MAXIMUM ECONOMIC YIELD AS RELATED TO WEED POPULATIONS AND HERBICIDE USE

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Abstract

Economic threshold levels and relative time of emergence for numerous common grassy and broadleaved weed species in small grains will be discussed. The importance of understanding; weed species present, control options available and proper application timing are presented as essential elements in achieving maximum economic yield. Recent research results on the role of adjuvants, ammonium sulfate, water volumes and droplet sizes in improving control and reducing costs will be reviewed.

Numerous studies and estimates have been conducted to determine crop losses due to weeds. Some of the loss figures established in various countries are presented in Table 1. Although the range of losses is great it is evident that weeds are of major economic importance in world crop production. In Canada, one of the most extensive studies was conducted in Manitoba (Friesen and Shebeski, 1960). In an area within a 60 mile radius of Winnipeg they found twenty-eight species of weeds growing in the one hundred and forty-two fields surveyed. Weed counts ranged from 0 in the cleanest field to 2,143 weeds per square yard in the weediest field with an over-all recorded average of 224 weeds per square yard. Yield losses as high as 61.5% were recorded.

Table 1. Crop Losses Caused By Weed Competition (Estimates)

United States	10 - 50%
England	7 - 20%
India	0 - 27.8%
Canada	0 - 25%
Manitoba	0 - 61%

Mathematical models have been developed by Dew (1972) and Dew and Keys (1976) to help western Canadian farmers determine the economics of wild oat control in wheat, barley, oats and canola. (Figure 1 and 2). This information, combined with an estimation of weed free yield potential can be used to indicate when wild oat control in these crops is cost effective.

Figure 1 Index of Competition for Estimating Crop Loss

$$L = ab\sqrt{x}$$

L = % crop loss

a = weed free yield

b = index of competition

0.0230 (barley)
0.0339 (wheat)
0.0601 (flax)

x = wild oat/square meter

Dew, 1972

Figure 2
Index of Competition for Estimating Loss of Rape Due to Wild Oat

$$\% \text{ loss} = ab\sqrt{x}$$

a = weed free yield

b = index of competition (0.0322)

x = wild oat density/m^2

Dew and Keys, 1976.

Plotting the percentage loss derived from the model against the number of wild oat plants/m^2 provides a simple method of estimating crop yield loss due to various infestations of wild oats (Figure 3). This information can be used to predict the economic threshold (the weed level at which the benefits of control equal the cost of the herbicide and its application) for controlling wild oats with herbicides. For example, application of a \$15.00/acre herbicide to an infestation of 10 wild oats/m^2 in a 60 bu/ac crop of barley, would not be economical at current prices. Large-scale field studies over three years in western Canada (Hamman, 1979) confirm that when an infestation of wild oats develops in a field of wheat or barley, the yield loss can be predicted with a high degree of accuracy by utilizing the level of wild oat infestation, the estimated weed-free yield, and the index of competition as determined by Dew.

A similar index of competition for Canada thistle in barley and canola was developed by O'Sullivan et al,(1982, 1985) using data gathered in Lacombe area of Alberta (Figure 4).on a black loam soil. It is not known how applicable this index is to other geographical locations. O'Sullivan's results suggest that Canada thistle is 3 to 4 times as competitive as wild oats. Cameron, 1936 studied the effect of Canada thistle on wheat yield and estimated that a density of up to 5 shoots/m^2 could reduce wheat yield by 18% and 20 shoots/m^2 as much as 60%. However, Canada thistle often grows in patches and it would be necessary to calculate the yield loss in these and then estimate the portion of the field infested with the patches; and make the appropriate adjustment to enable a more accurate estimate of yield loss for the whole field. It is also important to note when using any of the indicies that actual yield loss would be greater in a field with a high yield potential than a low yield potential.

Figure 3. **EFFECT OF WILD OAT DENSITY ON YIELD LOSS(DEW)**

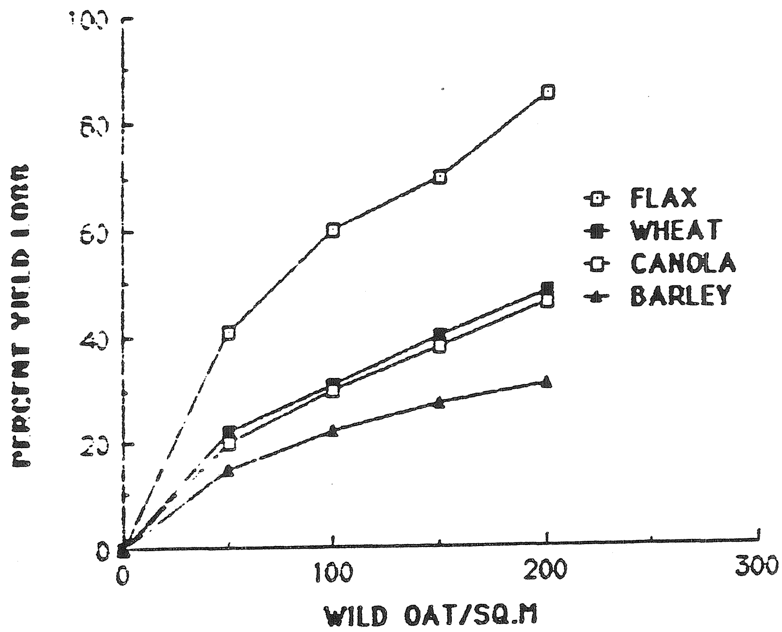


Figure 4. Yield Loss of Barley Due to Canada Thistle

$$y = 0.420 + 7.6\sqrt{x}$$

y = % yield loss barley

x = Canada thistle shoots/m^2

O'Sullivan et. al. 1982

Other reports indicate that annual broadleaved weeds can also compete vigorously with small grains resulting in significant yield reductions. Anderson (1956), reported that in the Regina area dense infestations of wild mustard reduced wheat, oats and barley yield by 53, 63 and 69% respectively (Table 2).

Table 2. Average Loss - Dense Infestation Wild Mustard over 9yrs- Regina

Wheat -	53 %
Oats -	63 %
Barley -	69 %

Anderson, 1956

In Alberta, tartary buckwheat at 30 plants/m^2 reduced barley yield by 16% andwheat yield by 22% (de St.Remy et al, 1985).

In recent years, competition from volunteer cereals in canola has become a concern to growers. Registration of the graminicides, Poast and Fusilade provided growers with excellent means of controlling volunteer cereals, however, the economics of applying these products had not been well determined. O'Donovan et al (1987) have developed a crop loss index which will help growers determine when volunteer barley control in canola is cost-effective. Based on data obtained at Scott, Saskatchewan and Lacombe and Vegreville, Alberta the model can be used to develop a cost analysis of barley control (Fig. 5). It is assumed that market prices of canola and barley were $260 and $75/tonne respectively. The herbicide cost was $33/ha and application cost and seed separation cost were $7/ha and $10/tonne respectively. These figures represent approximate average prices and costs for western Canada in 1986 and 1987. The cost-effectiveness of controlling the volunteer barley with a herbicide, as indicated by the economic thresholds, differed considerably depending on whether or not the volunteer barley seed was considered to have a market value. Where volunteer barley was considered to have no market value (D2), spraying was justified econimically at approximately 15plants/m^2. However if the potential yield value of the barleywas taken into account (D3), more than 50 plants/m^2 was required to break even on herbicide application. The results suggest that at current crop prices and herbicide costs, control of volunteer barley with post-emergence herbicides may be difficult to justify economically in some situations in western Canada.

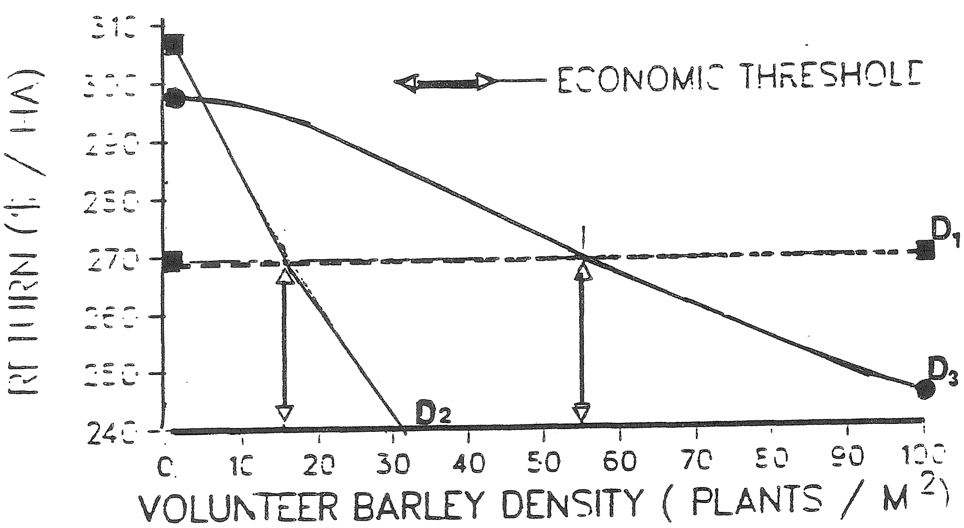


Fig. 5 Economics of volunteer barley control in rapeseed.
D1=rapeseed yields (and cash returns)
D2=volunteer barley considered to have no market value
D3=volunteer barley considered to have value at feed price

Delayed seeding is one of the major methods used in western Canada for the cultural control of many weeds but is particularily effective on wild oats. Korven, (1960) demonstrated that a delay of three weeks (May 1 to May 23) in southwestern Saskatchewan permitted a flush of wild oats to emerge, which could then be killed with tillage at time of seeding (Table 3). In both barley and wheat, the wild oat population was reduced by over 90%. In all years, there was a greater wild oat infestation, in the early than in the late seeded wheat. Delayed seedings yielded more than early seedings (Table 4). The increases varied from year to year and resulted in a 6 - year mean increase of 7.5 bushels per acre. It is of interest to note that the largest increases in yield resulted when the interval between early and late seeding was approximately 3 weeks.

Table 3 The Effect of Dates of Seeding on Wild Oat Populations

Seeding treatment	Date 1957	Wild oat plants per sq. yd. - 1957	Soil populations of wild oats bu/ac	
			Fall-1955	Fall-1957
Early barley	May 01	38.5	7.5	17.1
Late barley	May 23	1.5	8.7	5.6
Early wheat	May 01	41.0	6.2	22.0
Late wheat	May 23	3.5	8.8	5.4

Korven, 1960

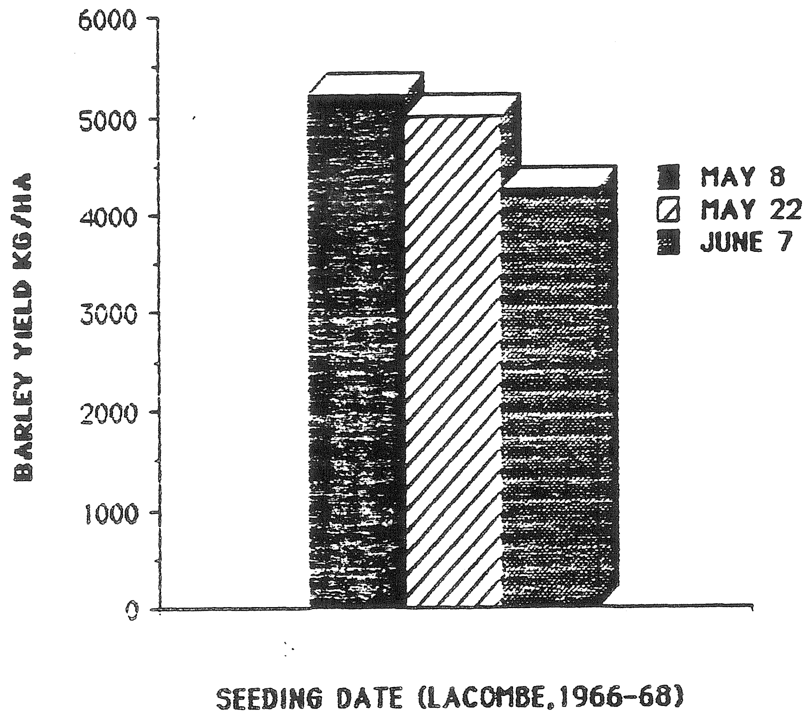
Table 4 The Effect of Dates of Seeding on Yield of Wheat Infested with Wild Oats

Year	Dates of seeding		Yield - bu/ac.	
	Early	Delayed	Early	Delayed
1954	May 10	May 25	15.0	18.0
1955	May 12	May 25	27.0	30.5
1956	May 05	May 25	26.0	35.0
1957	May 01	May 23	9.0	22.0
1959	Apr 27	May 20	19.0	33.2
1960	May 05	May 20	27.4	29.9

Korven, 1960

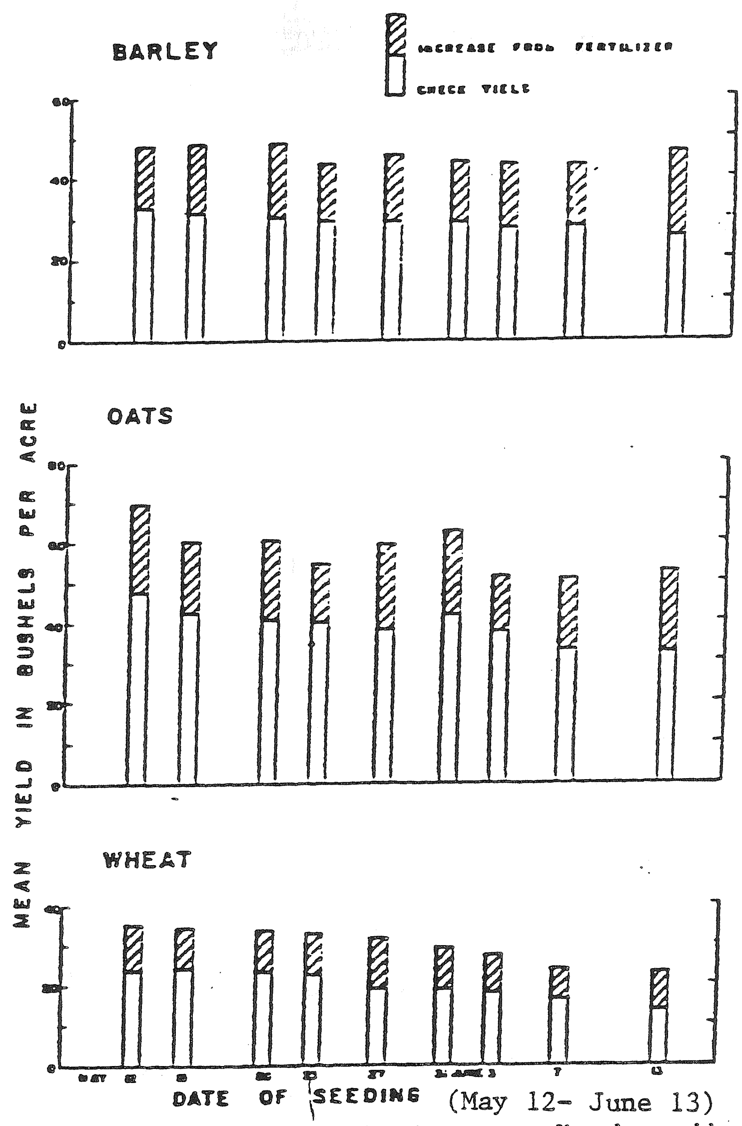
In northern Alberta, Darwent and Smith (1985) reported that allowing wild oats to grow to the 2-leaf stage, destroying them with cultivation and then seeding rapeseed resulted in commercially acceptable (70% or more) control with little or no loss of crop yield. Postponing cultivation until the wild oats reached the 3 to 4-leaf stage provided a similar level of control but resulted in reduced crop yields. McFadden, (1970) found that a delay in seeding Olli barley from May 8 to June 7 resulted in a yield loss of approximately 18% in central Alberta (Fig. 6).

Figure 6. YIELD,OLLI BARLEY AT THREE SEEDING DATES



At Beaverlodge, Anderson and Hennig (1964) reported that cereal yields declined steadily when seeded at 3-4 day intervals from May 12 - June 13. The addition of 11-48-0 at 35 lbs per acre increased yields of wheat, oats and barley (Fig. 7). The yield of fertilized barley was not influenced by date of seeding. However, yields of fertilized wheat and oats declined as seeding date was delayed. It is evident from these results that a delay in seeding date can be an effective method of weed control however, a significant economic loss in yield and quality can be expected in most spring sown crops.

Figure 7



Yields of wheat, oats, and barley for nine mean seeding dates, with and without 11-48-0 at 35 pounds per acre during 1951-56, inclusive.

In a five year study of continuous cropping (wheat) at three locations Brandt and Kirkland (1987)*found that the use of herbicides increased yield over all locations and years by 417 kg/ha (Table 5). With wheat selling at 1986-87 prices the gain in yield would barely cover the cost of the herbicide and application, no economic return could be expected. In this study,wild oat and broadleaved herbicide combinations were applied annually regardless of weed populations. At Lashburn, and Loon Lake, weed populations were not sufficient to warrant herbicide application in several years of the study. At Scott, weed populations were high (297/m^2) in all years and yield increases from weed control were 791 kg/ha in 1987 and 614 kg/ha annually from 1983-1987. If maximum economic return is to be achieved, controlling weeds (when populations warrant) is an essential component of the production formula

* unpublished data

Table 5 Yields of Wheat (kg/ha) with Several Herbicide Treatments in a Continuous Wheat Rotation

Herbicide treatment	Scott 1987	Scott 1983-87	Lashburn 1987	Lashburn 1983-87	Loon Lake 1987	Loon Lake 1983-87	All locations 1983 - 87
Check-no Herbicide	560	1128	1123	1937	447	1325	1569
Hoe-Glean	1331	1682	1461	2120	930	1750	1981
Hoe-Torch	1351	1742	1548	2176	761	1697	1986
Hoe-Buctril M[1]	1398	1759	1567	2183	900	1705	1961
Avadex-2,4D[1]	941	1525	1350	2072	903	1606	1828
L.S.D. P=0.05	66	113	93	46	67	90	49

[1] Comparisons of the Hoegrass-Buctril M and Avadex-2,4-D treatments with other treatments are not strictly valid as Hoegrass-Buctril M was applied only with normal height or tall stubble and Avadex - 2,4-D only with fall tillage.

Brandt and Kirkland, 1987

Brandt and Kirkland also reported that effective weed control greatly improved the efficiency of fertilizer use. At Scott, (Fig. 8) and Loon Lake (Fig. 9) in 1987, response to N and P increased several fold when weeds were controlled.

Figure 8. HERBICIDE EFFECT ON RESPONSE TO FERTILIZER

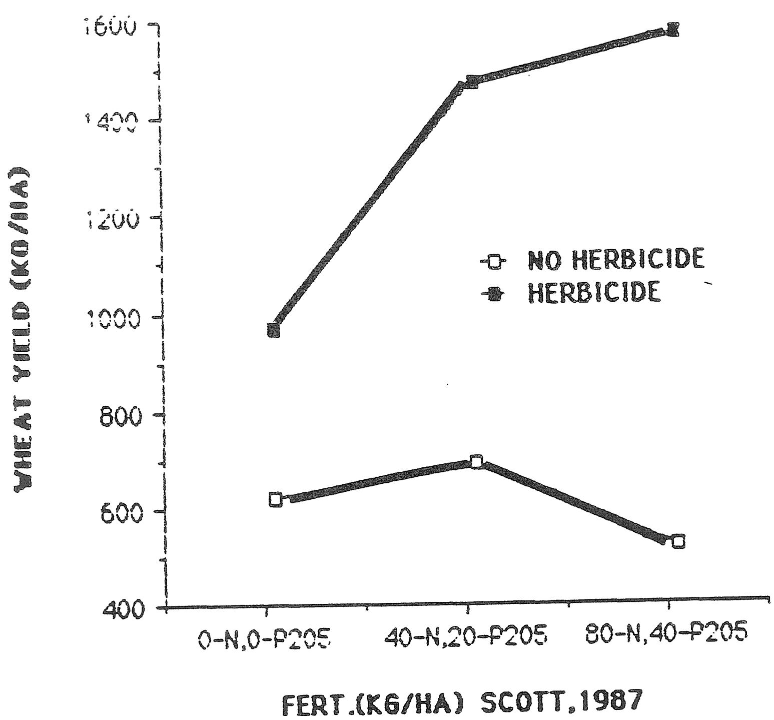
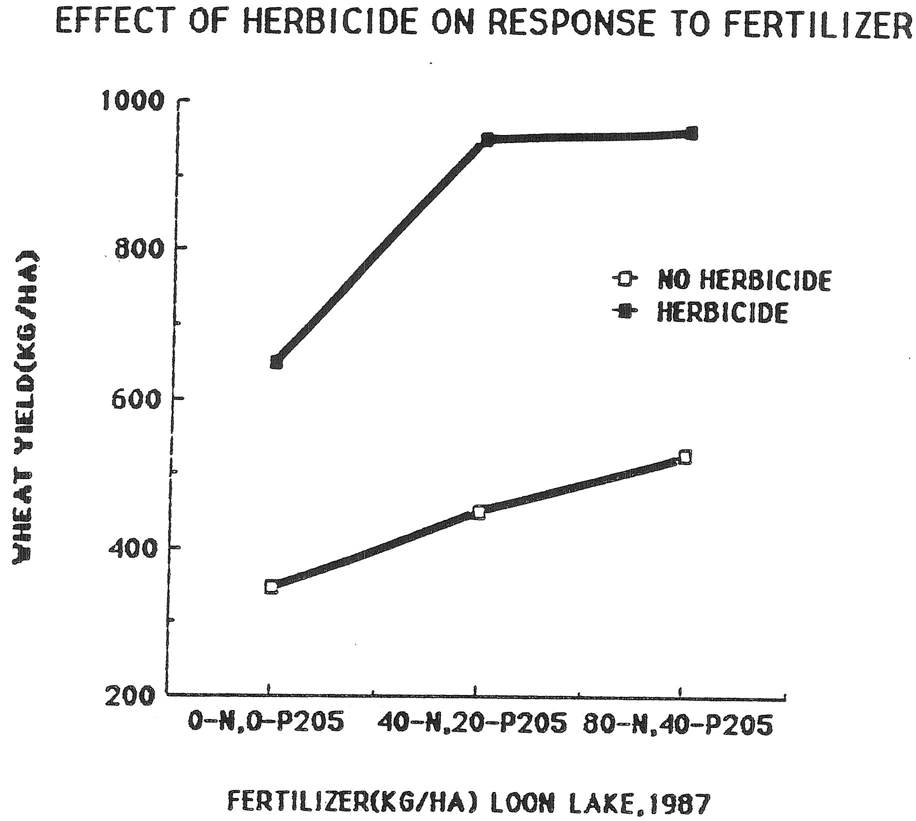


Figure 9.



The decision on when to spray broadleaved weeds in wheat is influenced by many factors. Some growers choose to wait until weeds are well advanced to ensure all have germinated. Others are forced to delay spraying due to adverse weather conditions or other priorities. To determine what losses (if any) a grower might incur by waiting, a study was conducted at Scott to determine the effect of herbicide application at the 3-leaf compared to the 6-leaf stage (8 day delay) (Kirkland, 1987). Buctril M, Glean, Torch + 2,4-D ester and the experimental herbicide combination Refine + DPX-L5300 (Dupont) were applied to heavy infestations of wild mustard and volunteer canola in Katepwa wheat (Table 6). Delaying the application of Glean and Torch + 2,4-D ester did not reduce the eventual effectiveness of the weed control. However, yields declined by approximately 400 kg/ha (data not shown). With Buctril M, a delay of 8 days reduced control of volunteer canola and wild mustard by 29 and 33%, respectively. The corresponding yield reduction was 700 kg/ha. The Refine + DPX-L5300 combination provided excellent control with the early application, but control was reduced by approximately 50% when the application was delayed. Yield loss from the delayed application was 760 kg/ha. Applying a higher rate did not significantly improve weed control or subsequent yield.

It is evident from these results that delaying application of these herbicides on heavy infestations of wild mustard and volunteer canola can result in significant economic losses. Timely herbicide application is a must if maximum economic returns are to be obtained.

Table 6 The Effect of Weed Seedling Growth Stage on Herbicide Efficacy in Wheat, Scott.

Treatment	Rate (kg/ha)	% control Leaf stage at application Vol. canola 3	6	Wild mustard 3	6
Buctril M	0.56	94	65	98	65
Glean	0.0225	100	99	100	99
Torch/2,4-De	0.56	100	100	100	100
Refine + DPX-L5300*	0.005 + 0.0025	96	48	99	48
Refine + DPX-L5300	0.0073 + 0.0037	100	53	100	53

* (Dupont)

If a pure herbicidal compound were placed on a plant leaf, it would exhibit only a small percentage of its potential herbicidal activity. Once a concentrate is dispersed in water, it may then be evenly distributed over a foliage surface. However, this surface (leaf area) presents a lipid barrier that prevents penetration of the herbicide, thereby preventing the compound from getting to a biological site of activity.

The net result is that in the absence of agents that aid in penetration (adjuvants) of the outer waxy layers of foliage, an herbicidal compound may exhibit as little as 10% of its possible biological activity. When properly formulated, and with the correct amount and type of adjuvant the effectiveness of a herbicide may be increased five - or ten - fold. It is important to note that biological activity is never created through the use of adjuvants. They merely make more efficient the herbicidal activity which already exists.

At Brandon, the addition of three commonly used adjuvants to the herbicide Poast resulted in major differences in the resulting biological activity (Table 7) Citowett had no effect, while Renex 36 markedly increased the effectiveness of the herbicide. The addition of Atplus produced the maximum increase in activity and made Poast activity commercially acceptable on wild oat.

Table 7 Effect of Adjuvants on Wild Oat Control with Poast

Treatment	Wild oat shoot wt. (g/pot)
Untreated	17.4 a
Poast	11.5 b
Poast + Citowett	10.9 b
Poast + Renex 36	6.4c
Poast + Atplus	1.2 d

a-d Values followed by the same letter are not significantly different at the 5% level (DMR) Chow, 1977.

Similar increases in the activity of Glean were noted when adjuvants were added (Table 8). Maximum effectiveness occurred with the addition of Agral 90 as compared to Citowett, Atplus or Renex 36. The addition of ammonium sulfate did not improve the activity of the Glean-Agral 90 combination.

Table 8 Effect of Surfactants and Ammonium Sulfate on Glean for Rapeseed Control

Treatment	Leaf fresh weight g/plant	Leaf fresh weight Reduction % of the check
Untreated	10.0	-
Ammonium sulfate*	9.8	3
Glean	8.7	14
Glean + Agral 90	1.9	81
Glean + Agral 90 + Amm. Sulfate	2.1	79
Glean + Atplus 411 F	3.7	63
Glean + Atplus 411 F + Amm. Sulf.	2.7	73
Glean + Citowett Plus	2.7	73
Glean + Citowett Plus + Amm. Sulf.	2.6	74
Glean + Renex 36	3.0	70
Glean + Renex 36 + Amm. Sulf.	2.6	74

* Adjuvants and ammonium sulfate added at 0.5% v/v. Chow, 1984

Several researchers have reported increased biological activity of Poast with the addition of ammonium sulfate fertilizer (21-0-0-24).

A summary of research reports published by the Expert Committee on Weeds (Western Canada) are presented in Table 9. The addition of ammonium sulfate to the 0.15 kg/ha rate of Poast increased the stand reduction of volunteer barley and wheat by 30 and 13% respectively.

Table 9. Control of Volunteer Cereals with Post plus Adjuvants 1984-85

Poast (kg/ha)	Assist (% v/v)	Amm. Sul (l/ha)	% stand reduction Vol. barley (7)	% stand reduction Vol. wheat (7)
0	0	0	0	0
0.15	0.5	0	57	73
0.15	0.5	4.0	87	86
0.25	0.5	0	84	92
0.25	0.5	4.0	95	97

(7) Average of 7 tests reported to the 1984, 1985 Research Report, Expert Committee on Weeds (Western Canada).

Kirkland,(1986) reported that both Agral 90 and ammonium sulfate were required to obtain optimum control with glyphosate (Roundup) applied to wild oats in the 6-leaf stage on chemical fallow (Table 10). When applied to wild oats in the 3-leaf stage, glyphosate alone at either the 0.28

or 0.21 kg/ha gave complete control (data for 3-leaf stage not shown).

Table 10 The Effect of Wild Oat Leaf Stage, Agral 90 and Ammonium Sulfate on the Efficacy of Glyphosate, 1986.

Glyphosate (kg/ha)	Agral 90 (0.5%)	Amm. Sulfate (4%)	Wild oat leaf stage	Wild oat % stand reduction
0.28	-	-	6	81
0.28	+	-	6	97
0.28	-	+	6	96
0.28	+	+	6	100
0.21	-	-	6	73
0.21	+	-	6	92
0.21	-	+	6	87
0.21	+	+	6	100

Kirkland, 1986

Several experimental graminicides currently under development have shown significant increases in effectiveness with the addition of ammonium sulfate. Kirkland(1986a), reported significant increases in activity when ammonium sulfate liquid at 4% v/v was added to BAS-517 and applied to wild oat and volunteer barley (Table 11). Although no price has been established for BAS-517 if one assumes the cost will be similar to the cost of registered graminicides, it should be possible to save \$5.00-\$6.00/acre by adding appromiately \$0.40 of ammonium sulfate.

Table 11 The Effect of Ammonium Sulfate on the Efficacy of BAS-517 on Wild Oat and Barley, Scott, 1986.

Treatment	Rate (kg/ha)	Amm. Sulfate 4%	Wild oat Culms (#/m2)	Wild oat Fresh wt. (g/m2)	Barley Culms (#/m2)	Barley Fresh wt. (g/m2)
BAS-517*	0	-	246	2163	472	2638
BAS-517	0	+	264	2418	429	2556
BAS-517	0.05	-	27	375	512	2231
BAS-517	0.05	+	0	0	170	1012
BAS-517	0.10	-	0	0	51	256
BAS-517	0.10	+	0	0	0	0
BAS-517	0.15	-	0	0	0	0
BAS-517	0.15	+	0	0	0	0

* Assist oil concentrate added to all treatments at 0.5% v/v.

Kirkland, 1986

The effect of water volume and herbicide rate on the efficacy of several herbicides has been the subject of considerable research and much discussion in recent years. The introduction of shrouded sprayers permits application of lower water volumes and smaller droplet sizes without the same concern for droplet drift as with open booms. This has led to some speculation that with finer droplets, better coverage should be possible and herbicides might be more effective. Thus would permit comparable control at lower rates of active ingredient and subsequently reduce weed control costs. At Scott, in 1986 (Table 12) and 1987 (data not shown) glyphosate (Roundup) demonstrated excellent potential for reduced volume, reduced rate application on wild oat. Glyphosate was applied at rates of 0.28, 0.21, 0.14 and 0.07 kg/ha, 100, 75, 50 and 25% of recommended rate respectively. Treatments were applied in 100, 50, 30 and 10 litres of water/hectare. As the rate of glyphosate declined, control, particularily at the highest water volume dropped markedly. At the 25% (0.07 kg/ha) rate control was only acceptable with the 10 l/ha water volume.

Table 12 The Effect of Water Volume and Herbicide Rate on the Efficacy of Glyphosate on Wild Oat, Scott, 1986.

Treatment	Rate (kg/ha)	Wild oat - % injury (Water volume l/ha) 100	50	30	10
Glyphosate	0.28	100	100	100	100
Glyphosate	0.21	96	99	100	100
Glyphosate	0.14	89	97	96	100
Glyphosate	0.07	15	81	86	100

Kirkland, 1986

Additional volume and rate research conducted at Scott in 1987 included diclofop methyl (Hoegrass), bromoxynil + MCPA (Buctril M), fluazifop butyl (Fusilade) and 2,4-D amine/dicamba (Banvel). With Fusilade (data not shown)control of wild oats and volunteer wheat was poor but similar at all water volumes. Control of wild mustard and volunteer canola with 2,4-D amine/Banvel was as good or better at all rates when applied in reduced water volumes (data not shown). Wild oat control with Hoegrass was not highly effective in 1987 due to dry conditions at the time of application. When rates or water volumes were reduced control was also reduced (Table 13). Control of volunteer canola with Buctril M was similar for all water volumes at the 100 and 75% rate (Table 14). At the 50% herbicide rate control was somewhat better at the 30 and 10 l/ha water volumes. At the 25% rate this trend was reversed with the higher water volumes giving the best control.

These results suggest that other herbicides are not significantly influenced by lower water volumes in the same manner as Roundup. While much more research is required, it is evident that significant economic benefits may be possible if the application of Roundup can be achieved with low water volumes applied as fine droplets.

Table 13 Effect of Water Volume and Herbicide Rate on the Efficacy of Diclofop Methyl, Scott, 1987.

Treatment	Rate (kg/ha)	Wild oat weight (g/m^2) 100	50	30	10	0*
		(water volume l/ha)				
Diclofop methyl	0.700	366	514	465	516	574
Diclofop methyl	0.525	566	577	612	562	615
Diclofop methyl	0.350	674	610	539	531	621
Diclofop methyl	0.175	668	609	661	603	642
LSD (0.05) Rate = 57, Volume = 56						

* 0 = untreated

Kirkland, 1987

Table 14 Effect of Water Volume and Herbicide Rate on the Efficacy of Bromoxynil/MCPA, Scott, 1987.

Treatment	Rate (kg/ha)	Volunteer rape - % injury 100	50	30	10
		(water volume l/ha)			
Bromoxynil/MCPA	0.56	95	95	98	99
Bromoxynil/MCPA	0.42	89	90	91	90
Bromoxynil/MCPA	0.28	85	85	90	93
Bromoxynil/MCPA	0.14	79	75	70	65
LSD (0.05) Rate = 2.8, Volume = 1.5					

Kirkland, 1987

Summary

It is evident that controlling weed infestations effectively and efficiently is essential if maximum economic yields of small grains are to be achieved. Several areas where management decisions are critical to the end result (economic yield) include:

- the correct identification of the weed species present.
- an understanding of the competitive ability of the weeds and crop(s) involved.
- correct assessment of the density and relative time of emergence of the weed species.
- knowledge of the effectiveness and cost of alternative cultural and chemical control measures.
- from the above, determine if weed control measures will be economical.
- proper timing when applying herbicides.
- adding extra adjuvants to herbicides only when recommended.
- avoid adding ammonium sulfate or any other enhancements to a herbicide unless the addition has been well researched and is recommended.

- reduced rate-volume application technology requires much more research. Most herbicides do not show increased activity when water volumes are reduced.
- herbicide rates can be reduced in many instances when:
  (a) application timing is correct.
  (b) optimum growing conditions prevail.

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