate with additional surfactant in combination with bromoxynil, dicamba and picloram

Treatment	Rate kg/ha	Visual ratings[1]		
		Wild oats	Green foxtail	Red root pigweed
Weedy check		0	0	0
Glyphosate + Bromoxynil[2]	0.28 + 0.28	7	7	6
Glyphosate + Bromoxynil	0.42 + 0.28	7	8	7
Glyphosate + Bromoxynil[3]	0.28 + 0.28	6	6	6
Glyphosate + Dicamba[3]	0.14 + 0.14	3	4	2
Glyphosate + Dicamba[3]	0.28 + 0.07	5	6	5
Glyphosate + Dicamba	0.14 + 0.14	4	5	4
Glyphosate + Dicamba	0.28 + 0.07	7	7	7
Glyphosate + Dicamba	0.28 + 0.14	6	7	6
Glyphosate + Picloram	0.28 + 0.035	7	8	8
Glyphosate + Picloram	0.42 + 0.035	8	7	8
Glyphosate + Picloram	0.42	8	8	9

1. Visual ratings made August 27.
2. Spray applications made August 17.
3. All treatments received additional surfactant except these.

APPENDIX TABLE 6. Visual ratings of weed control from paraquat and glyphosate treatments

Treatment	Rate kg/ha	Visual ratings[1]			
		Wild oats	Wild mustard	Lamb's quarters	Wild buckwheat
Weedy check		0	0	0	0
Paraquat[2]	0.28	5	6	7	6
Paraquat	0.42	7	7	8	7
Paraquat	0.56	7	7	8	7
Paraquat	0.84	8	8	8	8
Glyphosate	0.28	7	7	8	7
Glyphosate	0.42	8	8	8	8
Glyphosate	0.56	8	8	8	8
Glyphosate	0.84	8	8	8	8

1. Visual ratings made June 10.
2. Spray applications made May 27.

APPENDIX TABLE 7. Visual ratings of weed control from paraquat and glyphosate treatments

Treatment	Rate kg/ha	Visual ratings[1]			
		Wild oats	Wild mustard	Lamb's quarters	Wild buckwheat
Weedy check		0	0	0	0
Paraquat[2]	0.28	5	6	5	5
Paraquat	0.42	6	7	7	7
Paraquat	0.56	6	5	6	5
Paraquat	0.84	7	7	8	8
Glyphosate	0.28	5	6	6	7
Glyphosate	0.42	8	7	8	7
Glyphosate	0.56	8	6	7	7
Glyphosate	0.84	8	7	8	8

1. Visual ratings made July 7.
2. Spray applications made May 27.

APPENDIX TABLE 8. Visual ratings of weed control from treatments of paraquat and glyphosate with additional surfactant

Treatment	Rate kg/ha	Visual ratings[1] Wild oats	Green foxtail	Red root pigweed
Weedy check		0	0	0
Paraquat[2]	0.28	7	8	8
Paraquat	0.42	8	8	8
Paraquat	0.56	8	8	8
Paraquat	0.84	9	9	9
Glyphosate[3]	0.28	6	6	8
Glyphosate[3]	0.42	8	7	8
Glyphosate[3]	0.56	8	8	8
Glyphosate[3]	0.84	9	9	9
Glyphosate	0.28	6	6	7
Glyphosate	0.42	7	7	8
Glyphosate	0.56	7	8	8

1. Visual ratings made August 27.
2. Spray applications made August 17.
3. These treatments received additional surfactant.

APPENDIX TABLE 9. Visual ratings of wild oat control as influenced by date of seeding and treatments of paraquat and glyphosate

Treatment	Rate kg/ha	Seeding dates				
		May 3	May 10	May 17	May 24	May 31
Weedy check		0	0	0	0	0
Paraquat	0.28	8	8	7	7	7
Paraquat	0.42	8	8	8	7	8
Glyphosate	0.28	8	8	8	8	7
Glyphosate	0.42	8	8	8	8	8
Glyphosate	0.84	8	8	8	8	8
Glyphosate + Dicamba	0.28 + 0.14	8	8	8	8	7
Paraquat + Bromoxunil	0.28 + 0.28	8	7	8	8	8

APPENDIX TABLE 10. Visual ratings of wild mustard control as influenced by date of seeding and treatments of paraquat and glyphosate

Treatment	Rate kg/ha	Seeding dates May 3	May 10	May 17	May 24	May 31
Weedy check		0	0	0	0	0
Paraquat	0.28	8	8	8	7	7
Paraquat	0.42	8	8	8	7	8
Glyphosate	0.28	8	8	8	8	8
Glyphosate	0.42	8	8	8	8	8
Glyphosate	0.84	9	8	8	8	8
Glyphosate + Dicamba	0.28 + 0.14	8	8	8	8	8
Paraquat + Bromoxynil	0.28 + 0.28	8	8	8	8	8

APPENDIX TABLE 11. Visual ratings of wild buckwheat control as influenced by date of seeding and treatments of paraquat and glyphosate

Treatment	Rate kg/ha	Seeding dates May 3	May 10	May 17	May 24	May 31
Weedy check		0	0	0	0	0
Paraquat	0.28	8	7	7	5	6
Paraquat	0.42	8	7	7	7	6
Glyphosate	0.28	8	7	8	7	7
Glyphosate	0.42	8	8	8	7	7
Glyphosate	0.84	8	8	8	8	7
Glyphosate + Dicamba	0.28 + 0.14	8	8	8	7	7
Paraquat + Bromoxynil	0.28 + 0.28	7	8	8	8	8

APPENDIX TABLE 12. Visual ratings of weed control from glyphosate treatments as affected by water of different hardness

Rate of glyphosate[2] kg/ha	Source of water used as spray diluent	Visual ratings[1]		
		Wild oats	Wild mustard	Wild buckwheat
0		0	0	0
0.14[3]	Tap water	9	8	8
0.28	Tap water	9	9	8
0.14	Well water	9	7	8
0.28	Well water	9	8	8
0.14	Distilled water	9	7	8
0.28	Distilled water	9	8	8
0.14	Tap water + softener	9	8	8
0.28	Tap water + softener	9	8	9
0.14	Well water + softener	9	7	8
0.28	Well water + softener	9	9	8
0.14	Distilled water + softener	9	7	8
0.28	Distilled water + softener	9	9	8
0	Tap water + softener	0	0	0

1. Visual ratings made July 8.
2. All treatments received additional surfactant.
3. Spray applications made June 28.

APPENDIX TABLE 13. Weed control from glyphosate treatments as affected by different water hardness and surfactant

Rate of glyphosate kg/ha	Source of water used as spray diluent	Visual ratings[1]		
		Wild oats	Wild mustard	Green foxtail
0		0	0	0
0.14[2]	Tap water	8	8	8
0.28	Tap water	9	9	9
0.14	Well water	8	8	7
0.28	Well water	9	9	8
0.14	Distilled water	8	8	8
0.28	Distilled water	9	9	9
0.14	Tap water + softener	8	8	8
0.28	Tap water + softener	9	9	9
0.14	Well water + softener	8	7	7
0.28	Well water + softener	9	9	9
0.14	Distilled water + softener	8	8	7
0.28	Distilled water + softener	9	9	9
0.14	Tap water[3]	8	8	7
0.28	Tap water[3]	9	8	8

1. Visual ratings made July 27.
2. Spray applications made July 17.
3. All treatments received additional surfactant.

APPENDIX TABLE 14. Analysis of spray water used in experiments 19 and 20

	Calcium ppm	Magnesium ppm	Iron ppm	Calculated total hardness $CaCO_3$ equivalent (ppm)
Carman tap water	11.70	16.80	0.02	96.45
Distilled water	0.15	0.03	--	0.50
Well water	248.0	300.0	0.09	1820.0

APPENDIX TABLE 15. Chemical names of herbicides

Common name	Chemical name
Bromoxynil	3,5-dibromo-4-hydroxybenzonitrile
Dicamba	3,6-dichloro-O-anisic acid
Dichlofop-methyl	Methyl 2-(4-(,4-dichlorophenoxy) phenoxy) propanoate
Dinoseb	2-sec-butyl-4,6-dinitrophenol
Glyphosate	N-(phosphonomethyl) glycine
MCPA	((4-chloro-O-tolyl) oxy)acetic acid
Nitrofen	2,4-dichlofophenyl p-nitrophenyl ether
Oxyfluorfen	2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl) benzone
Paraquat	1,1'-dimethyl-4,4'-bipyridilium ion
Picloram	4-amino-3,5,6-trichloropicolinic acid
2,4-D	(2,4-dichlorophenoxy) acetic acid
VELPAR[1]	3-cyclohexyl-6-(dimethylamino)-1-methyl-1,3,5-triazine-2,4(1H,3H)-dione

1. Common name not available.

APPENDIX TABLE 16. Latin names of plants

Common name	Latin name
Barley	*Hordeum vulgare* L.
Canada thistle	*Circium arvense* (L.) Scop.
Faba beans	*Vicia faba* L.
Flax	*Linum usitatissimum* L.
Green foxtail	*Setaria virdis*
Lady's thumb	*Polygonum persicaria* L.
Lamb's quarters	*Chenopodium album* L.
Oats	*Avena sativa* L.
Quack grass	*Agropyron repens* L. Beauv.
Red root pigweed	*Amaranthus retroflexus* L.
Napayo wheat	*Triticum aestivum* cv. Napayo
Norquay wheat	*Triticum aestivum* cv. Norquay
Selkirk wheat	*Triticum aestivum* cv. Selkirk
Wild buckwheat	*Polygonum convolvulus* L.
Wild oats	*Avena fatua* L.
Wild mustard	*Brassica kaber* (DC.) L.C. Wheeler

APPENDIX TABLE 17. Representative costs of most feasible glyphosate treatments as of January 1977

Rate of glyphosate kg/ha	Type and rate of mixed herbicide	kg/ha	Total cost $/ha
0.14	None		6.35
0.28	None		12.71
0.42	None		19.07
0.28	Bromoxynil	0.28	19.48
0.42	Bromoxynil	0.28	25.84
0.14	Dicamba	0.14	9.45
0.28	Dicamba	0.07	14.26
0.28	Dicamba	0.14	15.81
0.28	Picloram	0.035	14.43
0.42	Picloram	0.35	20.79
0.28	Bromoxynil + MCPA	0.28	17.83
0.28	Nitrofen	1.0	23.61

APPENDIX TABLE 18. Representative costs of most feasible paraquat treatments

Rate of paraquat kg/ha	Type and rate of mixed herbicide	kg/ha	Total cost $/ha
0.28	None		14.19
0.42	None		21.29
0.56	None		28.39
0.28	Bromoxynil	0.28	20.96
0.42	Bromoxynil	0.28	28.06
0.28	Dicamba	0.14	17.29
0.28	Dicamba	0.28	20.39
0.42	Dicamba	0.07	22.84
0.42	Dicamba	0.14	24.39
0.28	Nitrofen	1.0	25.09

APPENDIX TABLE 19. Precipitation at Carman Research Station

(mm rain)

Date	1975 May	1975 June	1975 July	1975 Aug.	1975 Sept.	1976 May	1976 June	1976 July	1976 Aug.	1976 Sept.
1	1.5						0.5			
2		9.9			16.5		1.3			
3										
4		3.0								
5			0.8		1.5					
6							3.6			
7		1.3		18.8	0.3		3.3			
8		1.8					0.8		7.8	1.3
9		14.0					4.6	5.1	1.3	
10		1.3		9.1			0.3			
11										
12							22.1		4.3	
13	6.4	0.8				3.6	2.0			3.0
14							1.5			
15				1.5		5.3				
16	3.8									
17	4.1		8.1		12.7		27.7			
18	3.0		10.4		2.0					
19	1.8	1.5	3.8		3.6			0.3		
20	5.6	3.3	0.8	0.8				18.8	6.9	
21		7.6	1.0				1.3			
22	4.6	16.5		1.8						
23	7.6	1.3								
24	0.8			11.7						
25				4.1			2.0	5.8		
26							1.0			
27		34.3				1.0			4.3	1.0
28	0.3	0.3						0.5		
29		3.8		4.1	2.0		5.1			
30	0.8									
31			8.4							
TOTAL (mm)	40.3	100.7	33.3	51.9	38.6	9.9	77.1	30.5	24.6	5.3