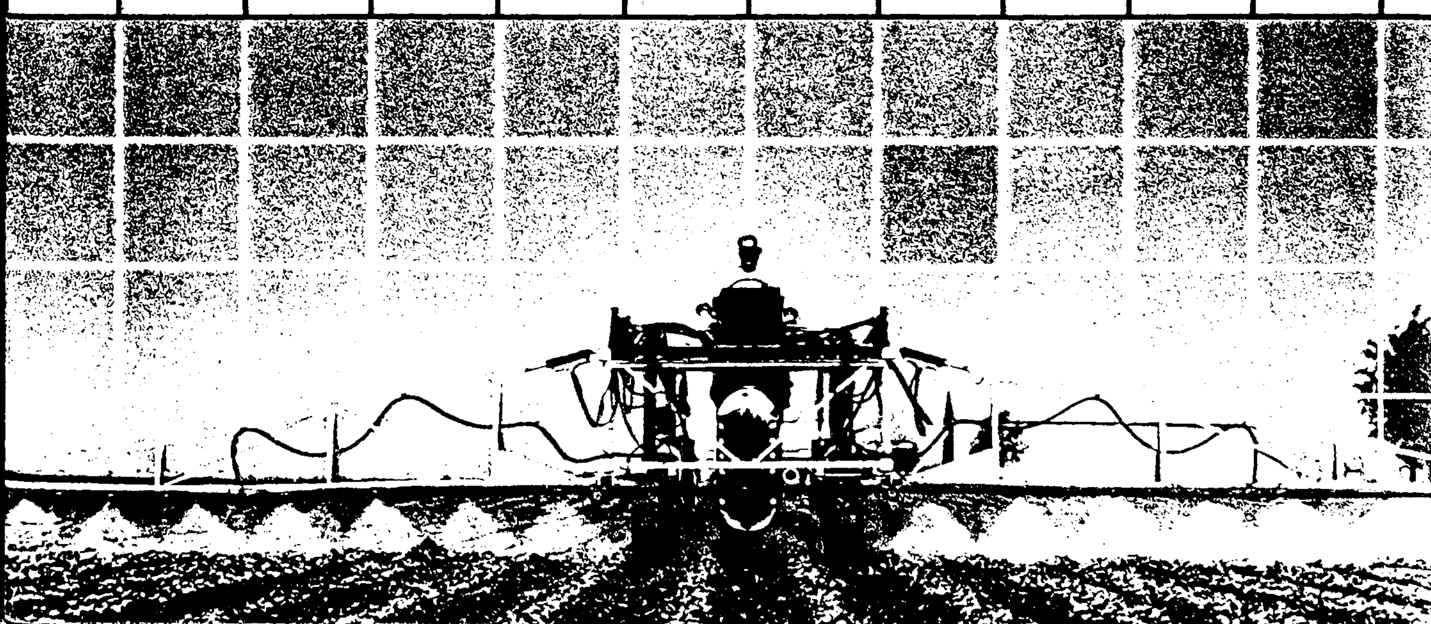
Soils, Fertilizer and Agricultural Pesticides Short Course

December 11-12, 1984

Minneapolis Auditorium

University of Minnesota
Agricultural Extension Service



PROCEEDINGS

SOILS, FERTILIZER AND AGRICULTURAL PESTICIDES

SHORT COURSE

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Presented by the
University of Minnesota
Institute of Agriculture, Forestry and Home Economics
Office of Special Programs
Agricultural Experiment Station
Agricultural Extension Service
College of Agriculture

In Cooperation With
Minnesota Plant Food and Chemicals Association
Minnesota Department of Agriculture

Office of Special Programs Education Series 7-2

Published by
Office of Special Programs
University of Minnesota
405 Coffey Hall
St. Paul, Minnesota 55108

December 11, 1984

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MOBILE NUTRIENT MANAGEMENT FOR CORN
PRODUCTION ON IRRIGATED SANDY SOILS

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When discussing nutrients for crop production, it's traditional to classify the nutrient with respect to the amount absorbed by the specific crop--i.e. macronutrient or micronutrient. However, when fertilizer management is considered, the mobility of the nutrient often becomes the major consideration. This is especially true for crop production on irrigated sandy soils.

There has been a rapid expansion of irrigation in the central sand plain of Minnesota in the past decade. Although yearly rainfall totals are not excessively high, it's common to have heavy rains in either May or June in many years. Because of the low water holding capacities of these soils, management of the mobile nutrients (nitrogen, sulfur, and boron) becomes a major concern.

Management of nitrogen fertilizers for irrigated corn production on these sandy soils has been the focus of several research projects in Minnesota as well as in other states. The major portion of this discussion will involve the recommendations that have evolved from these research efforts. Compared to nitrogen (N), less is known about the management of sulfur (S) and boron (B). Some limited information regarding the use of these nutrients is available and will be included in this discussion.

Rather than discuss the results of several studies in detail, it is probably more meaningful to provide answers, based on research, to some problems dealing with the management of mobile nutrients for corn production on the irrigated sandy soils. Answers to some common questions are discussed below. It's important to point out that this discussion relates to sandy soils only. THE CONCLUSIONS STATED IN THE FOLLOWING DISCUSSION WOULD PROBABLY NOT BE APPROPRIATE FOR FINE TEXTURED SOILS IN THE NORTH CENTRAL REGION.

Are Split Applications of Nitrogen Important?
Are Nitrification Inhibitors Important?

These two questions are related and should be considered together in describing N management systems for corn production on irrigated sandy soils. As might be expected, the importance of split N applications and nitrification inhibitors is related to rainfall patterns (Table 1).

In 1982, rainfall was uniformly distributed throughout the growing season with no major storms that would cause severe leaching of NO_3^--N. With this rainfall pattern, neither the timing of the N application nor the use of a nitrification inhibitor (N-Serve) had any effect on corn yield at the Becker site (Table 1).

Table 1. The effect of timing of N applications with and without a nitrification inhibitor on yield of corn grown on irrigated sands. Becker experimental field (Malzer).

Timing of N Application*	Inhibitor Used (N-Serve)	Year 1981	Year 1982
		---bu./acre--	
pp[1]	No	92	197
pp	Yes	108	196
Split (4)**	No	159	202
1/3 (pp) 2/3 (12 leaf)	No	134	194
1/3 (pp) 2/3 (12 leaf)	Yes (pp)	162	196
2/3 (pp) 1/3 (12 leaf)	No	105	194
2/3 (pp) 1/3 (12 leaf)	Yes (pp)	149	195
12 leaf	No	168	192
12 leaf	Yes	159	193
			NS

*N rate constant at 150 lb./acre supplied as urea

**4 applications of N: 1/6 pp, 1/6 8 leaf, 3/6 12 leaf; 1/6 tassel; no inhibitor used.

[1]pp = preplant application.

In 1981, a total of 5.23 in. of rain was recorded in two consecutive days causing leaching of NO_3^--N. With this rainfall situation, both the timing of N application and the use of a nitrification inhibitor had a significant effect on yield (Table 1). As might be expected, split applications of N were superior to a single preplant application either with or without the inhibitor. The use of the inhibitor with preplant N helped, but this practice did not produce the highest yield.

Yields were increased by the use of the inhibitor with all preplant applications. There was, however, no benefit from using the inhibitor with a sidedress treatment at the 12 leaf stage.

Yields resulting from the sidedress application of N were equal to yields from the use of split applications. In addition, yields produced by two N applications were equal to yields resulting from 4 applications provided an inhibitor was used with the preplant applications where two applications were used.

The data from studies conducted on irrigated sandy soils in north-central Minnesota are similar to the data collected from the Becker location (Table 2). Except for the situation where preplant N was used without an inhibitor at the Roth location, yields were not affected by either timing of N or inhibitor use in 1982. In 1984, the use of an inhibitor with the preplant N increased yields at the Roth, but not the Staples, location. However, split applications of N in 1984 were superior to a single preplant application either with or without an inhibitor.

Table 2. The effect of timing of N application with and without a nitrification inhibitor on yield of corn grown on irrigated sands. North-central Minnesota (Fenster).

N Timing and Rate (lb./Acre)	Inhibitor Used*	Location and Year			
		1982		1984	
		Staples	Roth	Staples	Roth
		--------------bu./acre--------------			
160 N (pp)	No	160	128	122	100
160 N (pp)	Yes	161	166	116	121
80 N (pp) 80 N (8 leaf)	Yes (pp)	165	163	143	142
80 N (pp) 40 N (8 leaf) 40 N (12 leaf)	Yes (pp)	163	167	150	156

*N-Serve was the nitrification inhibitor used.

Urea was the N source used for the studies summarized in Tables 1 and 2. There are also various nitrification inhibitors that can be used with urea and other N sources. A study designed to evaluate the effect of 3 N sources with 2 nitrification inhibitors was conducted at the Becker location in 1983 and 1984 (Table 3).

Table 3. Corn yield on irrigated sand as influenced by N source and nitrification inhibitor. Becker. (Malzer)

N Source*	Nitrification Inhibitor	Year	
		1983	1984
		---bu./acre---	
82-0-0	None	107	135
82-0-0	N-Serve	129	161
82-0-0	DCD**	139	165
82-0-0 SD***	---	148	170
28-0-0	None	90	73
28-0-0	N-Serve	113	76
28-0-0	DCD	140	104
28-0-0 SD	---	153	148
46-0-0	None	79	58
46-0-0	N-Serve	116	89
46-0-0	DCD	134	177

*N rate was 150 lb./acre preplant
**DCD - dicyandiamide
***SD - sidedress application

In both years, there were storms producing enough rain to cause leaching of NO_3^--N. The effects of N source were not consistent for the two years. In 1984 average yields resulting from the use of 82-0-0 without inhibitors were higher than those resulting from the use of urea which were, in turn, higher than those resulting from the use of 28-0-0. The effects just described were recorded when the N rate was 150 lb./acre. Yield differences due to N source were not as pronounced when the N rate was 75 lb./acre (data not shown).

The use of DCD (dicyandiamide) with the preplant application of all N sources produced the highest yields each year. The effectiveness of DCD used with urea was especially effective in 1984 (Table 3).

Preplant application of nitrogen with and without inhibitors can also be compared to a sidedress treatment of either 82-0-0 or 28-0-0. Highest yields on these irrigated sands were measured when the sidedress treatment was used.

Considering the many options available to those who grow corn on irrigated sandy soils, the results show that the application of fertilizer N after planting will produce the highest yields. The sidedress application of fertilizer N on sandy soils is a good management practice. If time for sidedress application of N is limited, split applications would be the preferred method of N application. Even if N is sidedressed, a management plan should include the application of some N with the irrigation water. This is a good insurance policy. Preplant applications of N on these sandy soils should be avoided. If a preplant N application cannot be avoided, use a nitrification inhibitor to reduce N losses. Use of a nitrification inhibitor is also an important management practice if N is sidedressed before the 8-leaf stage of development.

Are Nitrogen Sources Equal?
 What Rate of Nitrogen Should Be Used?

Substantial research throughout the Corn Belt has shown that N sources, if managed properly, are equally effective for corn production. Except for situations where substantial leaching of NO_3^--N is likely to occur. the results of the studies described previously would support this statement.

These studies were not designed to identify the optimum N rate for use for corn production on these sandy soils. Suggested N rates will vary with yield goal and cropping history.

Is Boron Necessary?

It's obvious that the large majority of the research with corn production on irrigated sandy soils has focused on N management. Management of S has been evaluated in limited studies. Very limited information is available regarding the use of B which is also considered to be a mobile nutrient.

The broadcast application of B to irrigated sands was evaluated in 1982 (Table 4). There was no response at either site. The amount of hot water soluble B in the soil at these sites would be considered as low. Either the soil was able to supply the requirement for B or a single application was not effective for achieving optimum yields. Further research with B on irrigated sandy soils is needed.

What About Sulfur Management?

The importance of S for corn production on irrigated sandy soils has been the object of research studies in Minnesota for several years. The value of S in a fertilizer program for this management situation is also related to rainfall patterns.

Table 4. Effect of the use of sulfur and boron on yield of corn on irrigated sandy soils in north-central Minnesota. 1982. (Fenster)

Nutrient Applied		Location	
S	B	Staples	Roth
----lb./acre----		----bu./acre----	
0	0	162	165
0	2*	163	152
25[1]	0	167	173
25[1] + 25[2]	2*	163	168
25[1]	2*	160	165
		NS	NS

*2 lb. boron/acre broadcast and incorporated before planting

[1] applied as K_2SO_4 in starter fertilizer

[2] applied as K_2SO_4 at 12 leaf stage

N rate for all treatments was 160 lb./acre in a split application

Table 5. Selected properties of soils at the experimental sites in north-central Minnesota. 1982 and 1984.

Property	Location and Year		
	1982		1984
	Staples	Roth	Roth
pH	6.6	5.8	5.8
P (Bray & Kurtz #1), lb./acre	37	123	115
K (1N $NH_4C_2H_3O_2$), lb./acre	207	217	242
Mg (1N $NH_4C_2H_3O_2$), lb./acre	231	206	145
S [$Ca(H_2PO_4)_2$], ppm	3	3	1.5
B (Hot water), ppm	.2	.2	--
O.M., %	3.0	2.0	2.1

In 1982, a year when growing season rainfall patterns were optimum, the use of S in a starter fertilizer as well as starter S combined with a mid-season application of S had no effect on corn yields in north-central Minnesota (Table 4). Although the S content of these soils is considered to be low (Table 5), there was apparently adequate amounts of S mineralized from the organic matter during the growing season to meet crop requirements. The fertilizer S and mineralized S was apparently not leached from the root zone.

In 1984, some early and mid-June rains were heavy and a positive response to S was recorded at the Roth location (Table 6). The heavy early season rains may have leached some of the mineralized S from the root zone and then fertilizer S had a positive effect on yield.

Table 6. Effect of sulfur applied in a starter fertilizer on yield of corn grown on an irrigated sandy soil in north-central Minnesota. (Fenster, 1984)

S Applied	Yield --bu./acre--
None	144
10 lb.S/acre, starter	158

S Source = K_2SO_4; N Rate = 160 lb./acre in split application

Research with S use on these sandy soils, to date, has involved either broadcast or row applied S. Additional research with S is needed. Specifically split applications of S in combination with split applications of N may lead to increased yields of corn grown on irrigated sandy soils.

MAP, DAP, POLY AND ORTHO -- WHAT'S THE DIFFERENCE?

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In today's agriculture, there are several phosphate fertilizers that can be used to enhance crop production on soils that have inadequate levels of available P. Because of the variety of phosphate fertilizer materials on the market, growers, fertilizer dealers, consultants, etc. frequently hear claims and counter claims for the various materials. These claims can be confusing and the question used for the title of this discussion is frequently raised.

Manufacture of Phosphate Fertilizers:

Before questions about the effectiveness of various phosphate fertilizers can be answered, it's important to have some understanding of the manufacturing processes used in the phosphate fertilizer industry. A simplified summary of the various processes used is outlined in the following diagram.

Rock phosphate is the starting point in the manufacture of phosphate fertilizers used today. Phosphoric acid is produced from the rock phosphate by 2 processes: 1) electric furnace and 2) phosphoric acid treatment. White phosphoric acid is the end product of the electric furnace process. This acid is commonly used in the food and other industries. Small amounts are used in the manufacture of phosphate fertilizers.

Green phosphoric acid (also called wet process acid) is produced from the treatment of rock phosphate with phosphoric acid. This wet process acid is reacted with ammonia to produce either monoammonium phosphate (MAP) or diammonium phosphate (DAP). The phosphate in wet process acid is in the orthophosphate form. Therefore, the phosphate in MAP and DAP is in the orthophosphate form.

MAP vs. DAP:

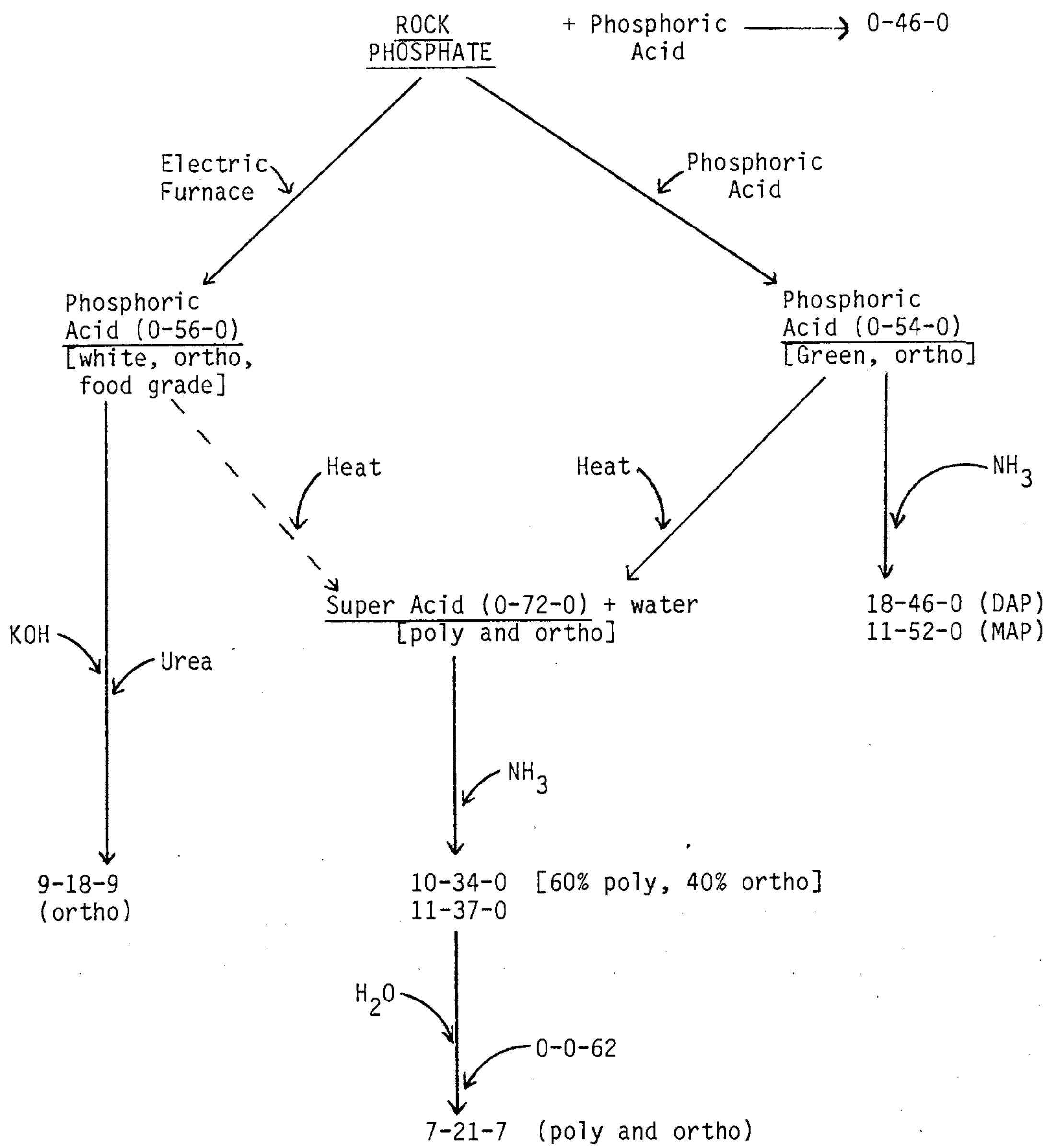
The relative merits and disadvantages of MAP and DAP have been thoroughly discussed and researched over the years. The summary of the research trials conducted would fill several pages. There is general agreement that, except for special situations, both materials are equally effective as phosphate fertilizers for crop production. Special considerations that relate to the use of these two materials are listed below.

- The use of DAP, compared to MAP, has resulted in some seedling damage when high rates are placed in direct contact with the seed in highly calcareous soil where soil moisture is limited.

- No damage from DAP was recorded when either low rates were used or in situations where there was some soil between seed and fertilizer.

- If the materials are not placed in direct contact with the seed at high rates, both should be equally effective for crop production in Minnesota.

- MAP has advantages for those dealers who prefer to make suspension fertilizers. The small crystals formed when this product is used increase the stability of the suspension.



Super Acid:

Both electric furnace acid and wet process acid can be heated to drive off water resulting in the production of super phosphoric acid. Because of the higher cost associated with the production of the electric furnace acid, the wet process acid is usually used for this process.

When water is removed the phosphorus in the resulting super acid (0-72-0) is present in both the polyphosphate and orthophosphate form.

A widely used fluid fertilizer (10-34-0) results from the addition of ammonia (NH_3) to the super acid. The 10-34-0 is then used for the production of 7-21-7. Since super acid was the starting point for these materials, the phosphorus is present as both polyphosphate (about 60%) and orthophosphate. The percentage of these two forms in the super acid will vary.

Fluid N-P-K fertilizers are also made from electric furnace acid. In this process, the furnace acid is neutralized with potassium hydroxide (KOH) and urea (46-0-0) is then dissolved in this mixture. The end result produces a 9-18-9 product or one of similar analysis. Since the starting material for this product is electric furnace rather than super acid, the phosphorus in this material is in the orthophosphate form. These two processes used in the manufacture of fluids has stimulated much debate about the relative merits of orthophosphates and polyphosphates for crop production.

Poly vs. Ortho:

In any discussion involving polyphosphates and orthophosphates the following two points are important and should be remembered.

1. Although a fertilizer may be described as being a polyphosphate material, there are no commonly sold materials where 100% of the phosphorus is in the polyphosphate form. For these fertilizers, its common to have about 60% of the phosphorus in the polyphosphate form and 40% of the phosphorus in the orthophosphate form.

2. When polyphosphate materials are added to soils, the polyphosphate is rapidly converted to orthophosphate.

$$\text{polyphosphate} + \text{water} \longrightarrow \text{orthophosphate}$$

With these two basic facts in mind, there is no reason to expect that crops would respond differently when fertilized with these two forms of phosphorus. Several studies have been conducted to compare the effect of polyphosphate and orthophosphate materials on crop production. Some of these studies are summarized in the following tables.

Results from a study comparing these two P sources for corn production on an acid soil in Nebraska are summarized in Table 1. In this study, the yield difference of 5 bu./acre was due to the natural variation of yields in the field and not the source of phosphorus that was used.

Table 1. Effect of phosphorus source on corn grown on an acid soil.

P Source*	Yield
	bu./acre
polyphosphate	169
orthophosphate	164

Source: Nebraska
*Rate constant at 40 lb. P_2O_5/acre in a starter fertilizer

These two P sources have also been evaluated for corn production on calcareous soils (pH higher than 7.4) and the data are summarized in Table 2.

Table 2. Effect of source and rate of phosphorus on corn grown on a calcareous soil.

P_2O_5 Applied	P Source	
	Polyphosphate	Orthophosphate
lb./acre	-----------bu./acre-----------	
15	124	124
30	134	134
45	142	142

Source: Nebraska
Soil P Test: Low

This study was conducted at 5 sites and the yields listed in Table 2 are averages for those sites. The soil test values for phosphorus at all sites were low and there was clearly a response to applied phosphorus. Yields, however, were not affected by the source of phosphorus used.

These two sources have also been evaluated for soybean production in Minnesota (see Table 3). There was a definite response to the use of phosphorus at all sites. The source of P used, however, had no effect on yield. Both were equally effective.

Table 3. Effect of phosphorus source on the yield of soybeans. (Minnesota)

		Treatment*	
Location and Year	Control	Polyphosphate	Orthophosphate
	bu./acre		
Lamberton (1967)	17.3	21.4	20.9
Lamberton (1968)	25.9	29.9	29.1
Rosemount (1968)	26.1	31.5	33.2

*Rate was constant at 32 lb. P_2O_5/acre

Source: R. C. Leslie, M. S. Thesis

When a comparison of these two phosphorus sources was extended to small grain production, conclusions were the same as those reached for both corn and soybeans (see Table 4). Yields were not affected by the source of phosphorus used.

Table 4. Effect of phosphorus source on the yield of spring wheat.

	P Source*	
Year	Polyphosphate	Orthophosphate
	bu./acre	
1981	42.6	42.0
1982	53.9	55.9

*Rate held constant at 56 lb. P_2O_5/acre

Source: Varvel, Northwest Experiment Station, Crookston

Summaries of similar studies conducted in other status would fill several pages. The dominant conclusion of those studies is that, if applied at the same rate, polyphosphate and orthophosphate are equal in their effect on crop production.

Phosphorus Availability and Utilization:

The debate over the advantages and disadvantages of orthophosphates and polyphosphates in recent years has created some confusion about the meaning of the terms "availability" and "utilization" as they relate to phosphorus fertilizers.

By law, all phosphate fertilizers are registered, bought, and sold on the basis of "available P_2O_5". The "available P_2O_5" is the amount of phosphate that is soluble in water plus the amount that is soluble in an ammonium citrate solution.

It's obvious that the P_2O_5 in clear fluids is 100% available. All common dry phosphate sources typically contain 90-100% water soluble phosphorus. So, the "available" phosphorus in these materials is nearly 100%. Considering all of the phosphate fertilizers in the market today, the "availability" of the phosphorus in all is nearly equal. There are no phosphate fertilizers that are 3 to 4 times more available than other commonly sold products.

We can define "utilization" as the amount of phosphorus from an applied phosphate fertilizer that is taken up or used by the growing crop during the growing season. Utilization of phosphorus by crops from any phosphate fertilizer that is applied is usually quite low. The percentage of applied phosphorus that is taken up (utilized) by crops in the season in which the phosphate fertilizer is applied usually ranges from 5% to 30%. This value varies with crop, soils, yield etc; but, utilization is not affected by the type of phosphate fertilizer that is applied.

The chemistry of the soil has a major influence on the amount of applied phosphorus that is taken up or utilized by crops. All phosphate fertilizers sold today (liquid or dry) react with soils in the same way. So, utilization of phosphorus from fluid phosphate materials (polyphosphates or orthophosphates) should be very similar to utilization of phosphorus applied as dry materials.

Summing Up:

If we listen to the claims and counter claims for the phosphate fertilizers on the market today, it's easy to see how someone could get confused. However, if we look at the steps used in the manufacture of these products and understand how they react in soils, the confusion disappears.

The various phosphate products have been evaluated and compared in numerous university and TVA studies. Some major points that come from the studies are:

1. Except for situations where high rates of DAP are applied in direct contact with the seed in soils with a high pH, DAP is just as effective as MAP for crop production.
2. If the fertilizer is placed so that there is soil between it and the seed, MAP and DAP should have an equal effect on crop production in Minnesota.
3. MAP and DAP should be equal in their influence on production if the materials are broadcast and incorporated before planting.
4. Numerous studies have shown that polyphosphates and orthophosphates have an equal effect on crop production.
5. Although some fluid fertilizers may be classified as being a polyphosphate material, some of the phosphorus is present in the orthophosphate form.
6. When applied to soils, polyphosphates are rapidly converted to orthophosphates.

7. The uptake of phosphorus (utilization) by crops is highly dependent on the chemistry of the soil.

8. All phosphate products commonly sold today go through the same reactions when applied to soils.

9. There are no phosphate fertilizers that are 3 to 4 times more available that other commonly sold phosphate products.

HOW MANAGEMENT WILL RAISE YOUR SOYBEAN YIELDS

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Many soybean studies in Minnesota over the past 10 years have shown an advantage of a narrow row spacing of 6-10 inches over the conventional 30-inch spacing. However, most of these studies were carried out on sites that had been fall moldboard plowed and then disked once or twice in the spring to incorporate herbicides.

Trials were started at the Lamberton, Morris, and Waseca Minnesota Agricultural Experiment Stations in 1982 on a corn-soybean rotation to evaluate the effect of several tillage systems at two row spacings. At the Morris location only, the same study was carried out also in a wheat-soybean rotation. The primary tillage systems used were fall moldboard plow, fall chisel plow, spring disk, no-till and till plant. Row spacings of 10 inches and 30 inches were compared on all tillage systems except till plant. With the till plant system a comparison was made between till plant with a ridge formed the previous season and with no ridge. Two planting dates were included: April 25-May 5 and May 15-25. The soybean varieties used were Corsoy 79 at Lamberton and Waseca and Evans at Morris.

Many variables were measured each season including plant residue both before and after planting, emergence rate, early stand, early plant growth, hourly 4-inch soil temperatures, soil moisture every two weeks, date of canopy closure, date of maturity, height, lodging, final stand, yield, harvest loss and seed weight.

RESIDUE

One of the main reasons to use reduced tillage is to maintain some residue on the soil surface. We did not find any effect of row spacing on the residue cover as would be expected. The data in Table 1 show a wide range in surface residue due to tillage. There is also a variation between years with the same tillage, probably due to differing soil conditions during the tillage operations and to differences in equipment settings and operation.

PLANT STAND AND POPULATION

With the moldboard plow, chisel, spring disk and no-till treatments, the seeds were counted before planting to achieve the desired stand. In the 30-inch rows 150,000 viable seeds/acre were planted, while in the 10-inch rows 175,000 viable seeds/acre were planted. The till plant treatments were planted with a row crop planter without pre-counted seeds, so populations are not comparable with the other four tillage systems.

The data in Tables 2 and 3 show the effect of tillage and planting date on percent stand of soybeans at Morris. In 1982 a reduction in tillage generally resulted in a lower soybean stand than with moldboard plowing regardless of rotation. In 1983 soybean stand was reduced in some cases in the corn-soybean (c-sb) rotation while in the wheat-soybean (w-sb) rotation there was very little effect on soybean stand. A comparison of soybean stands in ridged vs. unridged treatments shows very little difference.

Although there is some variation in actual soybean stands (Tables 4 and 5), most treatments have sufficient stands. The only treatment with soybean stands low enough to possibly affect soybean yield was the no-till treatment in 1982 in the w-sb rotation at the early planting date.

EARLY PLANT GROWTH

In some cases it was observed that soybean plants grew slower in the reduced tillage systems. Data in Table 6 show early plant heights at Morris in 1983. The soybean plants in the no-till treatments in most cases were significantly smaller than those in the moldboard plow, chisel and spring disk treatments.

MATURITY

The dates of soybean maturity were not greatly affected by tillage in either year in the c-sb rotation. In 1982 in the w-sb rotation there was about a 2-day delay in maturity with the no-till as compared to moldboard plow, while in 1983 the delay was 6 days.

Only in 1983 did row spacing affect soybean maturity with the 10-inch rows maturing 0.5-0.7 days later than the 30-inch rows.

Planting date significantly affected soybean maturity in both years with the early planting date 1.3-6.2 days earlier than the late planting date.

YIELD

At Lamberton and Waseca there were no significant tillage effects on yield in either year. At Morris in 1982 the moldboard plow treatment in the c-sb rotation was lower yielding than the other treatments. Also in 1982 the no-till treatment in the w-sb rotation was lower yielding than all other treatments. This no-till treatment was the treatment mentioned earlier with the very low plant population.

The 2-year averages at Lamberton and Waseca show a 5% yield advantage of early planting over late planting with the Corsoy variety. At Morris with the Evans variety, the early planting date out-yielded the late planting date by 2%.

The row spacing effect on yield was significant at all locations. The 2-year average at Lamberton and Waseca shows a 7.4% yield advantage of 10-inch over 30-inch rows. At Morris the 10-inch rows out-yielded the 30-inch rows by 13.1% in the c-sb rotation and by 16.4% in the w-sb rotation.

Table 1. Effect of tillage on residue cover after planting at Morris (30-inch row spacing, early planting date only).

Tillage	C-Sb Rotation 1982	C-Sb Rotation 1983	W-Sb Rotation 1982	W-Sb Rotation 1983
	% cover			
Moldboard	15	10	10	5
Chisel	35	34	34	17
Spring Disk	46	36	53	19
No-till	76	58	96	83
TP-Ridge	24(77)	11(55)	70(81)	29(62)
TP-No Ridge	32(63)	8(66)	58(66)	22(68)

Figures in ( ) are for the area between the rows for the till plant treatments.

Table 2. Effect of tillage and planting date on soybean stand at Morris in 1982.

Tillage	C-Sb Rotation Planting Date 5-6	C-Sb Rotation Planting Date 5-20	W-Sb Rotation Planting Date 5-6	W-Sb Rotation Planting Date 5-20
	Soybean Stand (% of Moldboard)			
Moldboard	100	100	100	100
Chisel	86	86	92	86
Spring Disk	88	80	84	87
No-Till	84	79	44	58
TP-Ridge	114	197	87	177
TP-No Ridge	118	205	93	179

Table 3. Effect of tillage and planting date on soybean stand at Morris in 1983.

Tillage	C-Sb Rotation Planting Date 5-2	C-Sb Rotation Planting Date 5-23	W-Sb Rotation Planting Date 5-2	W-Sb Rotation Planting Date 5-23
	Soybean Stand (% of Moldboard)			
Moldboard	100	100	100	100
Chisel	101	89	109	99
Spring Disk	95	84	97	88
No-Till	90	83	113	102
TP-Ridge	114	104	113	115
TP-No Ridge	113	96	108	113

Table 4. Effect of tillage and planting date on soybean population at Morris in 1982.

Tillage	C-Sb Rotation Planting Date 5-6	C-Sb Rotation Planting Date 5-20	W-Sb Rotation Planting Date 5-6	W-Sb Rotation Planting Date 5-20
	- - - - - 1000's plants/acre - - - - -			
Moldboard	134	99	133	108
Chisel	112	89	118	83
Spring Disk	122	82	114	88
No-Till	113	82	37	80
TP-Ridge	152	195	116	192
TP-No Ridge	158	202	124	193

Table 5. Effect of tillage and planting date on soybean population at Morris in 1983.

Tillage	C-Sb Rotation Planting Date 5-2	C-Sb Rotation Planting Date 5-23	W-Sb Rotation Planting Date 5-2	W-Sb Rotation Planting Date 5-23
	- - - - - 1000's plants/acre - - - - -			
Moldboard	135	146	134	133
Chisel	135	128	141	131
Spring Disk	134	112	130	122
No-Till	138	142	114	145
TP-Ridge	154	152	152	154
TP-No Ridge	152	141	146	150

Table 6. Effect of tillage and planting date on early plant growth[1] at Morris in 1983 (30-inch rows only).

Tillage	C-Sb Rotation Planting Date 5-3	C-Sb Rotation Planting Date 5-23	C-Sb Rotation Average	W-Sb Rotation Planting Date 5-3	W-Sb Rotation Planting Date 5-23	W-Sb Rotation Average
	- - - - - - - - - - - - inches - - - - - - - - - - - -					
Moldboard	4.6	5.7	5.1	5.3	5.5	5.4
Chisel	5.0	5.1	5.1	4.6	5.3	4.9
Spring Disk	4.9	5.0	5.0	4.8	5.2	5.0
No-Till	4.4	4.7	4.6	4.2	4.9	4.6
TP-Ridge	4.3	4.8	4.5	4.5	5.4	5.0
TP-No Ridge	4.3	4.4	4.3	4.7	5.1	4.9
Average	4.6	4.9		4.7	5.2	

Analysis of Variance Summary[2]

Source of Variation	C-Sb Rotation	W-Sb Rotation
Tillage	*	NS
Planting Date	**	**
Tillage x Planting Date	NS	NS

[1]Average height of 5 plants 45 days after planting for the early planting date and 37 days after planting for the late planting date.
[2]*,**,NS Significant at 5%, 1% and Not Significant, respectively.

SOIL TEST P & K - HOW HIGH IS HIGH?

Wallace W. Nelson
Professor and Superintendent
Southwest Experiment Station
Lamberton, Minnesota

Soil fertilization paid so well in the 1950-70's that for many we just put on the same each year because it had done such a good job. We forget that we started at very low levels especially for P in many areas of the State. (Figures 1 and 2).

Subsoil Phosphorus Levels

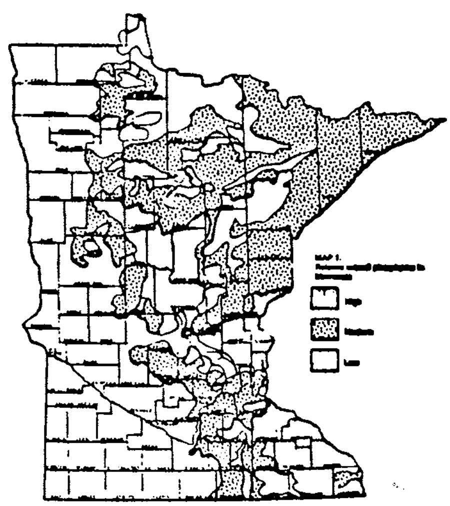


FIG. 1

Subsoil Potassium Levels

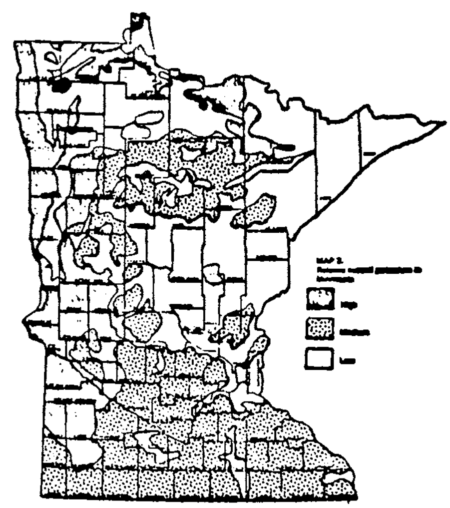


FIG. 2

Many have not taken a soil test or still believe they must be adding if they are going to keep getting high yields. It's time to look at soil tests and know what to expect with yields.

Studies to determine the long term effects of P and K fertilizer were initiated in 1973 at the Morris, Waseca, and Lamberton Experiment Stations. Soils were selected with high to very high P & K tests. The objectives were to determine (1) the time required for depletion of soil P & K, (2) rates of P & K needed for maintenance requirements, and (3) required frequency of P & K applications.

If we pick the treatments of 0, 50, and 100 pound per acre annual rates of P_2O_5, the soil tests and yields over the years have responded as indicated in Tables 1 - 6.

TABLE 1 EXTRACTABLE P AS INFLUENCED BY ANNUAL P_2O_5 RATE AT WASECA

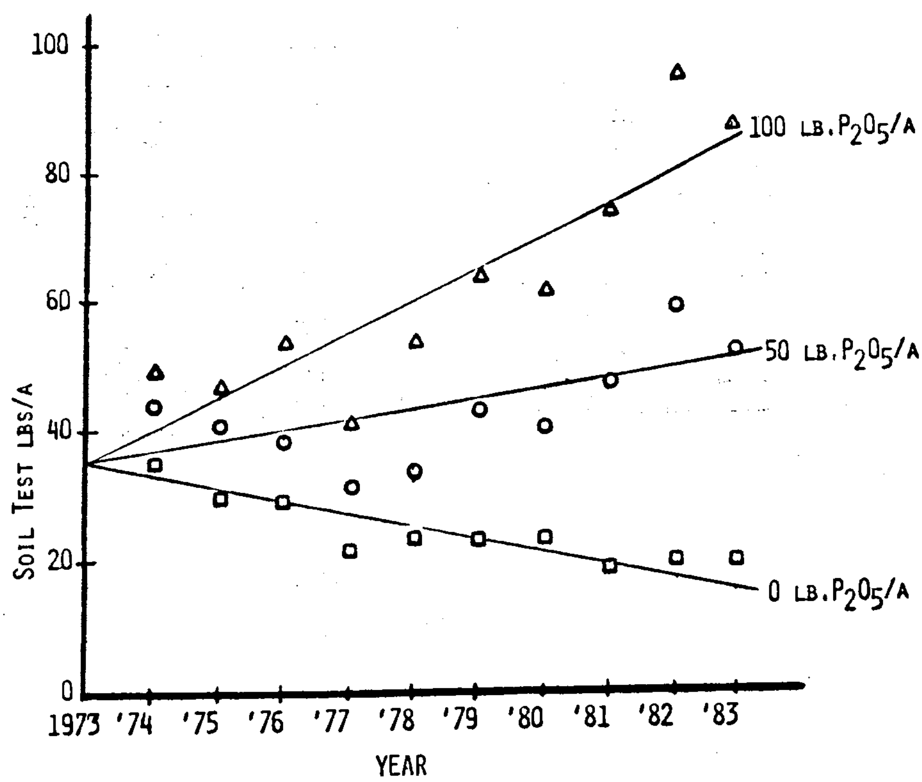


TABLE 2

RELATIVE YIELDS - WASECA
P+K STUDY

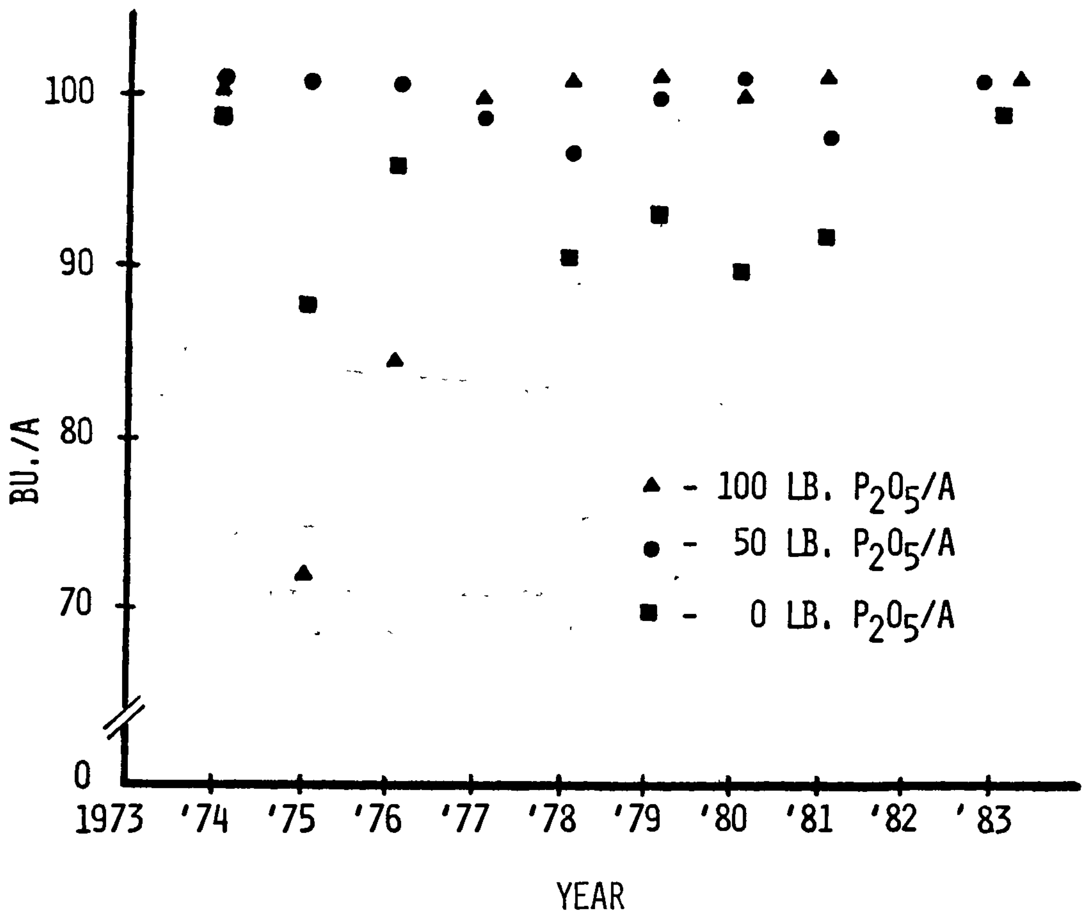


TABLE 3 EXTRACTABLE P AS INFLUENCED BY ANNUAL P_2O_5 RATE AT MORRIS

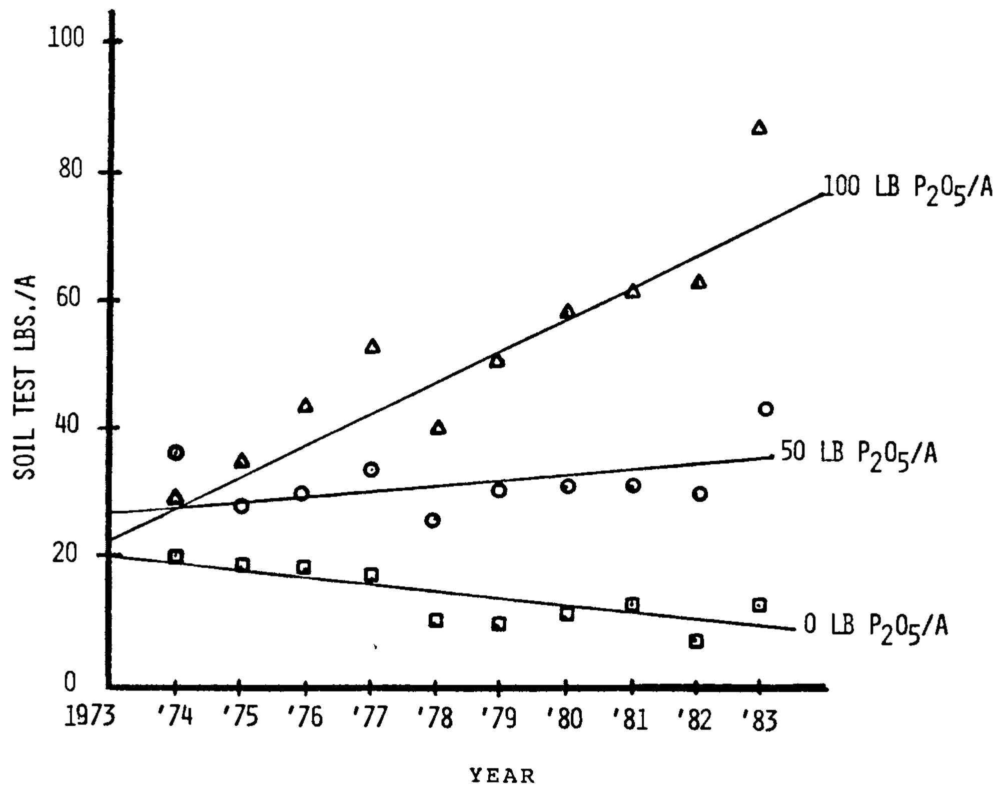


TABLE 4 RELATIVE YIELDS - MORRIS

P+K STUDY

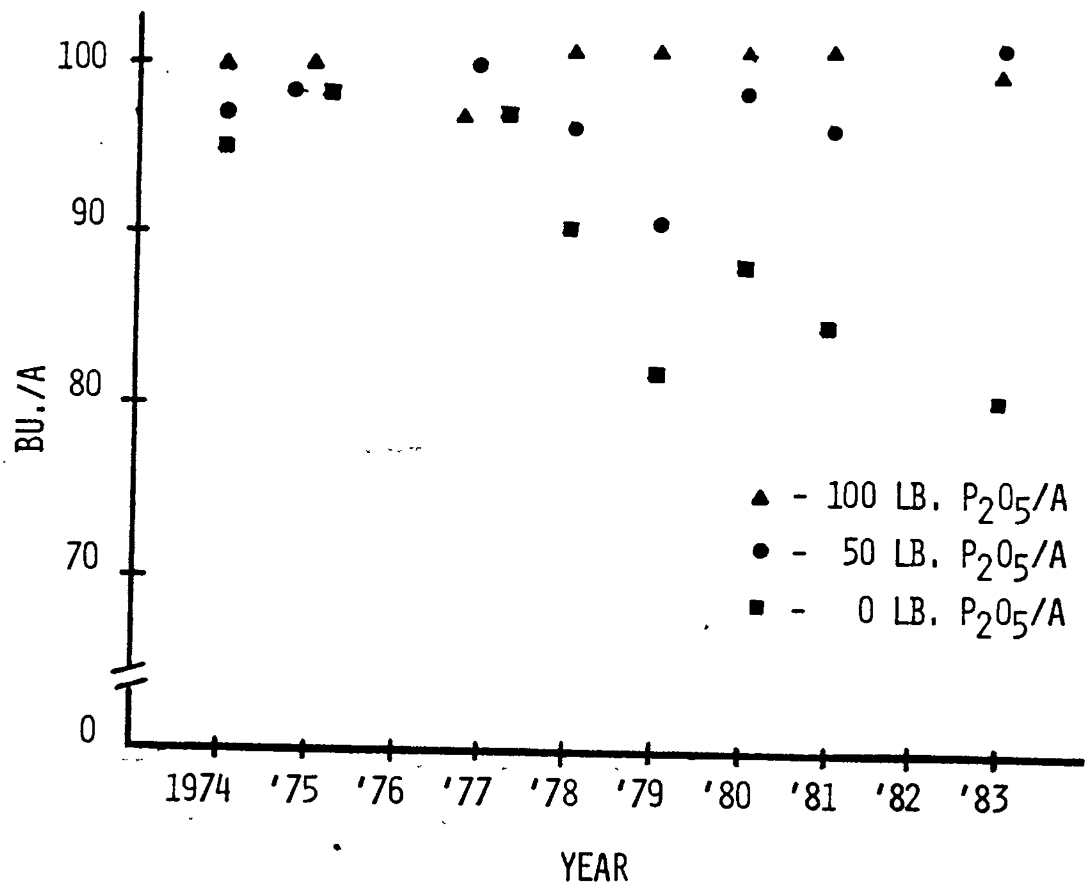


TABLE 5 EXTRACTABLE P AS INFLUENCED BY ANNUAL P_2O_5 RATE AT LAMBERTON

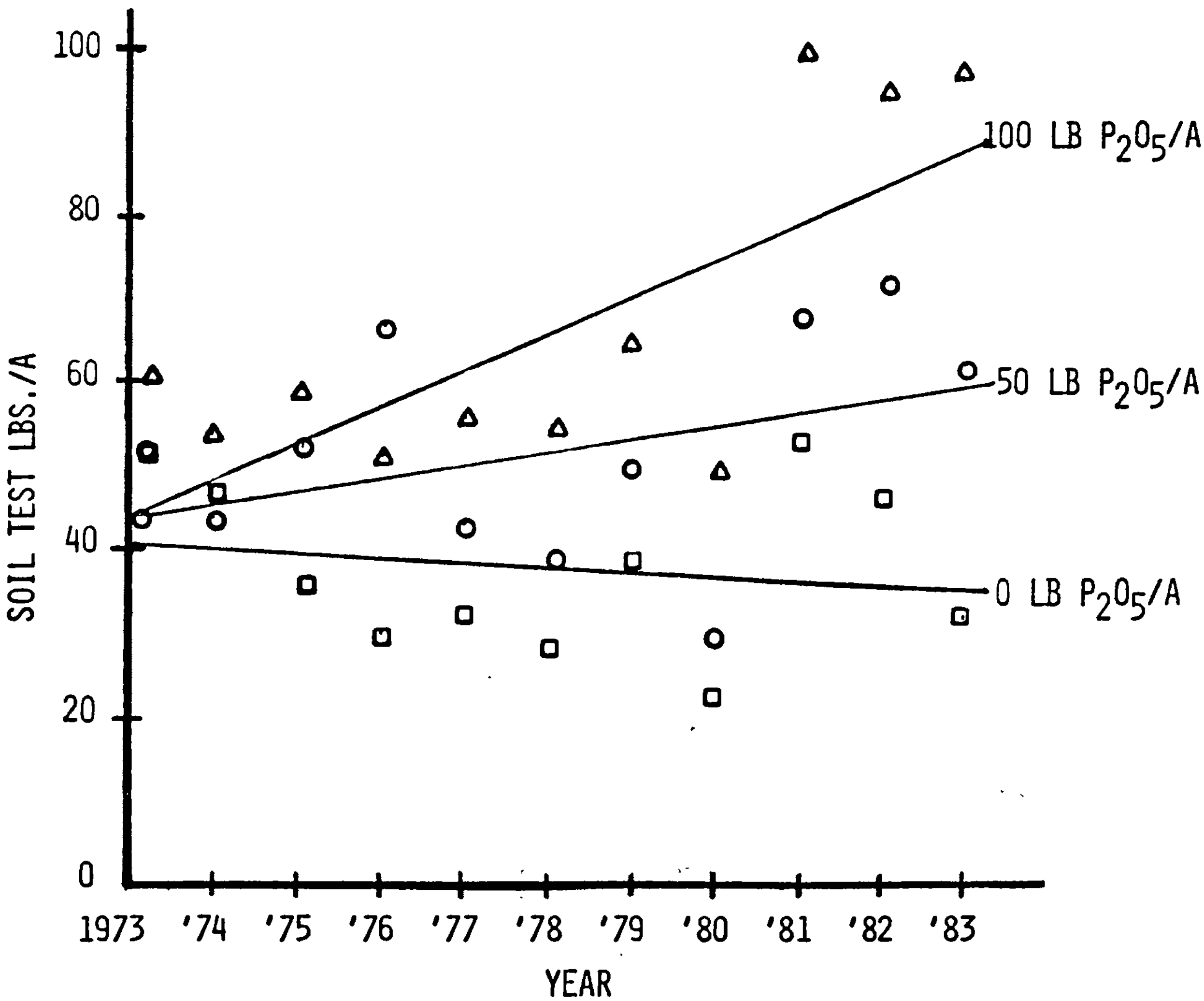
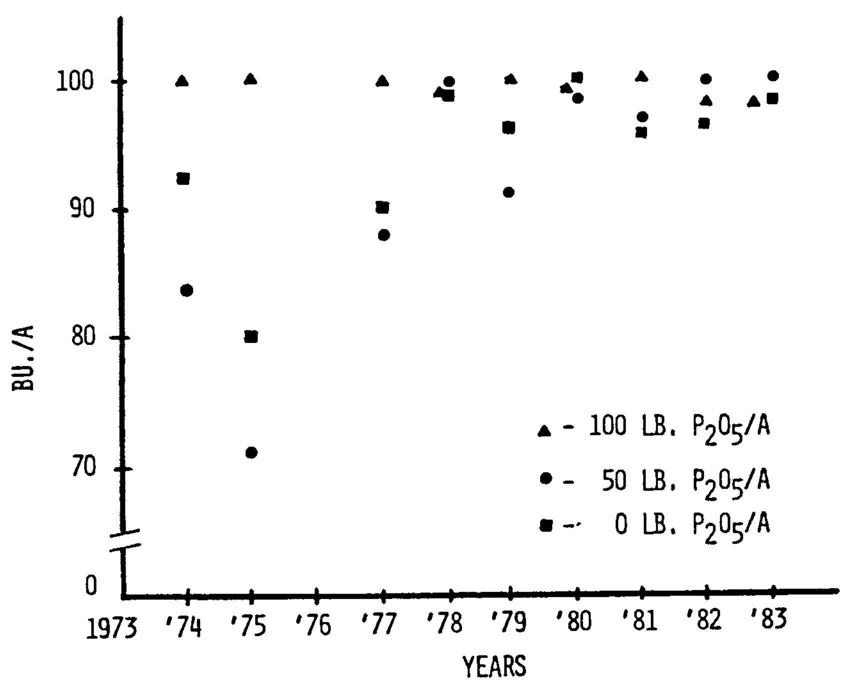


TABLE 6

RELATIVE YIELDS - LAMBERTON
P+K STUDY



The yield response is non-existent above approximately 30 pounds per acre. However, it is noted some irregularity in the test results from one year to the next. As a guideline, Dr. George Rehm of the University of Minnesota's Soils Department indicates the phosphorus test is ± 15% accurate. We are also trying to measure the availability of phosphorus to plants in changing environmental conditions, such as temperature, moisture, compaction, etc., so being any more precise is not essential.

As a result of yields and the accuracy of the phosphorus test Table #7 is my projection to responses to Soil P tests with conventional tillage or warm dry soils.

Table 7

RESPONSE TO STARTER FERTILIZATION

NELSON'S PROJECTION

SOIL P TEST	STARTER RESPONSE YEARS OUT OF 5	
16/A	CORN	SOYBEANS
10	5	4
10-20	3	2
20-30	2	1
Over 30	1	0

Soybean yield responses at Lamberton have not shown any more response than corn.

TABLE 8

SOYBEAN YIELD RESPONSE TO P

FERTILIZATION TO A HIGH LEVEL TEST

BU/A

P LBS/A	1981	1982	'83	'84
0	46.0	47.8	34.4	43.2
50	49.5	50.0	27.7	45.9
100	48.6	49.9	34.4	41.0

Lamberton, Minnesota

Looking at the rate of phosphorus build-up since 1973, Dr. Grava of the Soils Department has calculated the soil test response to fertilizer.

TABLE 9

RATE OF PHOSPHORUS BUILDING WITH FERTILIZER RATES

BY - John Grava

	RATE OF P_2O_5	#P_2O_5 TO RAISE P TEST 1#
MORRIS	50	17
	100	14
WASECA	50	15
	100	15
LAMBERTON	50	21
	100	19

This agrees with the results at Lamberton indicating without P fertilization the soil test drops about 2½ pounds per year and it takes about 40-50 pounds to maintain a P test level.

The P & K fertility level and fertilizer will depend on a number of factors:

1. Own Land -

   a. Build to soil test of approximately 40 pounds P and 250 pounds K.

   b. Maintain with 40 pounds P_2O_5 and K_2O per acre per year.

   c. This will give flexibility to not having to apply any during periods of cash flow crunches, high fertilizer prices or shortages, and poor weather conditions. Works as an insurance policy.

   d. Allows application of 100+ pounds every 2-3 years, so saves trips.

   e. If conventional tillage, no need for starter unless poorly drained and cold, so improves timeliness.

   f. Need high fertility to switch to severely reduced tillage and then use a starter.

2. Buy Low Fertility Farm -

   a. Use starter plus broadcast fertilizer to build toward the 40's so can become a fertility manager.

3. Rent Land -

   a. Use starter if unsure of length of tenancy and low fertility. Starter is approximately 4 times as efficient as broadcast for this years crop.

   b. Work out with landlord for rebate of part of P & K applied last 2 years if lose farm. This will build his farm up.

If someone has a P soil test above 40 pounds per acre or a K test above 250 pounds per acre, the likelihood of a fertilizer response with conventional tillage is very minimal. It is on these soils that I could sell "NELSON'S WONDER WOOF-N-POOF SUPER DUPER FERTILIZER" for one-third to one-half of what has usually been the cost for P & K and get just as good a yield. THATS TRUE but the same yield would have also probably been achieved without any "NELSON'S WONDER WOOF-N-POOF SUPER DUPER FERTILIZER" or anything else.

Know your soil test, use it for your management of fertility, cash flow, timeliness, and just good productivity.

PUTTING THE PRODUCTION PACKAGE TOGETHER

Edward Staudinger, President
Blue Royal Farms, Inc.

I. Information on Dairy Operation

   A. Dairy Herd

      1. Feeding
      2. Production

   B. Field Crops

      1. Alfalfa Haylage Production

         a. Steps for producing quality alfalfa haylage

      2. Corn

         a. Silage
         b. High Moisture Corn

      3. Wheat

         a. Ripe grain
         b. Wheatlage as a forage

      4. Beans and Milo

      5. Peas and Oats

   C. Fertilization

      1. Corn Fertilization

         a. Liquid Manure

      2. Alfalfa Fertilization

         a. Liquid Manure
         b. Commercial Fertilizer

   D. Herbicides

      1. Alfalfa Crop
      2. Corn Crop

   E. Pesticides

      1. Alfalfa
      2. Corn

II. Summary

   A. Profit or Loss on the Dairy

ADVANCES IN SOYBEAN WEED CONTROL

Richard Behrens
Extension Agronomist-Weeds
University of Minnesota

The 1985 revision of "Cultural and Chemical Weed Control in Soybeans," AG-FO-0841 has been completed and a copy is included in this publication immediately following this report. There have been no clearances of new herbicides for soybeans in 1984, though there are several compounds nearing EPA clearance. In Table 1, "Effectivenss of herbicides on major weeds in soybeans," ethalfluralin (Sonalan) has been included for the first time. No new weed species have been added to Table 1. There has been a major reorganization of Tables 2 and 3. Information in Tables 2 and 3 have been combined into a new Table 2 entitled "Herbicide choices for soybeans." So many herbicide mixtures are now available for use in soybeans that it is becoming difficult to recognize all of the tank mix possibilites. It is hoped that the new format which lists the potential tank mixes under major use herbicides and includes comments on how these mixtures may improve weed control will be more useful than in the old format.

The number of research herbicides that we were asked to evaluate on soybeans in 1984 was so great that we were unable to include many useful application date and rate, herbicide mixture or sequential treatments, soil type and soybean varietal comparisons. Our various experiments included 16 promising compounds that are now being developed for use in soybeans. Several compounds may be cleared by EPA for commercial use in 1986 but new clearances for the 1985 season seem doubtful. The largest group of related compounds includes 7 herbicides which are very effective in the postemergence control of grasses in soybeans. These compounds are herbicidally effective on many grasses including volunteer corn, quackgrass, wild proso millet and woolly cupgrass. They have little or no effect on soybeans or other broadleaf plants. They differ considerably in the rate of application required to provide control of various weed species. However, this is important to users only if greater activity translates into lower per acre treatment costs.

There are 4 promising compounds for broadleaf control. Soybean tolerance to this group varies and further evaluation will be requred to determine the effects of climatic factors on their activity and the tolerance of soybean varieties. There are two promising compounds, imazaquin (Scepter) and FMC 57020 (Command) that have good herbicidal activity on both broadleafs and grasses when applied to the soil or to the foliage. A major concern with these compounds is their potential for carryover injury to sensitive crops planted the following year. The three remaining herbicides are soil-applied compounds mainly for annual grass control. Acetochlor (Harness), similar to alachlor (Lasso) is the closest to EPA clearance and may be available for use on limited acreage in 1985 under an experimental use permit.

The future looks bright for improved soybean weed control if some of the large number of promising herbicides now being evaluated for use in soybeans receive EPA clearance. Their use should provide safer, more effective and, hopefully, more economical soybean weed control.

The herbicide alachlor (Lasso) is now undergoing a Special Review by the U.S. Environmental Protection Agency (EPA) because tests show that tumors are caused when high levels of alachlor are fed daily to laboratory animals over long periods of time. In this Special Review, EPA is re-examining all health and safety tests and product benefits from alachlor usage. Recommendations from EPA on future uses of alachlor will be developed based on their estimates of these risks and benefits. As of November, 1984, it seems probable that alachlor will continue to be available in 1985 for use by Minnesota farmers.

AGRICULTURAL EXTENSION SERVICE **AG-FO-0841—REVISED FOR 1985**
UNIVERSITY OF MINNESOTA

Cultural and Chemical Weed Control in Soybeans

RICHARD BEHRENS, Extension Agronomist

Weeds can be most effectively controlled in soybeans with a well-planned program that involves a thorough analysis of the field situation and use of a combination of cultural practices and appropriate herbicides. The most effective weed control system depends on the kinds of weeds in the field, soil characteristics, tillage practices, crop rotation, and soybean row width.

Weeds are vigorous competitors with soybeans. Weeds usually germinate and emerge with the soybeans, so the soybeans cannot get ahead of the weeds. Soybeans are relatively short and susceptible to shading from taller weeds. Weeds also compete with soybeans for nutrients and water. Since soybeans are expecially sensitive to moisture deficiencies in late summer, a few large weeds can severely reduce yields. Nearly complete weed control must be accomplished within three to four weeks after emergence of the soybeans in order to avoid yield losses due to early emerging weeds.

Cultural Practices

Several cultural practices aid weed control in soybeans. Seedbed preparation immediately prior to planting will kill weeds that have germinated. Killing these weeds is important in obtaining good results from preemergence herbicides. For effective weed control, herbicides applied preemergence need to be moved into the soil by rainfall before weed seeds germinate. If rainfall has not been sufficient for herbicide activation, control the weed seedlings with a rotary hoe, harrow, or cultivator as soon as they emerge.

Herbicides

A herbicide or herbicide combination should be selected on the basis of the weed species in the field (table 1), performance, soil texture, pH of the soil, amount of organic matter in the soil, soybean tolerance, crop rotation, tillage practices, and economics. Field conditions that affect a herbicide's performance or limit its usefulness must be considered. Dry soil, heavy rain after application, surface trash, or a poor seedbed may reduce weed control. Cultivation practices and postemergence herbicide applications should be used when necessary to supplement soil applied herbicides.

Herbicide mixtures are used to overcome the limitations of single chemicals. Certain mixtures may (1) control more kinds of weeds, (2) give more consistent performance with different soils and weather conditions, (3) lessen soil residue problems, (4) increase persistence enough to give full season weed control, or (5) reduce crop injury. See table 2 for labeled tank-mixes of herbicides suggested for use in Minnesota. Only those mixtures that have been field tested under local conditions should be used. The use of some mixtures may result in poor weed control or crop injury.

The correct herbicide rate must be used to obtain good weed control and to minimize soybean injury. Herbicide rates must be adjusted for soil texture, percent organic matter, soil pH, kinds of weeds, potential for soil residue, and whether the herbicide is to be used alone or in combination. See table 2 for herbicide rate ranges. Always consult herbicide labels for specific rates. Only chemicals that are cleared by the Environmental Protection Agency for the specific use intended should be used.

No Till or Minimum Till

In no till or minimum till soybean production, herbicides may be required to control emerged weeds. Glyphosate (Roundup) or paraquat (Paraquat Plus or Gramoxone) non-selective herbicides that will kill emerged weeds. These herbicides have no soil activity and are usually tank-mixed with other herbicides which provide residual control of later germinating weeds (see table 2). Paraquat is a restricted use herbicide.

Preplant Incorporated Applications

Ethalfluralin (Sonalan), pendimethalin (Prowl), trifluralin (Treflan), or vernolate (Vernam or Reward) are suggested for preplant incorporated use in soybeans. Trifluralin also may be applied in the fall after October 15. These herbicides have provided good control of annual grasses and some broad-leaf weeds (see table 1).

Proper herbicide application and favorable soil conditions are necessary for optimum herbicide performance. The soil should be moist, but not wet, to ensure maximum mixing of herbicide and soil during preplant herbicide incorporation. To provide good control, adequate moisture is needed at the point where the emerging weed seedling contacts the herbicide.

Good incorporation thoroughly mixes the herbicide with 2-3 inches of soil. Incorporate the herbicide twice with a disk, field cultivator with sweep shovels, or similar implement, or once with a power-driven rotary tiller. The second incorporation should be carried out at a right angle to the direction of the first incorporation. This is needed to ensure thorough mixing of the herbicide with the soil. Observe label instructions for proper equipment depth eration speed. Under ideal soil conditions, adequate incorporation may be accomplished with one trip using multiple implements.

To prevent herbicide loss by evaporation, vernolate must be incorporated immediately after application and should not be applied to a wet soil surface. Consult specific labels to determine the maximum time period allowed between application and incorporation of other herbicides.

Ethalfluralin, pendimethalin, and trifluralin may persist more than one year in some soils under dry or cold conditions. Sensitive crops such as small grains, grain sorghum, or sugarbeets can be affected the following year. Some instances of corn injury from trifluralin carryover have been observed in Minnesota when recommended rates have been exceeded on lighter soil areas, in overlapping spray swaths or in sprayer turn-around areas. Plowing with a moldboard plow, compared to reduced tillage systems that do not include moldboard plowing, reduces the potential for crop injury from residues of these herbicides.

Preplant Incorporated or Preemergence Applications

Several herbicides including alachlor (Lasso), chloramben (Amiben), metolachlor (Dual), and metribuzin (Sencor or Lexone) are suggested for use either preplant incorporated or preemergence. These herbicides may be left on the soil surface or incorporated with one or two tillage operations. Preplant incorporated applications of these herbicides into moist soil are more effective when there is inadequate rainfall to activate preemergence applications. However, preemergence applications provide more effective weed control when adequate rainfall does occur. If weed seedlings begin to emerge following a preemergence application due to lack of rainfall, an early harrowing, rotary hoeing, or shallow cultivation will improve weed control.

Alachlor and metolachlor control annual grasses, nutsedge, redroot pigweed, and nightshade. Control of other broadleaf weeds has been erratic. Preplant incorporation of alachlor or metolachlor has resulted in more consistent yellow nutsedge control than preemergence applications.

Chloramben controls many annual broad-leaved and grass weeds on a wide range of soils when sufficient rainfall occurs before weeds emerge. Excessive rainfall after application may move chloramben below the zone of weed germination and may reduce control. Soybean tolerance is good on a wide range of soils, including high pH soils. Infrequently, very heavy rainfall on coarse-textured (sandy) soils may move chloramben into contact with the germinating soybeans, resulting in stunted roots and delayed emergence.

Metribuzin has provided good control of several hard-to-control broadleaf weeds, but it has marginal crop safety. Potential crop injury can be decreased by using reduced rates of metribuzin with another herbicide. See the label for restrictions on various soils and soybean varieties. Soybean injury is more likely on alkaline soils, sandy soils, where atrazine residues are present, or if used with vernolate.

Chlorpropham (Furloe, Chloro IPC) applied preplant incorporated or preemergence has given good control of annual smartweed species. Soybeans have good tolerance to chlorpropham.

Pendimethalin (Prowl) applied preemergence to soybeans may cause callusing and brittleness of soybean stems under Minnesota conditions. Such injury is unlikely when pendimethalin is applied preplant incorporated.

Preemergence applications of linuron (Lorox) controls annual broad-leaved weeds and some grasses in soybeans. Linuron is best suited for medium-textured soils with 4 percent organic matter or less. Weed control has been inconsistent on fine-textured soils with high organic matter content. Soybean injury may occur on sandy, low organic matter soils. Potential crop injury can be decreased by using reduced rates of linuron with another herbicide (see table 2).

Postemergence

Acifluorfen (Blazer) and bentazon (Basagran) alone or mixed are suggested for postemergence broadleaf weed control in soybeans. The herbicide or mixture used should be determined by the weed species present (see table 1). The leaf stage and size of the weeds at the time of herbicide application are critical for consistent control with either herbicide. Applications made to weeds larger than the maximum labeled leaf stage may result in inconsistent, or partial control with regrowth from surviving roots and stems.

Crinkling, bronzing or burning of young soybean leaves is a common response to acifluorfen treatments but soybeans typically recover and develop normally. Hot, humid weather, active growth at application, and the addition of surfactants or oil concentrates increase both herbicidal effectiveness and the possibility of soybean injury. Do not apply acifluorfen to weeds under stress because effectiveness may be reduced.

Bentazon may cause some leaf burn if applied to soybeans under stress; especially when an oil concentrate is added to improve weed control effectiveness. A split application may be necessary to control Canada thistle, yellow nutsedge, and annual broad-leaved weeds that continue to germinate throughout the growing season.

Chloramben applied early postemergence to soybeans will control a few species of broadleaf weeds; but, for the best weed control with this herbicide, germinated weeds should be controlled with an appropriate postemergence herbicide or removed by cultivation.

Diclofop (Hoelon) is suggested for postemergence annual grass and volunteer corn control in soybeans. Wild oat, giant foxtail, green foxtail, and barnyardgrass should be treated before they exceed the four-leaf stage. Yellow foxtail should be treated before it reaches the three-leaf stage for best results. The full label rate of diclofop should be used when the annual grass is at or near the maximum leaf stage for treatment. Volunteer corn should not be sprayed with diclofop until all of the corn plants have emerged. Do not tank mix diclofop with any other product or apply any other product within seven days of a diclofop application because diclofop may be deactivated by other pesticides. Diclopfop is a restricted use pesticide.

Fluazifop (Fusilade) and sethoxydim (Poast) are postemergence chemicals for annual and perennial grass control in soybeans. Soybeans have good tolerance. Neither chemical controls broad-leaved weeds. An oil concentrate is used with the spray to improve performance. Mixtures with bentazon and acifluorfen will also control many broadleaf weeds but control of grasses may be reduced.

Dinoseb (Premerge) or a mixture of naptalam plus dinoseb (Dyanap) applied at the crook-stage of soybeans give fair control of some broadleafs (see table 1) with temporary soybean burn and stunting likely. Applications of dinoseb or dinoseb plus naptalam made after the first trifoliolate leaf stage of the soybeans have resulted in inconsistent weed control and frequent soybean leaf kill and stunting.

Barban (Carbyne) can be used as a postemergence treatment for wild oat control in soybeans. Application should be made when most of the wild oat plants are in the two-leaf stage. Do not apply later than 30 days after soybean emergence.

2,4-DB amine (Butoxone, Butyrac 200) is labeled for postemergence control of common cocklebur in soybeans. Weed control is less satisfactory and the potential for crop injury greater when 2,4-DB is used than when other post-emergence broadleaf herbicides are used.

Read the pesticide label and follow the instructions as a final authority on pesticide use.

Issued in furtherance of cooperative extension work in agriculture and home economics, acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture. Patrick J. Borich, Dean and Director of Agricultural Extension Service, University of Minnesota, St. Paul, Minnesota 55108. The University of Minnesota, including the Agricultural Extension Service, is committed to the policy that all persons shall have equal access to its programs, facilities, and employment without regard to race, religion, color, sex, national origin, handicap, age or veteran status.

Table 1. Effectiveness of herbicides on major weeds in soybeans.

	Preplant incorporated								Preemergence						Postemergence								
	Alachlor (Lasso)	Chloramben (Amiben)	Metolachlor (Dual)	Metribuzin (Sencor or Lexone)	Pendimethalin (Prowl)	Ethalfluralin (Sonalan)	Trifluralin (Treflan)	Vernolate (Vernam, Reward)	Alachlor (Lasso)	Chloramben (Amiben	Naptalam + dinoseb (Dyanap)	Linuron (Lorox)	Metolachlor (Dual)	Metribuzin (Sencor or Lexone)	Acifluorfen (Blazer)	Bentazon (Basagran)	2,4-DB (Butoxone or Butyrac 200)	Diclopfop (Hoelon)	Dinoseb (Premerge)	Naptalam + 2,4-DB (Rescue)	Naptalam + dinoseb (Dyanap)	Fluazifop (Fusilade)	Sethoxydim (Poast)
Crop tolerance	G	G	G	F	F/G	F/G	F/G	F	G	G	P	F	G	F	F	G	P	G	P	F/P	F/P	G	G
Grasses																							
Barnyardgrass	G	G	G	F	G	G	G	G	G	F/G	P	F	G	F	P	N	N	G	P	P	P	G	G
Woolly cupgrass	G	G	G	P	G	G	G	F/G	G	G	P	P	G	P	P	N	N	P	P	P	P	G	G
Giant foxtail	G	G	G	F	G	G	G	G	G	F/G	P	F	G	F	P	N	N	G	P	P	P	G	G
Green foxtail	G	G	G	F	G	G	G	G	G	F/G	P	F	G	F	P	N	N	G	P	P	P	G	G
Yellow foxtail	G	G	G	F	G	G	G	G	G	F/G	P	F	G	F	P	N	N	F	P	P	P	G	G
Wild proso millet	F	F	F	P	F	F	F	F	F	F	P	P	F	P	P	N	N	P	P	P	P	G	G
Nutsedge	G	P	G	P	N	N	N	G	F	P	P	P	F	P	P	G	N	P	P	P	P	N	N
Quackgrass	N	N	N	P	P	P	P	F	N	N	P	P	N	P	N	N	N	N	P	N	P	F	F
Sandbur	F	P	F	P	G	G	G	G	F	P	P	P	F	P	P	P	P	P	P	P	P	G	G
Broadleafs																							
Canada thistle	N	N	N	P	N	N	N	N	N	N	P	P	N	P	P	G	P	N	P	P	F/P	N	N
Cocklebur	P	P	N	F	N	N	N	P	N	P	F	P	N	F	F	G	F	N	F	F	F	N	N
Kochia	P	G	P	G	G	G	G	-	P	G	F	F	P	G	-	F	-	N	-	F	F	N	N
Lambsquarters	F/P	G	F/P	G	F/G	F/G	F/G	F	F/P	G	F	G	F/P	G	P	F	P	N	P	-	P	N	N
Venice mallow	P	G	P	G	P	P	P	G	P	G	-	G	P	G	F	G	P	N	-	-	F	N	N
Mustard	P	F	P	G	N	N	N	F	P	F	G	G	P	G	G	G	P	N	G	-	G	N	N
Eastern black nightshade	F	F	F	P	P	F	P	P	G	G	-	P	G	P	G	F	P	N	G	-	F/P	N	N
Hairy nightshade	F	F	F	P	P	P	P	P	G	G	-	-	F	P	F	F	-	N	-	-	-	N	N
Pigweed	G	G	G	G	G	G	G	G	G	G	F	G	G	G	G	P	P	N	P	-	P	N	N
Common ragweed	P	G	P	G	N	N	N	P	P	G	F	G	P	G	G	G	P	N	F	F	F	N	N
Giant ragweed	P	F	P	F	N	N	N	P	P	F	F	F	P	F	G	F	F	N	-	-	F	N	N
Smartweed	P	G	P	G	F	P	P	P	P	G	F	F	P	G	G	G	P	N	G	-	F	N	N
Wild sunflower	P	P	P	F	N	N	N	P	P	P	F	P	P	F	F/G	G	P	N	F	F	F	N	N
Velvetleaf	P	F	P	F	F	N	N	F	P	F	P	F	P	F	P	G	P	N	P	-	P	N	N

G = good; F = fair; P= poor; N = no control; - = insufficient information.

Table 2. Herbicide choices for soybeans.

Herbicide	Active ingredient (lb/A or (formulation/A)	Remarks
NO-TILL or MINIMUM TILL		
Glyphosate	.75 to 3	Kills emerged weeds. Has no soil activity so commonly combined with residual herbicides.
(Roundup)	(1 to 4 qts)	Apply prior to soybean emergence to prevent soybean kill.
Mixtures listed on the label		
Alachlor (Lasso or Bronco)	2.5 to 4	Adds preemergence control of annual grasses and a few broadleaf weeds.
Alachlor + Linuron (Lorox)	2.5 to 4 + .5 to 1.5	Adds preemergence control of annual grasses and broadleaf weeds.
Alachlor + Metribuzin	2.5 to 4 + .25 to .75	Adds preemergence control of annual grasses and broadleaf weeds.
Mixtures listed on other labels		
Chloramben (Amiben)	2 to 3	Adds preemergence weed control. Use any preemergence chloramben tank mix.
Metolachlor + Linuron	1.5 to 2.5 + .5 to 1.5	Adds preemergence weed control.
Metolachlor + Metribuzin	1.5 to 2.5 + .25 to .5	Adds preemergence weed control.
Paraquat	.25 to 1	Kills emerged weeds. Has no soil activity so commonly combined with residual herbicides.
(Paraquat Plus or Gramoxone)	(1 to 4 pts)	Apply prior to soybean emergence to prevent soybean kill. A restricted use herbicide.
Mixtures listed on the label		
Linuron (Lorox)	.5 to 1.5	Adds preemergence weed control.
Metribuzin (Sencor or Lexone)	.38 to 1	Adds preemergence control of broadleaf weeds.
Alachlor (Lasso) + Linuron	2 to 3 + .5 to 1.5	Adds preemergence weed control.
Alachlor + Metribuzin	2 to 3 + .25 to .5	Adds preemergence weed control.
Mixtures listed on other labels		
Chloramben	2 to 3	Adds preemergence weed control. Use any preemergence chloramben tank mix.
Metolachlor (Dual) + Linuron	1.5 to 2.5 + .5 to 1.5	Adds preemergence control of annual grasses and broadleaf weeds.
Metolachlor + Metribuzin	1.5 to 2.5 + .25 to .5	Adds preemergence control of annual grasses and broadleaf weeds.
PREPLANT INCORPORATED		
Ethalfluralin	.56 to 1.12	Controls annual grasses and some broadleaf weeds. Use preplant incorporated. At maximum rate gives partial control of eastern black nightshade.
(Sonalan)	(1.5 to 3 pts)	
Mixtures listed on the label		
Alachlor (Lasso)	2 to 4	Adds control of nightshades, witchgrass and yellow nutsedge.
Chloramben (Amiben)	2 to 3	Adds control of broadleaf weeds.
Metolachlor (Dual)	1.5 to 3	Adds control of black nightshade and yellow nutsedge.
Metribuzin (Lexone, Sencor)	.25 to .5	Adds control of broadleaf weeds.
Pendimethalin	.5 to 1.5	Controls annual grasses and some broadleafs. Preplant incorporated.
(Prowl)	(1 to 3 pts)	
Mixtures listed on the label		
Alachlor (Lasso)	2.5 to 4	Improves grass control and adds control of nightshades and yellow nutsedge.
Chloramben (Amiben)	2	Adds control of smartweeds, velvetleaf and common ragweed.
Metolachlor (Dual)	1.5 to 3	Improves control of grasses and adds control of nightshades and yellow nutsedge.
Metribuzin (Lexone, Sencor)	.5 to .75	Controls additional broadleaf weeds.
Chloramben + Metribuzin	1.5 to 2 + .37 to .55	Controls additional broadleaf weeds.
Trifluralin	.5 to 1	Controls annual grasses and some broadleafs. Use preplant incorporated in the fall or spring. Do not exceed recommended rates for the soil type or carryover may injure sensitive crops the following year.
(Treflan 4E)	(1 to 2 pts)	
(Treflan 5G)	(10 to 20 lbs)	
Mixtures listed on the label		
Alachlor (Lasso)	2.5 to 4	Adds control of nightshades and yellow nutsedge. Preemergence overlay cleared.
Chloramben (Amiben)	2 to 3	Controls additional broadleafs. Preemergence overlay cleared.
Metolachlor	1.5 to 3	Adds control of nightshades and yellow nutsedge. Preemergence overlay cleared.
Metribuzin	.25 to .5	Adds control of yellow nutsedge, velvetleaf and wild mustard.
Chloramben + Metribuzin	1.5 to 2.5 + .25 to .38	Controls additional broadleafs. Preemergence overlay cleared.
Vernolate	2 to 3	Controls annual grasses, some broadleafs plus yellow nutsedge. Use preplant and incorporate immediately. Extender in Reward increases vernolate soil persistence. Reward or Vernam 10-G may be applied and incorporated after preplanting.
(Vernam 7E)	(2.3 to 3.5 pts)	
(Vernam 10-G)	(20 to 30 lbs)	
(Reward)	(2.7 to 4 pts)	
Mixtures listed on the label		
Alachlor (Lasso)	1 to 2	Adds control of nightshades.
Chloramben (Amiben)	1.5	Adds control of many broadleaf weeds.
Pendimethalin (Prowl)	.38 to .75	Adds control of velvetleaf, kochia and smartweeds.
Trifluralin (Treflan)	.5 to 1	Adds control of kochia and improves annual grass control.
Trifluralin + Metribuzin	.5 + .25 to .38	Adds control of many broadleaf weeds and improves annual grass control.

Linuron (Lorox)	.5 to 2.5	Do not incorporate. Added broadleaf control.
Metribuzin (Sencor or Lexone)	.25 to .5	Adds control of many broadleaf weeds.
Chloramben + Metribuzin	.75 to 3 + .25 to .5	Adds control of many broadleaf weeds.
Chloramben	1.8 to 3	Controls broadleafs and grasses, but more effective on broadleafs.
(Amiben)	(4 to 6 qts)	Cleared postemergence but less effective on emerged weeds.
(Amiben DS)	(2.4 to 3.6 lbs)	Weak on wild mustard.
(Amiben Granular)	(20 to 30 lbs)	
<u>Mixtures listed on the label</u>		
Alachlor (Lasso)	1.5 to 3	Improves grass, nutsedge and nightshade control.
Dinoseb (Premerge)	1.5 to 4.5	Preemergence or before first soybean leaves open. Use low rate for emerged broadleafs at cracking stage. It terminal bud is exposed soybean injury can be serious.
Linuron (Lorox)	.33 to 1.5	Preemergence only. Improves grass and broadleaf control.
Metolachlor (Dual)	1.5 to 2.5	Improves grass, nutsedge and nightshade control.
Metribuzin (Sencor, Lexone)	.25 to .5	Improves broadleaf control, especially wild mustard
Pendimethalin (Prowl)	.75 to 1.25	Preplant incorporated. Improves grass control.
Trifluralin (Treflan)	.5 to 1	Preplant incorporated only. Improves grass control.
Vernolate (Vernam, Reward)	2.7 to 4	Preplant incorporated. Improves grass and velvetleaf control.
Alachlor + Metribuzin	1.5 to 3 + .25 to .5	Improves grass, nutsedge, nightshade and mustard control.
Metolachlor + Metribuzin	.75 to 1.5 + .25 to .5	Improves grass, nutsedge, nightshade and mustard control.
Pendimethalin + Metribuzin	.75 to 1.5 + .25 to .5	Preplant incorporated. Improves grass and mustard control.
Trifluralin + Metribuzin	.5 to 1 + .25 to .5	Preplant incorporated. Improves grass and mustard control.
Diallate	1.5 to 2	Controls wild oats only. Apply preplant or preemergence incorporated.
(Avadex)	(1.5 to 2 qts)	<u>A restricted use herbicide</u>.
Linuron	.5 to 2.5	Use in preemergence mixtures to improve broadleaf weed control. Ineffective if incorporated. If emerged, soybeans will be severely injured. Do not use on sandy soils with less than 1/2% organic matter. Directed postemergence for small broadleafs.
(Lorox WP)	(1 to 5 lbs)	
(Lorox 4L)	1 to 5 qts)	
<u>Mixtures listed on the label</u>		
Alachlor (Lasso)	2 to 4	Improves grass control and adds nutsedge and nightshade control.
Chloramben (Amiben)	1.5 to 2.5	Improves overall grass and broadleaf control.
Metolachlor (Dual)	1.25 to .25	Improves grass control and adds nutsedge and nightshade control.
Pendimethalin (Prowl)	.5 to 1.3	Improves grass control. Apply pendimethalin preplant and linuron preemergence.
Propachlor (Ramrod)	.65 to 3	Improves grass control. Seed crop only.
Dinoseb (Premerge)	1.5 to 4.5	Directed spray to soybeans over 8 inches tall to control weeds up to 3 inches tall.
2,4-DB (Butyrac)	.2	Directed spray to soybeans over 8 inches tall to control 1- to 3-inch weeds.
<u>PREPLANT or PREEMERGENCE</u>		
Alachlor	2 to 4	Controls annual grasses and some broadleafs including nightshade.
(Lasso)	(2 to 4 qts)	Cleared postemergence but less effective on emerged weeds.
(Lasso II)	(15 to 30 lbs)	
<u>Mixtures listed on the label</u>		
Chloramben (Amiben)	2	Adds control of many broadleaf weeds.
Dinoseb (Premerge)	1.5 to 4.5	Preemergence or before soybean leaves unfold. Use low rate for emerged broadleafs. If terminal bud is exposed soybean injury can be serious.
Metolachlor	2 to 3	Controls annual grasses and some broadleafs. Apply preplant incorporated or preemergence. Cleared early preplant for no-till and minimum till.
(Dual)	(2 to 3 pts)	
<u>Mixtures listed on the label</u>		
Chloramben (Amiben)	1.8 to 2.7	Adds control of many broadleaf weeds.
Dinoseb (Premerge)	1.5 to 4.5	Preemergence or before soybean leaves unfold. Use low rate for emerged broadleafs. If terminal bud is exposed soybean injury can be serious.
Linuron (Lorox)	.5 to 1.5	Preemergence only. Adds control of broadleaf weeds.
Metribuzin (Sencor or Lexone)	.25 to .5	Adds control of many broadleaf weeds.
Dinoseb + Naptalam (Dyanap)	1.1 to 1.5 + 2.3 to 3	Use preemergence or before soybean leaves unfold. If terminal bud is exposed soybean injury may occur.

Metribuzin (Sencor or Lexone WP) (Sencor or Lexone 4L) (Sencor or Lexone DF)	.25 to .87 (.5 to 1.7 lbs) (.5 to .17 pts) (.5 to 1.2 lbs)	Controls many broadleaf weeds including wild mustard. Apply early preplant, preplant incorporated or preemergence. Use in mixtures with grass herbicides. Soybean tolerance only fair. In early preplant application, a second preemergence (split shot) application can be used to extend weed control.
<u>Mixtures listed on the label</u>		
Alachlor (Lasso)	2 to 3	Adds grass, nutsedge and nightshade control.
Chloramben (Amiben)	1.5 to 2.5	Adds some grass and nightshade control.
Ethalfluralin (Sonalan)	.56 to 1.12	Preplant incorporated only. Adds grass control.
Metolachlor (Dual)	1.25 to 2.5	Adds grass, nutsedge and nightshade control.
Pendimethalin (Prowl)	.75 to 1	Preplant incorporate to minimize soybean injury. Adds grass control.
Trifluralin (Treflan)	.5 to 1	Preplant incorporated only. Adds grass control.
Dinoseb + Naptalam (Dyanap)	1.1 to 1.5 + 2.3 to 3	Improves control of cocklebur. Preemergence or before soybean leaves unfold. If terminal bud is exposed soybean injury can be serious.
Alachlor + Dinoseb + Naptalam	2 to 3 + 1.12 to 1.5 + 2.3 to 3	Adds control of grasses and cocklebur. Preemergence but before soybean leaves unfold. If terminal bud is exposed soybean injury can be serious.
<u>POSTEMERGENCE</u>		
Aciflurorfen (Blazer)	.37 to .75 (1.5 to 3 pts)	Controls small broadleaf weeds. Apply postemergence. Apply again if necessary for late emerging weeds. Burn of soybean leaves is common but recovery is usually complete. Surfactant is needed for maximum effectiveness.
<u>Mixtures listed on the label</u>		
Bentazon (Basagran)	.5 to .75	Improves control of nutsedge, Canada thistle, lambsquarters, cocklebur and sunflowers.
Chloramben (Amiben)	2.5 to 3	Provides residual activity for later germinating weeds.
Fluazifop (Fusilade)	.13 to .25	Adds grass and corn control. Some antagonism in tank mixes.
Sethoxydim (Poast)	.23 to .38	Adds annual grass and corn control. Use 50% greater rates of sethoxydim in tank mixes.
Bentazon + Sethoxydim	.5 to .75 + .23 to .38	Adds annual grass and corn control. Use 50% greater rates of sethoxydim in tank mixes.
2,4-DB (Butyrac 200)	.03	Improves control of larger cocklebur, pigweed and ragweed.
Barban (Carbyne 2EC)	.38 (3 pts)	Controls wild oat only. Apply when wild oats is in the 2-leaf stage.
Bentazon (Basagran)	.75 to 1 (1.5 to 2 pts)	Controls many annual broadleafs, nutsedge and Canada thistle. Apply when weeds are small. Add oil concentrate under adverse conditions.
<u>Mixtures listed on the label</u>		
Acifluorfen (Blazer)	.25 to .5	Improves control of nightshade, pigweeds and common ragweed. Soybean leaf burn occurs.
Sethoxydim (Poast)	.3 to .4	Adds annual grass and corn control. Use 50% higher sethoxydim rate in tank mix.
Acifluorfen + Sethoxydim	.25 + .3	Improves control of broadleafs. Adds control of annual grasses and corn.
Diclofop (Hoelon)	.75 to 1.25 (2 to 3.3 pts)	Controls many annual grasses and volunteer corn. <u>A restricted use herbicide</u>.
Fluazifop (Fusilade)	.13 to .5 (.25 to 1 pt)	Controls grasses plus corn and suppresses quackgrass. Quackgrass may require a second application. Add a surfactant or crop oil concentrate.
Sethoxydim (Poast)	.1 to .5 (.5 to 2.5 pts)	Controls grasses plus corn and suppresses quackgrass. Quackgrass may require a second application. Add a crop oil concentrate.
<u>Mixtures listed on the label</u>		
Bentazon (Basagran)	.75 to 1	Adds broadleaf weed control. Reduced grass control requires a 50% sethoxydim rate increase. Avoid antagonism by using sequential applications.
Bentazon + Acifluorfen (Blazer)	.75 to 1 + .25 to .5	Adds broadleaf weed control. Reduced grass control requires a 50% sethoxydim rate increase. Avoid antagonism by using sequential applications.
2,4-DB (Butyrac 200)	.18 to .4 (.7 to 1.6 pts)	Mainly for common cocklebur. Apply as a directed spray to soybeans at least 8 inches tall and cocklebur to 3 inches tall or other weeds 2 inches tall.
<u>Mixtures listed on the label</u>		
Naptalam (Alanap) (Rescue-pre mix)	1 to 1.5 (2 to 3 qts)	Tank mix rate .03 to .045 lb/A of 2,4-DB. Apply broadcast to soybeans after first blooms appear to suppress cocklebur, giant ragweed, sunflower and wild mustard. Some soybean injury should be expected.

INFLUENCE OF RATE AND ADDITIVES ON BLAZER INJURY TO SOYBEANS

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Since Basagran was introduced into the herbicide market several years ago, postemergence weed control in soybeans has become a rather common practice. With the introduction of Poast and Fusilade for postemergence grass control, there is the possibility of using a total postemergence weed control program in soybeans. In such a program the use of Poast or Fusilade in combination with Basagran allows certain broadleaf weeds--pigweed and eastern black nightshade--to escape. The introduction of Blazer as a postemergence soybean herbicide helps fill this gap in weed control since Blazer has good activity on these weed species.

Little or no soybean injury is normally associated with Basagran, Poast, or Fusilade application. On the other hand, Blazer has given rather consistent leaf burn and frequently slows down growth of soybeans for several days following application. After new leaves emerge, the soybean plants appear normal but may remain somewhat shorter than soybeans not receiving an application of Blazer.

Because of the potential for soybean leaf damage with Blazer, experiments were designed to evaluate the influence of rate of Blazer application and the type and rate of additive on weed control and soybean injury. These two-year studies were conducted at Waseca, Minnesota. In 1983 the soil type was a Webster clay loam containing 6% to 7% organic matter. A Nicollet clay loam soil with 5% to 6% organic matter was the site selected for the 1984 study. These studies were designed as randomized complete block experiments with three replications in 1983 and four replications in 1984. The data were analyzed as factorial experiments with appropriate BLSD values listed in the tables. Both years 'Evans' soybeans were planted in 30-inch rows. Planting dates were June 10, 1983 and May 21, 1984. All postemergence herbicide treatments were applied as tank mixtures of Basagran, Blazer and Poast on July 12, 1983 and June 20, 1984 using a sprayer calibrated to deliver 20 gallons/A at 30 psi.

When the herbicides were applied on July 12, 1983, air temperature ranged from 81° to 86°F with 45% to 60% relative humidity. At this time soybeans were 8 to 10 inches tall (fourth trifoliolate leaf stage). Redroot pigweed and foxtail species were 4 to 10 inches tall when herbicides were applied in the weedy study. Soybeans were 6 inches tall when herbicides were applied on June 20, 1984; the air temperature was 84°F with 60% relative humidity, broadleaf weeds were 3 to 6 inches tall (4 to 8 leaves) and giant foxtail was 6 inches tall. No rainfall occurred for at least 48 hours following herbicide applications in either year.

Two studies were conducted each year. One study was conducted on weed-free soybeans to evaluate crop injury. In this study Treflan (.75 lb/A) was applied and incorporated before planting and Amiben (2.0 lb/A) was applied preemergence each year to control weeds in this weed-free study. Hand-weeding was also done to prevent weeds from reducing soybean yields. A second study was conducted to evaluate weed control and crop injury where Basagran, Blazer and Poast were applied as tank mixtures. This will be referred to as the weedy study.

In both studies Basagran (0.75 lb/A) and Poast (0.2 lb/A) were applied as a tank mixture with either 0.125, 0.25, or 0.50 lb/A of Blazer (2L). Three additives were used in these studies: 0.25% (0.4 pt/A) surfactant (Ag98) and crop oil concentrate (Atplus 411F) at either 0.63% (1 pt/A) or 1.25% (1 qt/A) of the total spray volume. The additives were always added last after the herbicides were dispersed in the water carrier.

Rate of Blazer application influenced soybean injury in weed-free soybeans (Table 1). Early visual injury ratings (leaf burn and stunting) averaged over the two years were 9%, 12%, and 19%, respectively, for the 0.125, 0.25 and 0.50 lb/A rates of Blazer. Plant height on July 11 and July 26, 1984 was reduced by Blazer application. Compared to the plots not receiving Blazer, plant height on July 11, 1984 was reduced 1 to 2 inches where Blazer was applied; a reduction in plant height of 2 to 3 inches was observed on July 26, 1984. There were no significant effects of Blazer on plant height at harvest. Similar observations were observed in the weedy study (Tables 2 and 3).

Compared to the checks that received no Blazer, applying Blazer without a surfactant reduced yields in 1984 (Table 1). A similar trend was observed in 1983, however, this difference was not statistically significant. Plots receiving no Blazer application in 1984 yielded 44.7 bu/A while yields for the 0.125, 0.25 and 0.50 lb/A Blazer rates were 42.4, 41.1 and 40.6 lb/A, respectively, with a least significant difference ($P > .05$) of 1.4 bu/A. Therefore, the injury obtained from applying Blazer in combination with Basagran and Poast in 1984 was sufficient to reduce yields of weed-free soybeans. In 1983 there was little difference in soybean yields among the three rates of Blazer application.

Not only was rate of Blazer important, but the additive used with the Blazer, Basagran and Poast tank mixture also influenced yields in weed-free soybeans (Table 1). Compared to applying Blazer without surfactant, there was a general trend toward reduced yields as the additives were changed from surfactant to 1 pt/A of oil concentrate and then to 1 qt/A of oil concentrate. Although all of these differences were not significant ($P > .05$), the trend was evident both years. The 1 qt/A rate of oil concentrate significantly reduced yields both years as compared to applying the Basagran, Blazer and Poast tank mixture without any additives.

There was a significant Blazer x Additive interaction for yield in weed-free soybeans in 1984. This was primarily the result of yields declining steadily as Blazer rate increased where 1 qt/A of oil concentrate was added. There was little difference in soybean yields among the other additive treatments as Blazer rate increased.

Control of pigweed, a mixture of redroot pigweed and Powell amaranth, was improved as rate of Blazer application was increased (Tables 2 and 3). However, the degree of pigweed control at harvest only ranged from 58% to 80% in 1983. Early season pigweed control in 1984 ranged from 67% for the 0.125 lb/A rate of Blazer to 90% for the 0.50 lb/A rate. However, pigweed control at harvest in 1984 was poor with no differences among Blazer rates (Table 3).

Pigweed control in 1983 was similar for the surfactant and both rates of oil concentrate for the July 19 rating; these additives gave better pigweed control than where no additive was used (Table 2). On June 27, 1984, there were no differences among the additive treatments for pigweed control. (Table 3). Although there were some significant differences among additives for pigweed control at harvest in 1984, the level of control was poor (36% to 57%) and these differences probably are not meaningful.

One of the most significant effects of herbicide additive was observed for control of giant foxtail (Tables 2 and 3). Grass control at harvest with the Basagran, Blazer and Poast tank mixtures was similar where no additive and the surfactant was used. These treatments gave poor control of foxtail. Control of foxtail was significantly better where either 1 pt/A or 1 qt/A of oil concentrate was used as the additive. The oil concentrate treatments generally provided 90% or better grass control. Over the two years, treatments applied without additive or with surfactant gave only 43% to 82% grass control at harvest. These findings are not new since the benefits of using oil concentrate with Poast has been demonstrated several times.

Control of velvetleaf and common lambsquarters was generally not influenced much by either the rate of Blazer or the type of additive (Tables 2 and 3).

In both years in the weedy study, the rate of Blazer application did not influence soybean yields (Tables 2 and 3). However, the effect of additive was significant in 1984. Although greater soybean injury was associated with the use of oil concentrate as the herbicide additive, yields were highest in the weedy study with these treatments. This is primarily the result of improved grass control where oil was the additive.

In summary, both rate of Blazer and type and amount of additive influenced soybean injury, yield, and weed control in these studies. In the weed-free study, soybean yields were reduced 3 bu/A over two years when comparing the yields of plots not receiving Blazer with the average yield across all three rates of Blazer and all additives. The rate of Blazer did not appear to be an important factor; all rates effectively lowered yields compared to the weed-free checks not receiving the Blazer, Basagran and Poast tank mixture. The greatest yield reductions were associated with the 1 qt/A rate of oil concentrate.

Increasing the rate of Blazer from 0.125 to 0.25 lb/A generally increased control of pigweed more than increasing the rate from 0.25 to 0.50 lb/A. Rate of Blazer had little effect on all other weed species. As compared to no additive or surfactant, use of oil concentrate greatly improved foxtail control with the Basagran, Blazer and Poast tank mixture.

Because of the risk of soybean injury where oil concentrate is used at 1 qt/A, it is recommended that the rate of oil concentrate be reduced to 1 pt/A when Poast and/or Basagran are tank mixed with Blazer. Since the oil concentrate was the superior additive for annual grass control, it is not recommended that a surfactant be substituted for the oil where Poast is involved in the tank mixtures. In these studies, lack of weed control had a greater effect on soybean yield than soybean injury resulting from Blazer application.

The best approach would be to split the application of postemergence broadleaf and grass herbicides. Applying the Basagran plus Blazer first and delaying the application of Poast for 1 to 7 days would allow greater discretion in the use of additives with the broadleaf herbicides. If common lambsquarters or velvetleaf are among the target weed species, the use of 1 to 2 pt/A of oil concentrate with Basagran or Basagran plus Blazer is recommended to improve the consistency of control. When applications of these herbicides are made under hot ($85^{o}F$) and humid conditions, oil concentrate should be applied at no more than 1 pt/A to reduce the risk of serious soybean injury. If pigweed or nightshade are the only target species, use of surfactant with Blazer should provide adequate control. Oil concentrate should always be applied with Poast to provide the best opportunity to control annual grasses.

Table 1. Influence of Blazer and herbicide additive on weed-free soybeans at Waseca in 1983 and 1984.

		1983				1984					Average 1983-84	
		% Injury			Bu/A	% Injury	Plant Height (inches)			Bu/A	Early[b]	Bu/A
Blazer[a] (lb/A)	Additive (%)	7/14	7/19	9/12	13.5%	6/27	7/11	7/26	9/17	13.5%	Injury	13.5%
Basagran .75 lb/A + Poast .2 lb/A tank mixed with each of the following:												
.125	None	1	8	2	41.9	5	17	29	33	43.2	5	42.6
.25	None	1	7	0	41.9	11	16	29	32	44.2	7	43.0
.50	None	7	13	2	40.6	14	18	29	32	41.2	12	40.9
.125	Surf.(.25)	1	7	0	38.6	8	17	29	33	40.8	6	39.7
.25	Surf.(.25)	3	8	0	42.1	10	17	29	32	40.3	7	41.2
.50	Surf.(.25)	5	13	2	39.6	14	16	28	33	42.9	11	41.2
.125	Oil Conc.(.63)	4	7	0	40.3	14	17	29	33	42.9	10	41.6
.25	Oil Conc.(.63)	9	12	3	38.7	20	16	28	32	40.0	15	39.3
.50	Oil Conc.(.63)	24	18	10	38.3	25	15	28	33	40.8	23	39.5
.125	Oil Conc.(1.25)	18	18	5	37.2	16	16	29	32	42.9	17	40.1
.25	Oil Conc.(1.25)	18	13	0	39.0	20	16	28	31	40.1	18	39.5
.50	Oil Conc.(1.25)	40	25	5	36.6	25	15	26	30	37.4	29	37.0
Check:												
Treflan .75 lb/A + Amiben 2 lb/A		0	0	0	42.2	0	18	31	32	44.7	0	43.4
Means for Blazer Rates:												
.125		6	10	2	39.5	11	17	29	33	42.4	9	41.0
.25		8	10	1	40.4	15	16	28	32	41.1	12	40.8
.50		19	17	5	38.8	20	16	28	32	40.6	19	39.6
BLSD .05		3	3	2	NS	2	1	1	NS	1.4	2	NS
Means for Additive:												
None		3	9	1	41.5	10	17	29	32	42.9	8	42.2
Surf.(.25)		3	9	1	40.1	10	17	28	33	41.3	8	40.7
Oil Conc.(.63)		12	12	4	39.1	20	16	28	33	41.2	16	40.1
Oil Conc.(1.25)		25	19	3	37.6	20	16	28	31	40.1	21	38.9
BLSD .05		3	4	2	2.6	2	1	1	2	1.6	2	1.5
Significance Level for Rate x Additive:		99	51	99	28	44	91	76	67	99	94	83

[a]Herbicide formulations: Basagran=4S; Blazer=2L; Poast=1.53EC
[b]Average of 7/14/83 and 7/19/83 and the 6/27/84 rating.

Table 2. Influence of Blazer rate and herbicide additive on soybeans and weed control in weedy soybeans at Waseca, MN in 1983.

		% Injury			% Control[c]				Bu/A
					Ftsp		Rrpw		
Blazer[a] (lb/A)	Additive(%)[b]	7/14	7/19	9/12	7/19	9/12	7/19	9/12	13.5%
Basagran .75 lb/A + Poast 0.2 lb/A tank mixed with each of the following treatments:									
.125	None	1	3	5	35	73	40	50	24.6
.25	None	3	7	2	55	82	45	62	27.9
.50	None	4	5	5	57	80	63	78	25.8
.125	Surf.(.25)	0	3	2	43	85	52	75	32.4
.25	Surf.(.25)	5	7	0	57	87	62	82	32.0
.50	Surf.(.25)	3	7	8	58	74	65	78	27.0
.125	Oil Conc.(.63)	4	10	5	43	97	43	52	26.3
.25	Oil Conc.(.63)	7	12	5	55	95	53	57	30.9
.50	Oil Conc.(.63)	20	13	3	73	97	73	73	31.2
.125	Oil Conc.(1.25)	6	15	15	52	85	50	55	24.1
.25	Oil Conc.(1.25)	10	13	3	58	95	62	67	27.8
.50	Oil Conc.(1.25)	18	15	0	77	100	77	91	31.0
Weedy Check		0	0	0	0	0	0	0	22.3
Hand-Weeded		0	0	0	100	100	100	97	36.5
Means for Blazer Rate:									
.125		3	8	7	43	85	46	58	26.8
.25		6	10	3	56	90	55	66	29.6
.50		11	10	4	66	88	69	80	28.7
BLSD .05		3	NS	NS	12	NS	9	11	NS
Means for Additive:									
None		3	5	4	49	78	49	63	26.1
Surf.(.25)		3	6	3	53	82	59	78	30.5
Oil Conc.(.63)		11	12	3	57	96	57	61	29.5
Oil Conc. (1.25)		11	14	5	62	93	63	71	27.6
BLSD .05		3	4	NS	NS	11	11	13	NS
Significance for Acifluorfen Rate x Additive:		99	8	94	12	48	19	53	40.0

[a]Herbicide formulations: Basagran=4S; Blazer=2L; Poast=1.53EC.

[b]Additive: Surf.=Ag98; Oil Conc.=Atplus 411F. % on a V/V basis with a total spray volume of 20 gpa.

[c]% Control: Ftsp=mixture of green and giant foxtail; Rrpw=redroot pigweed.

Table 3. Influence of Blazer rate and herbicide additive on soybeans and weed control in weedy soybeans at Waseca, MN in 1984.

		% Injury	Plant Height (inches)			% Control[c]								Bu/A
						Gift		Rrpw		Vele		Colq		
Blazer[a] (lb/A)	Additive (%)[b]	6/27	7/11	7/26	9/17	6/27	9/17	6/27	9/17	6/27	9/17	6/27	9/17	13.5%
Basagran .75 lb/A + Poast 0.2 lb/A tank mixed with each of the following treatments:														
.125	None	10	14	24	23	51	35	75	55	81	58	59	51	19.2
.25	None	10	14	25	25	55	54	85	56	90	66	66	48	20.7
.50	None	15	14	23	25	58	64	91	55	95	79	71	59	21.6
.125	Surf.(.25)	10	15	23	24	50	43	70	58	84	66	69	51	18.2
.25	Surf.(.25)	11	14	23	23	53	31	85	55	88	60	65	43	17.0
.50	Surf.(.25)	22	13	22	24	61	55	89	59	90	56	73	36	20.2
.125	Oil Conc.(.63)	13	14	23	24	55	89	60	30	93	70	68	41	22.2
.25	Oil Conc.(.63)	15	14	24	26	56	88	85	43	84	76	65	54	24.3
.50	Oil Conc.(.63)	24	13	23	25	58	87	89	35	89	75	74	36	22.5
.125	Oil Conc.(1.25)	13	14	23	24	58	89	61	33	85	75	58	49	21.5
.25	Oil Conc.(1.25)	24	14	21	25	60	90	86	34	85	59	76	35	22.0
.50	Oil Conc.(1.25)	31	13	22	27	68	91	90	54	94	76	79	43	23.6
Weedy Check		0	15	24	20	0	0	0	0	0	0	0	0	9.8
Hand-Weeded		0	18	29	32	100	100	100	100	100	100	100	100	28.9
Means for Blazer Rate:														
.125		11	14	23	24	53	64	67	44	86	67	63	48	20.3
.25		15	14	23	25	56	66	85	47	87	65	68	45	21.0
.50		23	13	22	25	61	74	90	51	92	71	74	44	22.0
BLSD .05		3	NS	NS	NS	5	8	4	NS	6	NS	9	NS	NS
Means for Additive:														
	None	12	14	24	24	55	51	84	55	89	68	65	53	18.5
	Surf.(.25)	15	14	23	24	55	43	81	57	87	61	69	43	20.5
	Oil Conc.(.63)	17	14	23	25	56	88	78	40	89	74	69	44	23.0
	Oil Conc.(1.25)	23	14	22	25	62	90	79	36	88	70	71	42	22.4
BLSD .05		4	NS	NS	NS	6	8	NS	13	NS	NS	NS	NS	3.4
Significance for Acifluorfen Rate x Additive:														
		91	11	27	24	15	96	89	38	65	22	50	62	9.0

[a]Herbicide formulations: Basagran=4S; Blazer=2L; Poast=1.53EC.

[b]Additive: Surf.=Ag98; Oil Conc.=Atplus 411F. % on a V/V basis with a total spray volume of 20 gpa.

[c]% Control: Gift=giant foxtail; Rrpw=Redroot pigweed; Vele=Velvetleaf, and Colq=Common lambsquarters.

ANTAGONISM BETWEEN POSTEMERGENCE BROADLEAF AND GRASS HERBICIDES

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Poast and Fusilade are relatively new postemergence herbicides which give good to excellent control of annual grasses, volunteer grains, and certain perennial grasses. Poast and Fusilade have no effect on annual or perennial broadleaf weeds. Poast is presently registered for use on soybeans, sugarbeets, cotton, and certain ornamentals, nursery, and non-food crops while Fusilade is registered on soybeans and cotton. Poast and Fusilade should be applied in spray solutions containing a nonphytotoxic oil concentrate because grass control is generally improved by an oil concentrate. The Poast label suggests using 1 quart/A of oil concentrate while the Fusilade label suggests using oil at 1% of the spray volume. An oil concentrate should have 15 to 20% emulsifier. Research at North Dakota State University has indicated that petroleum oil additives have improved grass control from Poast and Fusilade slightly more than crop origin oil additives.

Tank mixing a postemergence herbicide for broadleaf weed control with postemergence Poast or Fusilade would often be desirable since the weed spectrum generally includes both grasses and broadleaves. Unfortunately, a mixture of a broadleaf herbicide plus Poast or Fusilade often gives less grass control than Poast or Fusilade used alone. In other words, the broadleaf herbicide "antagonizes" the grass control from Poast or Fusilade. Poast and Fusilade have no influence on broadleaf weed control from the postemergence broadleaf herbicides.

Several postemergence grass herbicides similar to Poast and Fusilade are presently under development but are not registered for any uses. These include Verdict, Assure, Whip, Selectone, and SC-1084. This paper will only discuss Poast and Fusilade since they are registered for use in Minnesota and North Dakota. The postemergence broadleaf herbicides will be limited to Basagran, Blazer, and Betanex.

Several factors can influence the level of antagonism between Basagran, Blazer, or Betanex and Poast or Fusilade. One factor is the relative susceptibility of the target grass weeds (Table 1).

Poast was more effective on foxtail than oats while Fusilade was more effective on oats than foxtail (Table 1). Antagonism was less when the herbicide combinations were applied to the species that was easier to control. Poast was antagonized less on foxtail than on oats while Fusilade was the opposite. Generally, the easier the grass to control, the less antagonism.

The specific grass herbicide plus broadleaf herbicide combination influenced the level of antagonism (Table 1). Basagran was more antagonistic to Poast than Blazer or Betanex but Betanex was more antagonistic to Fusilade than Blazer or Basagran. Basagran and Blazer had no effect on oats control from

Table 1. Control of oats and foxtail spp with herbicides and herbicide combinations averaged over one experiment conducted in 1982, 1983, and 1984 at Fargo, ND.

Herbicide	Rate	Oats control	Foxtail spp control
	(lb/A)	(%)	(%)
Poast+OC	0.2	95	98
Poast+Basagran+OC	0.2+0.75	58	85
Poast+Blazer+OC	0.2+0.375	87	95
Poast+Betanex+OC	0.2+0.75	87	94
Fusilade+OC	0.25	99	93
Fusilade+Basagran+OC	0.25+0.75	98	77
Fusilade+Blazer+OC	0.25+0.375	98	76
Fusilade+Betanex+OC	0.25+0.75	88	69

[a] OC = AT Plus 411F at 1 qt/A, petroleum oil with 17% emulsifier.

Fusilade but caused a reduction in foxtail control. Each combination of a postemergence grass herbicide plus a postemergence broadleaf herbicide must be tested on each target weed species to determine the risk of significant antagonism.

The environment can influence the level of antagonism. For example, Betanex caused more than 5% loss in tame or wild oats control in seven of ten experiments with Poast and in four of ten experiments with Fusilade. The reduction in wild oats control varied from zero to over 35% in the various experiments. Thus, antagonism was greatly influenced by environment. The precise environments which increase or decrease antagonism cannot be predicted at this time. Generally, environments which favor excellent grass control give reduced antagonism. Environments which cause less grass control give increased antagonism. High soil moisture and high humidities tend to allow better grass control from Poast and Fusilade than dry conditions. Research at Fargo, ND and Crookston, MN in 1984 indicated that Poast and Fusilade applied in 8.5 gpa of spray solution gave better grass control than when applied in 17 or 25 gpa. This agrees with research conducted at the University of Nebraska by Buhler and Burnside (Weed Science 32:574-583). Buhler and Burnside found that control of forage sorghum with Poast or Fusilade was generally better with 10 gpa or less than with 20 gpa or more. The research at Fargo and Crookston indicated that antagonism between Betanex and Poast or Fusilade was less at 8.5 gpa spray volume than at 17 or 25 gpa. Thus, reduced spray volume may reduce the antagonism from herbicide combinations.

Antagonism can be overcome by increasing the rate of the grass herbicide. The amount of grass herbicide needed to overcome antagonism will vary with grass species, environment, and the broadleaf herbicides. More research is needed to precisely establish proper grass herbicide rates in combination with broadleaf herbicides. Present label guidelines suggest a 50% increase in Poast when applied with Basagran.

As stated previously, Poast and Fusilade should be used with an oil concentrate. This is true when the herbicides are used alone or in combination with a postemergence broadleaf herbicide. Persons using tank mixes need to be aware of the influence of the oil additive on the phytotoxicity of the broadleaf herbicide. Basagran is commonly used with oil additive in soybeans without excessive crop injury. However, the phytotoxicity of Betanex to sugarbeets and Blazer to soybeans may be increased by the oil additive. This injury may be excessive in some environments or to certain crop growth stages.

Antagonism between postemergence broadleaf and postemergence grass herbicides can be avoided by applying the herbicides separately. Research at Fargo, ND suggested that Betanex applied 24 hours after Poast did not reduce wild oat control. Betanex applied 2 hours after Poast caused antagonism. Poast application had to be delayed 48 hours to avoid antagonism when Betanex was applied first.

SUMMARY

Postemergence grass herbicides and postemergence broadleaf herbicides should be applied separately for the most consistently effective grass control and the least risk of crop injury. Leaving 48 hours between treatments eliminated antagonism when Betanex was applied before Poast while 24 hours was sufficient when Poast was applied first.

The following steps will reduce the risk of antagonism if a postemergence grass herbicide and a postemergence broadleaf herbicide must be applied in combination. Combinations only should be applied to the more susceptible grass species. A less antagonistic broadleaf herbicide should be used when possible. Apply combinations in environments that favor excellent grass control. Apply combinations in low spray volume. Increase the rate of the grass herbicide.

WEED CONTROL IN CONSERVATION TILLAGE

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Tillage practices have changed rapidly in response to concerns about soil erosion and to reduce inputs into crop production. Conservation tillage systems which leave residue from the previous crop on the soil surface can effectively reduce soil erosion. This erosion control system allows growing row crops like corn and soybeans while reducing soil erosion, with a minimal capital investment. Alternative erosion control systems such as terracing or growing non-erosive crops such as alfalfa or pasture are equally or more effective in reducing soil erosion, but either require a great input of capital or require growing crops which may not be profitable or efficiently usable for all farm operations. Thus, many farmers are switching to conservation tillage systems for production of corn and soybeans.

Before the introduction of selective herbicides, repeated tillage was the primary method of weed control in row crops. Common weeds of corn and soybean production have been selected over hundreds of years to survive and reproduce under the conditions of repeated tillage. The rapid introduction of herbicides in the 1950s and 1960s brought about greatly improved weed control and allowed for a decrease in the amount of secondary tillage and row cultivation. The chemical weed control technology also brought about a shift in weed populations, favoring certain weeds not controlled by available herbicides.

The recent shift to reduced tillage systems which cause less soil disturbance and leave more crop residue on the soil surface can also be expected to cause changes in our weed spectrum. The common belief that weeds intensify under conservation tillage systems more properly should be stated "weed problems may change under conservation tillage systems".

EFFECT OF TILLAGE ON WEEDS

ANNUAL WEEDS

Most weeds commonly associated with row crops are summer annual plant species favored by disturbed soil conditions. Summer annual plants originate from seeds each year -- not from overwintering roots. Before man began planting crops, these plants were limited to natural areas of soil disturbance such as eroded stream banks. Man's soil tillage created hundreds of millions of acres of prime habitat for these previously obscure species, and they became what we now call weeds. To reproduce under the conditions of repeated soil disturbance, the weed needs to germinate quickly after a disturbance and then quickly mature and produce seed. Most weed seeds have built-in "sensors" which detect when tillage has occurred. Many small-seeded species require light for germination. This may be provided by tillage or be received if the seed is near the soil surface and not underneath a canopy of plant leaves (the kind of light passing through the plant leaves actually inhibits some weed seeds from germinating). Other seeds may need greater oxygen or a change in temperature caused by tillage. Weed seeds can germinate in the absence of tillage, but tillage stimulates a greater percentage of weed seeds to germinate.

Before the introduction of herbicides, repeated preplant tillage was a widely practiced weed control method. An initial tillage operation in the spring killed previously emerged weeds and stimulated a new germination flush. Tillage was then repeated to kill the new flush and stimulate more weeds to germinate in an effort to reduce the number of viable seeds in the soil. The introduction of soil-applied herbicides meshed nicely with the intensive tillage system in use at that time. The preplant tillage stimulated weed germination, while the planting-time soil herbicide killed the susceptible weeds as they germinated. These intensive tillage systems resulted in fairly predictable and consistent weed germination patterns from year to year.

Problems from annual weeds begin with the reservoir of weed seeds in the soil. Weed seeds can remain alive in a dormant state in the soil for many years before eventually germinating when conditions and favorable and dormancy is broken. While seeds of some grassy species have a potential life in the soil of only 10 to 20 years, some broadleaf weed seeds can remain viable for as long as 50 years or more. This tremendous survival potential of weed seeds does not mean that weed control efforts are futile. In a University of Illinois study where corn was grown continuously for 6 years and weed control was effective, weed seed numbers in the soil decreased by 70 percent. Even velvetleaf, which is notorious for its seed longevity, can be reduced by preventing seed production. In a University of Minnesota study, velvetleaf seed numbers were reduced by 90 percent over 4 years by repeated tillage which stimulated germination, but allowed no seed production.

Moldboard plowing buries many recently produced weed seeds to depths unfavorable for germination. These seeds are not killed, but actually are placed into a deeper state of dormancy and are able to survive longer than are seeds placed more shallowly in the soil. Plowing also brings other buried weed seeds near the surface where they germinate. What effect does going to a reduced tillage or no-till system have on weed seed distribution in the soil? Recently produced weed seeds are no longer buried to depths too deep for germination. If a significant number of weeds are allowed to go to seed, weed seed numbers in the top inch or two of soil will begin to increase and weed problems can intensify. However, if weeds are controlled to prevent seed production, the number of seeds near the soil surface will begin to decline because shallow seeds either germinate and are killed by the weed control system or die more quickly than deeply buried weed seeds. If no deep tillage is performed, the reservoir of dormant seeds below is not brought up to germinate. This principle explains why some farmers report that weed control seems to improve each year under conservation tillage, while others report that weed problems seem to intensify.

Leaving weed seeds shallow in the soil can be an advantage over the long term if you can start with several years of good weed control. However, following years when a large number of weeds go to seed due to poor weed control, shallow placement of those seeds can be a disadvantage since all of that crop of weed seeds faces you the next season. In that situation, moldboard plowing may reduce the number of weeds germinating the following season, but only if fewer weed seeds are present in the soil that is turned up.

Besides influencing weed seed placement in the soil, varying tillage systems also influence when and how many seeds germinate. Iowa State University studies have shown that disturbing the soil 1 inch deep resulted in a 30 percent increased density of weeds such as foxtail, redroot pigweed, common lambsquarters, velvetleaf, and Pennsylvania smartweed, compared to no tillage.

With deeper tillage, germination of weeds was similar to that with no tillage, except for velvetleaf and cocklebur, which germinated to a greater extent with deeper tillage.

Reduced or no tillage results in cooler and wetter soil in early spring. This may in turn influence weed seed germination. Germination of certain warm temperature requiring weeds such as pigweed may be delayed. Compared to plowing, conservation tillage systems have usually resulted in germination of fewer broadleaf weeds in Iowa State studies. Moderate tillage systems which use chisel plows or discs have sometimes increased germination of foxtails, compared to plowing; while no-till plots usually have had the fewest weeds germinating. Weed germination may be more periodic and uneven with no-till systems, since there is no one-time stimulus of tillage, and the soil warms up more slowly. In general, when shifting from moldboard plowing to a reduced tillage system, annual grasses such as foxtails remain a major weed problem, while certain broadleaf weeds tend to decrease. Weed germination may be delayed or more sporadic. Consequently, herbicides with greater persistence or follow up postemergence treatments may be advantageous in conservation tillage systems.

Winter annual weeds germinate in the fall, overwinter, and resume growth in early spring. Spring tillage kills winter annual weeds. Consequently these weeds are usually not a problem in row crops produced in conventional or reduced tillage. They often do persist as weed problems in no-till systems. Winter annual weeds often infesting no-till fields include marestail or horseweed, purselane speedwell, field pennycress, daisy fleabane, and shepherds purse. Non-selective herbicides such as paraquat and Roundup often used in no-till systems control most of these weeds. Also 2,4-D applied before planting has provided excellent control.

PERENNIAL WEEDS

Perennial weeds have the capability of regrowing from overwintering roots, unlike annual weeds which die with frost in the fall. Simple perennials reproduce only by seed. They are usually killed by tillage and thus are not a problem in conventional tillage systems. Simple perennials include plants such as dandelions, alfalfa, and bromegrass. These plants are not weed problems in conventional tillage. However, in no-till systems, these simple perennials can survive and become weed problems. Special techniques are needed to control problems such as alfalfa and bromegrass when planting no-till into sod.

Other perennial plants can reproduce vegetatively from buds on underground roots or rhizomes. These perennial weeds can survive tillage operations and are problems both in conventional, reduced and no-till systems. Tillage may be partially effective in suppressing some of these perennial weeds. They rely on stored food in their extensive root systems to produce new shoots after tillage. Repeated tillage weakens the weed's ability to send up new shoots by depleting the stored reserve of food. Some perennials with relatively shallow root or rhizome systems such as quackgrass can be suppressed by tillage which drags the roots and rhizomes to the soil surface where they dry out or are winter-killed.

How do reduced tillage systems affect these vegetatively reproducing perennial weeds? Over the short term, effects may be small, but certain of these perennial weeds have increased in several states where no-till or reduced tillage systems have been used for many years. Reduced tillage is not the only reason some perennial weeds have increased. Most soil herbicides are ineffective on these weeds, allowing them to multiply as other weeds are controlled. Many fields are now row cropped continuously rather than rotated with crops such as alfalfa which compete strongly with perennial weeds.

A long-term study at the Northeast Iowa Research Center at Nashua involving acre-sized plots has shown certain perennial weeds to increase under reduced tillage systems (table 1). The study was begun in 1976 and involved no-till, ridge-till, chisel plow and moldboard plow systems as well as continuous corn and corn-soybean rotations. Perennial weed counts were made in 1980 after the study had been conducted for four years. Hemp dogbane, common milkweed, and Canada thistle increased in populations over the four-year period with reduced tillage systems, especially no-till and ridge-till. On the other hand, field bindweed was more prevalent in the plowed plots. Other studies have shown that perennial grasses such as quackgrass and wirestem muhly may spread more rapidly when tillage is reduced.

Table 1. Nashua Tillage Study. Counts of perennial weeds in 1980 during the fourth year of the long term study. Counts are the average of the continuous corn and corn-soybean crop rotations (R. L. Becker and R. S. Fawcett, Iowa State University, 1980).

	Weed population per hectare						
Tillage Treatment	Hemp dogbane	American germander	Field bindweed	Yellow nutsedge	Common milkweed	Canada thistle	Total
No-till	4,626	3,164	241	1,075	86	12	9,202
Ridge till	2,674	4,084	275	327	146	26	7,531
Chisel plow	2,313	1,513	241	146	8	8	4,255
Plow	2,201	2,202	980	95	0	0	5,289

Another tillage study conducted at Iowa State University illustrates why perennial weed increases may occur under reduced tillage systems. No-till, chisel-disc, disc, and moldboard plow systems were used in an existing heavy stand of hemp dogbane. The moldboard plow completely disrupted the dogbane crowns and root system and delayed emergence of shoots coming from root pieces. The chisel plow disrupted about half of the dogbane crowns, leaving the remaining crowns intact and ready to produce shoots in the spring, while the disc cut off the tops of dogbane plants, but left nearly all of the crowns intact. No-till, of course, left all of the crowns intact. While over the long-term weed shifts may occur after adopting conservation tillage, effective controls are available for most perennial weeds. In fields where perennial weed problems are severe, it is wise to control these weeds through combination of herbicides and tillage before attempting no-till.

Does plowing one year help in reducing hemp dogbane populations? Plowing set back the emergence of dogbane and reduced its competitiveness (table 2). However, any tillage actually increased the number of plants (table 3). Populations of hemp dogbane continued to increased with all tillage systems, with the greatest increase with tandem discing where row cultivation was practiced. Tillage broke up the dogbane root system, releasing dormancy of underground buds, resulting in more, but smaller plants. Plowing only one year did not result in a reduction of dogbane populations the following year. Three years of intensive tillage were needed to start reversing the trend of population increase. Therefore, while plowing may help temporarily by reducing the competitiveness of hemp dogbane, intensive tillage in rotation with conservation tillage does not appear to be a useful control technique. Effective herbicides are available and may be more useful. The faster emergence of perennial weeds in reduced tillage systems may actually help chemical control, by allowing greater height difference between weed and crop. This aids control with selective applicators, such as rope wicks, or simplifies the timing of selective postemergence herbicides. Plowing is effective in controlling simple perennials and woody perennials which may become established when no-till systems are used for many years.

Table 2. The effect of two years of various tillage systems on hemp dogbane development in corn. Hemp dogbane was uniformly dense in all plot areas before the study was begun. (R. L. Becker and R. S. Fawcett, Iowa State University, 1980).

Tillage	Ground Cover 7/9/80 (%)	Height 7/9/80 (ft)	Flowering 6/24/80 (%)
Moldboard plow	35	2.8	11
Chisel plow	64	3.4	62
Tandem disc	66	3.7	74
No tillage	76	4.3	65

Table 3. The effect of two years of various tillage systems on hemp dogbane populations in corn. Hemp dogbane was uniformly dense in all plot areas before the study was begun. Populations increased in all plots during the study. (R. L. Becker and R. S. Fawcett, Iowa State University, 1980).

	Average population increase (%)	
Tillage	Without row cultivation	With row cultivation
Moldboard plow	168	119
Chisel plow	215	154
Tandem disc	388	102
No tillage	109	256

Weed problems are not worse in conservation tillage systems; they may be different. Farmers should be alert to shifts in weed populations and be ready to adjust their herbicide programs if needed.

TILLAGE SYSTEMS AND HERBICIDES

With conventional tillage systems involving the moldboard plow, herbicides are applied to a bare soil surface. The soil-herbicide interface is relatively constant from year to year. With reduced tillage systems, some or all of the previous crop residue is left on the soil surface. In this situation, soil conditions in which the herbicide is applied to may vary more from year to year, thus requiring more accurate application.

Intact crop residue is not like organic matter in the soil. It does not strongly bind herbicides as does soil organic matter. Research conducted at Iowa State University has shown that most commonly used herbicides are quickly washed from cornstalks to the soil by rainfall. Crop residue, especially cornstalks, can intercept soil herbicides and may change their distribution in the soil. Evenly distributed crop residue does not cause great problems with herbicide performance, but bunched residue can. Because of the tendency for heavy crop residue to change the distribution of soil herbicides, accurate application becomes especially important in conservation tillage systems. Application systems which deliver more droplets per unit area have provided superior weed control under high crop residue conditions. This may be accomplished by applying more water per acre, but may also be accomplished through nozzle selection and higher spray pressures.
In 1984, experiments were conducted at Ames, Chariton, and Nashua to investigate the effect of nozzle type and carrier volumes on preemergence herbicide activity in no till corn with heavy corn stalk residue (Table 4). No emerged weeds were present when herbicides were applied. Rainfall varied considerably between the sites. The Ames location received greatly above

normal rainfall and weed control with Bladex was nearly complete for all nozzle types and carrier volumes. With Lasso, all flat fan tips gave nearly complete control, but flood tips provided less control.

Rainfall was moderate at the Chariton location. There was little difference between flat fan tips or carrier volumes with Bladex, but flood tips provided less control. Lasso gave satisfactory control with the flat fan tips regardless of carrier volume, but significantly poorer control with the lower volume flood tips. The Nashua site was the driest site, receiving about normal rainfall. Here Bladex performance with flat fan tips was better at 20 and 40 gal/A than at 10 gal/A. Flat fan tips were generally superior to flood tips. Lasso performance was better with 20 and 40 gal/A than at 10 gal/A using flat fan tips. Operating 80015 tips (10 gal/A tips) at half speed which delivered 20 gal/A gave the best control. This suggests that number of spray droplets per unit area is more important than actual gal/A carrier. Flat fan tips generally performed better than flood tips. This is probably due to the fact that flat fan tips produce more spray droplets per unit area than flood tips, thus improving herbicide distribution. These studies confirm previous Iowa State University research results where better spray coverage, accomplished by either greater carrier volumes or more spray droplets, improved herbicide performance under high crop residue conditions. Apparently when rainfall is abundant, differences between carrier volumes and nozzles types are reduced or eliminated. However, flat fan tips usually provided better weed control than flood tips and 20 gal/A carrier performed better than lower carrier volumes in at least some experiments.

Table 4. Carrier volume-nozzle type studies at Ames, Chariton, and Nashua, Iowa, 1984. No till corn where corn stalk residue provided at least 60% ground cover. No emerged weeds present. (R. S. Fawcett and M. D. K. Owen, Iowa State University, 1984).

				% Giant Foxtail Control			
Treatment	Rate lb/A	Nozzle Tip	Carrier Volume gal/A	Ames	Chariton	Nashua	Average
Lasso	2.5	Flat Fan 80015	10	99	90	71	87
Lasso	2.5	Flat Fan 8003	20	98	98	83	93
Lasso	2.5	Flat Fan 8005	40	96	98	85	93
Lasso	2.5	Flat Fan 80015	20	96	95	92	94
Lasso	2.5	Flood TK 3	10	82	73	72	76

Table 4. Continued...

Treatment	Rate lb/A	Nozzle Tip	Carrier Volume gal/A	% Giant Foxtail Control Ames	Chariton	Nashua	Average
Lasso	2.5	Flood TK 2	20	87	86	73	82
Lasso	2.5	Flood TK 7.5	40	93	97	81	90
Lasso	2.5	Flood TK 2	20	90	95	83	89
		LSD 0.05		11	15	9	
Bladex	2.5	Flat Fan 80015	10	95	97	68	87
Bladex	2.5	Flat Fan 8003	20	99	93	82	91
Bladex	2.5	Flat Fan 8005	40	99	97	82	93
Bladex	2.5	Flat Fan 80015	20	98	91	72	87
Bladex	2.5	Flood TK 2	10	99	73	65	79
Bladex	2.5	Flood TK 3	20	99	84	57	80
Bladex	2.5	Flood TK 7.5	40	98	87	70	85
Bladex	2.5	Flood TK 2	20	99	85	73	86
		LSD 0.05		2	19	17	

Do herbicide rates need to be increased with conservation tillage? Labeled rates of herbicides will provide satisfactory weed control in conservation tillage systems, provided they are accurately applied. Because conditions at the soil-herbicide interface may be more variable with conservation tillage than with conventional tillage, reduced herbicide rates which sometimes provide satisfactory weed control in conventional systems may not work with conservation tillage systems. Rates outlined on herbicide labels are selected to provide satisfactory weed control under a wide variety of conditions and are adequate for conservation tillage systems.

Can herbicides be incorporated while leaving crop residue on the soil surface? Crop residue can interfere with the distribution of incorporated herbicides in a similiar manner to preemergence herbicides. It is possible to incorporate herbicides in conservation tillage systems. Soybean stubble causes little interference with incorporation of herbicides even if no prior tillage has been done as long as soybean straw is evenly distributed. Some form of tillage usually must be done to heavy cornstalks before incorporating a herbicide. Chisel plowing or discing will cut up and bury enough cornstalks to allow herbicide incorporation. The soil surface should not be prominently ridged at the time of herbicide application. Ridges and valleys should be no deeper than the incorporation tool will be operated. One or two passes of the incorporation tool may be needed, depending on how well the soil works, how much breakdown of stalks has occurred over the winter, and the properties of the herbicide. Volatile herbicides such as Sutan^{+} and Eradicane can redistribute laterally in warm soils thus overcoming streaking that otherwise might occur from marginal soil mixing. Water soluble herbicide such as Lasso, Dual, Atrazine, Bladex, and Sencor/Lexone can move with water for short distances laterally, but move mainly downward.

Combination tools which combine a disc gang with a field cultivator and leveling device can usually be used to successfully incorporate herbicides in one pass. If the soil is excessively ridged, spraying immediately behind the disc gang and ahead of the field cultivator shovels of a combination tool allows for both leveling and herbicide incorporation in one pass.

Field cultivators usually incorporate herbicides to a shallower depth than discs. This may be advantageous for shoot-adsorbed herbicides such as Dual and Lasso. Field cultivators also leave more crop residue on the soil surface than do discs. For successful one pass incorporation with field cultivators, the tool should be equipped with enough 6 inch sweeps to turn all soil and have a leveling device. Operate at 5-7 mph and make sure the tool is level.

Incorporation of herbicides in conservation tillage systems, especially when incorporation is accomplished with one pass, is a compromise. More variability may be encountered resulting in occasional weed streaking if conditions are not ideal. If soil does not mix well, usually due to excess moisture or residue cover, a second pass of the tillage tool should be used.

HERBICIDE OPTIONS IN REDUCED TILLAGE SYSTEMS

Reduced tillage systems involving tillage tools such as the chisel plow, disc, field cultivator, or rotary tiller are compatable with nearly all herbicides used in conventional tillage systems. Preplant incorporated, preemergence, and postemergence herbicides can be effectively used, considering the factors previously discussed. The Weed Control Guide (publication Pm-601) discusses specific herbicide treatments, their relative effectiveness, and proper application. Soil herbicides will continue to be the backbone of most herbicide programs, but the use of postemergence herbicides may increase, especially as effective new herbicides are introduced. Postemergence herbicides may be used as a back-up for weeds escaping soil treatments, or may be used as planned treatments.

Certain perennial weeds which are tolerant to most soil herbicides and may become problems in conservation tillage systems can be controlled with postemergence herbicides. Hemp dogbane and several other broadleaf perennial weeds can be controlled in corn with preharvest applications of Banvel + 2,4-D. This treatment goes on several weeks prior to harvest when the weeds are most susceptible and the corn is mature and safe from injury. Two years of treatment are usually needed for satisfactory control. Roundup can be used as a spot treatment to control many troublesome perennial weeds. Roundup applied with a selective applicator such as a rope wick controls tall weeds such as milkweed, dogbane and volunteer corn in soybeans.

Postemergence grass killers for soybeans provide a new weed control option. Fusilade, Hoelon and Poast are useful for control of volunteer corn, which can increase with reduced tillage. Fusilade and Poast also control foxtail and tough annual grasses such as woolly cupgrass and shattercane as well as perennials like quackgrass and wirestem muhly.

After planting tillage such as rotary hoeing or row cultivation still has an important role in weed control systems. Rotary hoeing can be used to salvage a preemergence herbicide in dry weather conditions; row cultivation controls weed escapes and slows the process of weed selection which allows new weeds tolerant to the herbicides to increase.

HERBICIDE OPTIONS IN NO-TILL SYSTEMS

Weed control in no-till crop production is different from other systems since tillage is not performed to kill existing weeds and create the even start situation for the crop and weeds. Since no tillage is performed, this also eliminates the potential for using an incorporated herbicide. Preemergence and postemergence herbicides are available to control most common weeds in corn and soybeans.

If weeds have emerged at planting-time, a nonselective burndown herbicide such as paraquat, Roundup, or Bronco (Roundup + Lasso package mix) may be needed in combination with the proper residual herbicide. The nonselective herbicide may be applied before or after planting, but must be applied before crop emergence. When the nonselective herbicide is tank mixed with the residual herbicide, best results are usually obtained when the herbicides are applied immediately after planting, otherwise the planter may disturb the herbicide distribution in the immediate area of the row. Some soil-applied herbicides such as atrazine, Bladex, Sencor/Lexone, and Lorox have postemergence activity and can burn down small weeds. However, larger weeds are not always completely controlled. Preemergence grass killing herbicides such as Lasso and Dual have little effect on emerged weeds.

With early planting, weeds may not have emerged at planting time or may be small and few in number. Under these conditions, a burndown herbicide may not be needed, especially if the residual herbicide has postemergence properties (table 5). Liquid nitrogen has burndown properties, especially when mixed with herbicides. High rates of liquid N (30 gal per acre or more) have generally provided good burndown of small weeds when mixed with herbicides. If weeds are greater than 1 1/2 to 2 inches tall or conditions are dry, include a nonselective herbicide.

Table 5. **McNay No-Till Corn Experiment. Burndown ratings for no-till herbicide combinations. Weeds were from 1/2 to 3 inches tall at application time. Ratings made one week after treatment (R. S. Fawcett and A. L. Seim, Iowa State University, 1981).**

		% Burndown	
Treatment	Rate (lb/A)	Foxtail	Smartweed
Paraquat + Lasso + Atrazine	0.25 + 2.5 + 1.6	99	85
Paraquat + Bicep	0.25 + 3.25 qt.	99	82
Paraquat + Bladex 4L	0.25 + 3.4	99	87
Paraquat + Lasso + Bladex 4L	0.25 + 2 + 2.4	98	80
Roundup + Lasso + Atrazine	2 qt. + 2.5 + 1.6	98	85
Roundup + Bicep	2 qt. + 3.5 qt.	98	83
Bladex 4L	3.4	95	73
Bladex 4L + oil conc.	3.4 + 1 qt.	94	82
Bicep	3.25 qt.	91	62
Bicep + oil conc.	3.25 qt. + 1 qt.	92	70
Lasso + Bladex 4L	2 + 2.4	93	60
Bladex 4L in 28% N	3.4 in 30 gal.	98	89
Bicep in 28% N	3.25 qt. in 30 gal.	97	85
Lasso + Atrazine in 28% N	2.5 + 1.6 in 30 gal.	96	88

When using paraquat, excellent spray coverage is essential since this herbicide does not redistribute inside plants, but kills plant tissue only where leaves are contacted by spray droplets. The use of a nonionic surfactant such as X-77 is also necessary to improve spray coverage. Use 20 to 60 gal of spray solution per acre. Paraquat may be mixed with fluid fertilizers, but should not be used with suspension or high phosphate fertilizers.

The Roundup label describes using 10 to 40 gal of spray per acre, but because this herbicide translocates or redistributes inside plants, thorough spray coverage is not as critical as with paraquat. For all conditions except very dense weed foliage, 10 to 20 gal spray per acre is adequate when using Roundup. Mixing Roundup with liquid fertilizers can reduce its effectiveness. Roundup, unlike paraquat, can kill the root systems of perennial weeds. However, for most perennial weeds, planting-time applications are too early for complete control. Perennial grasses such as quackgrass, wirestem muhly, and orchardgrass can be controlled if as at least about 8 inches of growth is present.

The Roundup label has been revised to describe low volume applications at reduced herbicides rates for fallow and reduced tillage systems. Unlike most herbicides, Roundup is sometimes more active when applied in carrier volumes of 3 to 10 gal per acre than when applied at higher volumes as long as coverage is adequate. This low volume effect may be due to the greater concentration of Roundup in spray droplets and less inactivation of Roundup by calcium and magnesium found in hard water. A rate of 1/2 pt per acre of Roundup will control foxtails less than 6 inches tall. A rate of 3/4 pt per acre controls volunteer small grains less than 6 inches tall. Banvel or 2,4-D may be tank mixed with Roundup for control of many small emerged broadleaf weeds. Add a nonionic surfactant as described on the label. This treatment is for Roundup applied alone or with 2,4-D or Banvel. These reduced rates will not provide consistent control when residual herbicides are tank mixed with Roundup. Many residual herbicides reduce Roundup activity. Roundup rates labelled for tank mixes with residual herbicides provide satisfactory control, but the reduced rates labelled for low volume applications may not provide satisfactory control if residual herbicides are tank mixed.

Paraquat or Roundup are not necessary when using the till-plant (Buffalo till) system, since the wide sweep clears all vegetation out of the crop row. Cultivation is used to control emerged weeds in row middles. However, a considerable number of farmers use a burndown herbicide with the till-plant system. This is not needed in the row area, but may be beneficial in row middles when weed growth is dense. This allows more complete weed control with cultivation, especially if cultivation must be delayed. It may be advantageous to apply soil herbicides with the planter so that the herbicide comes in contact with moist soil exposed by the planter. Because row cultivation is an integral part of this planting system, many growers apply herbicides in a band over the row.

EARLY PREPLANT APPLICATION

The reliance on preemergence herbicides in no-till rather than preplant incorporated herbicides, introduces more chance of poor herbicide performance under dry weather conditions when herbicides are not moved into the weed germination zone by rainfall.

An alternative herbicide application system called early preplant or early preemergence has been developed at Iowa State University. This system involves the application of preemergence herbicides several weeks before crop planting and before germination of most weeds. The crop is then planted through the herbicide at normal planting-time. This system is best for no-till where there is little disturbance of soil in the row. It may be used with till-plant systems, but additional herbicide would have to be applied over the row after planting, since the till planter would throw herbicide-treated soil out of the row.

Early preplant application offers several advantages over traditional no-till herbicide treatments which usually include nonselective herbicides. The herbicide treatment is applied earlier in the spring resulting in a greater probability that rainfall will move the herbicide into the weed germination zone prior to weed emergence, compared to a herbicide treatment applied at planting. More consistent weed control has been the biggest advantage of early preplant herbicide application. Usually there is no need for a nonselective herbicide at planting-time as weeds have been prevented from emerging. If the early-applied herbicide fails to prevent weed emergence, a nonselective herbicide can still be used if needed. If perennial weeds are present or when planting into sod, nonselective herbicides are usually needed. An added benefit for early preplant application may be that fields are less attractive to insects such as black cutworm moths if early weed growth is prevented. Often problems due to common stalkborer are reduced, as emerging larvae starve due to lack of host plants prior to emergence of corn.

Split applications of herbicides may be needed for most consistent results with the early preplant application system. If all of the residual herbicide is applied early and little rainfall occurs between the time of herbicide application and planting, soil disturbance caused by the planter can throw some of the herbicide-treated soil out of the row, which may result in weeds surviving in the crop row. Application of part of the herbicide after planting eliminates this problem. The herbicide may be banded over the row to reduce costs. Application of some herbicide after planting also helps the herbicide persist longer into the growing season to provide season-long weed control. This is more of a concern with soybeans, since up to a month or more may pass between early herbicide application and planting time. Application of herbicides this early means that part of the herbicide will break down before planting. If crops are planted within two weeks of herbicide application, this early herbicide breakdown is not a major concern. However, with longer application-to-planting intervals, herbicide rates may have to be increased about 25% to compensate for early breakdown, or herbicides known to be persistent should be used. Another application system option is to apply an early preplant treatment at normal rates and followup with a postemergence treatment.

Early preplant herbicide application normally should be done form early to late April in Iowa, depending on the year. If soil temperatures are below 50^{o} and weeds are not germinating, there is no need to rush the application. The major objective is to apply the herbicides before most weeds germinate. Beating grass germination is most important; and foxtails normally don't germinate until early May. If a few early broadleaf weeds are present at the time of early preplant application, they may be controlled by a broadleaf herbicide like atrazine or Bladex (for corn) or Sencor, Lexone, or Lorox (for soybeans). 2,4-D ester is very useful to control winter annual and early emerging summer annual broadleaf weeds prior to planting corn. In the future, 2,4-D ester may be registered for use at least one week prior to planting soybeans.

Several corn and soybean herbicides are now registered for early preplant application either as split treatments or applied as one early treatment.

PLANTING NO-TILL INTO SOD

Planting no-till into sod presents special problems. Legumes such as alfalfa and clover as well as perennial forage grasses such as bromegrass and orchardgrass may persist as weed problems. Alfalfa can be controlled by applications of 2,4-D ester at 1 qt/A (3.8 lb a.e./gal) when 4 to 5 inches of growth are present prior to planting corn. Tank mixing 2,4-D with paraquat can result in reduced control of alfalfa, since the quick burndown of alfalfa topgrowth can reduce the translocation of 2,4-D to alfalfa roots. In the future 2,4-D ester may be registered for use at least one week prior to planting soybeans. If red clover is present, 2,4-D often provides only partial control. For red clover control, apply Banvel at 1 pt/A or a combination of Banvel + 2,4-D. Do not apply Banvel prior to planting soybeans or severe injury may occur. Roundup provides good control of red clover, but often gives only partial control of alfalfa. If alfalfa or clover regrow after corn emergence, 2,4-D or Banvel can be used postemergence. If alfalfa or clover regrow after soybean emergence, there is no selective herbicide which will control these legumes.

If a cutting of hay is removed prior to planting corn or soybeans, planting and herbicide application need to be delayed until at least 4 to 5 inches of healthy alfalfa regrowth occurs. Otherwise 2,4-D or Roundup will not translocate to the legume roots and poor control will result. Control of alfalfa with Roundup following cutting for hay has been variable.

Perennial forage grasses can be difficult to control when no-till planting into sod. Bluegrass is controlled easily by paraquat + atrazine or Bladex. Orchardgrass can be very difficult to control, while bromegrass is intermediate. When anticipating no-till planting corn into sod, avoid planting orchardgrass. Orchardgrass and bromegrass can be controlled with paraquat + atrazine at planting followed by atrazine + oil postemergence. Often orchardgrass persists through part of the growing season after treatment. Bladex may be substituted for part of the atrazine to reduce carryover risk, but for most consistent control, a total of 4 lb/A total triazine has been needed. Early preplant application of Bladex and atrazine has been successful and sometimes eliminates the need for paraquat.

Roundup is useful to control perennial forage grasses and can be used where atrazine carryover cannot be tolerated or when planting no-till soybeans. The Roundup label calls for the use of 3 qts per acre for orchardgrass control and describes treating when plants are at heading stage. Research at Iowa State University has shown that earlier treatments and lower rates can be effective. Fall treatments have been more effective than spring treatments, with 1 qt/A sometimes providing satisfactory, but not complete control. With spring applications results have been variable, with 2 qts/A or more usually needed. Treatment should be delayed as long as practical to allow orchardgrass to reach at least 8 inches tall. When planting soybeans, Fusilade or Poast can be used postemergence to control forage grasses.

ROW CULTIVATION

Row cultivation should be considered as an important component of no-till weed control systems. Cultivators designed specifically for no-till systems work well in heavy residue. Conventional sweep cultivators may be modified by removing shanks, substituting wider sweeps and or adding disc hillers so that they work satisfactorily with heavy residue. Conventional cultivators are usually not heavy enough for use in sod. Row cultivation, if needed, controls weeds escaping herbicide treatments and slows the process of weed shifts where new weeds tolerant to the herbicides being used increase to become major weed problems.

SUMMARY

The common belief that weeds intensify under conservation tillage systems more properly should be stated "weed problems may change under conservation tillage systems." The continued development of effective herbicides has made conservtion tillage systems possible and practical. Weed control systems are available now to provide consistent weed control in conservation tillage systems. Many of the tools are the same as we use with conventional tillage systems; however, they may be used differently and a higher level of management may be needed to adapt systems if weed problems change.

ADVANCES IN SMALL GRAIN WEED CONTROL: POSTEMERGENCE WILD OAT HERBICIDES

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Wild oats growing in hard red spring wheat, durum wheat, or barley may be controlled postemergence with Carbyne, Hoelon, or Avenge. Carbyne should be applied when the majority of wild oats are in the 1 1/2 to 2 leaf stage, which generally occurs 9 days after wild oat emergence (in the Red River Valley of Minnesota). Crop competition is important for wild oat control with Carbyne, so control may not be satisfactory in thin crop stands. Carbyne is different from most herbicides in that phytotoxicity is greater at lower temperatures. Therefore, to reduce the possibility of Carbyne injury to wheat or barley, Carbyne should be applied when the daytime temperature will exceed 60 F for several hours during each of the first three days following application. Research at North Dakota State University has shown that Carbyne activity on wild oats may be increased by 10 to 20% by mixing one gallon per acre of aqueous nitrogen with the Carbyne spray solution. Carbyne is also labeled for tank-mixing with bromoxynil (Buctril or ME4 Brominal) or Glean to provide broadleaf weed control, or with Hoelon or Avenge to enhance control of wild oats in the 1 to 4 leaf stage. Low rates of Hoelon in combination with Carbyne may result in reduced foxtail control, however. Carbyne + Avenge tank mixes should be applied only to wheat varieties listed on the Avenge label since some wheat varieties are susceptible to Avenge injury. The economics of Carbyne + Hoelon or Carbyne + Avenge tank mixes should be carefully considered before application.

Hoelon will control wild oats and foxtail in the 1 to 4 leaf stage. Wild oats in the 3 to 4 leaf stage, or under moisture stress at the time of application will require higher rates for control than 1 to 3 leaf wild oats. Wild oat control with Hoelon is usually better when cool rather than warm temperatures follow application. In spring wheat, addition of crop oil at 1 pint to 1 quart/A to the Hoelon spray solution may improve the consistency of wild oat control, especially under moisture stress conditions. Hoelon should <u>not</u> be applied with oil additives in barley, as crop injury may result. Hoelon may be tank-mixed with bromoxynil for the control of broadleaf weeds in addition to wild oat and foxtail; oil additives should not be used with this tank-mix. Hoelon should not be tank-mixed with any herbicide other than bromoxynil.

Avenge controls wild oats in the 3 to 5 leaf stage of growth. Large wild oats (4 to 5 leaf) are more susceptible than smaller wild oats (3 leaf). Some wheat varieties are susceptible to Avenge injury, and Avenge is cleared for use only on 'Butte', 'Era', 'Kitt', 'Olaf', 'Solar', 'Walera', 'Coteau', 'Pro-Brand 711', 'Pro-Brand 715', 'Marshall', 'Wheaton', 'Oslo', 'Pioneer 369', 'Pondera', 'Marberg', 'Fortuna', and 'Stoa' hard red spring wheat varieties. All durum varieties except 'Vic', 'Edmore', 'Lakota', and 'Wascana' may be treated with Avenge. There are no restrictions on barley varieties that may be treated with Avenge. Avenge is labeled for tank-mixing with several broadleaf herbicides including MCPA ester or amine, 2,4-D ester or amine, bromoxynil, bromoxynil + MCPA, and Glean.

Assert (AC222,293) is an experimental herbicide being developed by American Cyanamid for control of wild oats in the 1 to 4 leaf stage in wheat, barley and sunflower. Assert also controls wild mustard and suppresses wild buckwheat, field pennycress, and kochia. Use rates will probably range from 0.38 to 0.50 lb/A, with the higher rate used on larger wild oats. Research conducted at the University of Minnesota and at North Dakota State University has shown that certain herbicides may be antagonistic with Assert when tank-mixed. Reduced wild oat control has sometimes been observed when low rates of Assert were tank-mixed with amine formulations of 2,4-D or MCPA, bromoxynil, dicamba, picloram or propanil. It appears that antagonism may be overcome by increasing the rate of Assert applied. Assert may be tank-mixed with ester formulations of 2,4-D or MCPA without reducing wild oat control. Assert may be available on a limited use basis under an Experimental Use Permit (EUP) in 1985.

WEED ALERT--A NEW SMARTWEED IDENTIFIED IN MINNESOTA

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In the spring of 1984, we were asked to identify seedlings of an annual weed that was heavily infesting a soybean field near Mapleton in Blue Earth County, Minnesota.

Seedlings from the infested field were transplanted to a pot and grown to maturity in the greenhouse. The weed was obviously a smartweed. As it grew, it developed small prickles on the stems. We were unable to identify the weed locally. Pressed plants, sent to various plant taxonomists, were identified as *Polygonum bungeanum* Turcz. and appeared to be the first specimens from North America. The plant occurs in China, Korea, and Japan.

The new smartweed is easily distinguishable from other smartweeds commonly found in Minnesota because of the small prickles on the stems. We are proposing to use 'prickly smartweed' as the common name for this species.

We do not know how or when this weed came to Minnesota. Conversations with growers suggest that it has been here for some time, perhaps for 25 years or more.

In preliminary surveys in the fall of 1984, prickly smartweed was found in more than 40 fields in the Minnesota counties of: Blue Earth, Brown, Faribault, Martin, Waseca, and Yellow Medicine. Infestations ranged from only a few plants per field to those in which it was the dominant weed throughout the entire field. Prickly smartweed appears to be most prevalent near Mapleton (Blue Earth Co.) and Frost (Faribault Co.).

The seriousness of this new species as a weed is not yet clear. It would appear that it would be at least as serious as the annual smartweeds already known as weeds in Minnesota.

ADVANCES IN CORN WEED CONTROL

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A copy of "Weed Control in Corn," AG-FO-0892, 1984 revision, is included in this "Proceedings." The 1985 revision of the corn weed control folder was not completed in time to meet the publication deadline for the Soils, Fertilizer and Agricultural Pesticides Short Course Proceedings. However, changes in the 1985 revision will be minor. Table 1, "Effectiveness of herbicides on weeds in corn," in the 1985 revision will not include any additional weed species. Several new effectiveness ratings have been added and several slight modifications in the old effectiveness ratings have been made. In the 1985 revision, Table 2, "Suggestions for chemical control in weeds," has been substantially reorganized to more clearly indicate tank mixes that can be used. Brief comments on advantages or use limitations of the various tank mixes are included. As of this date there are no EPA clearances of new herbicides for inclusion in the 1985 revision.

Applications of dicamba to corn early postemergence has several advantages over 0.5 lb/A preemergence applications or postemergence applications at the lower, 0.25 lb/A, recommended rate. Early postemergence applications can be used on lighter soils where preemerge applications are restricted because of the probability of corn injury. Further, early postemergence dicamba applications at 0.5 lb/A result in better residual control of later germinating broadleafs than is provided by postemergence applications of 0.25 lb/A when the corn is larger. Also, early postemergence applications avoid, to a great extent, the possibility of vapor drift injury to nearby sensitive crops that may occur when dicamba is applied to larger corn later in the season when temperatures are higher. To determine the safety of the 0.5 lb/A early postemergence dicamba applications on corn, a series of experiments were conducted in 1984 at five locations in Minnesota. In these experiments the 0.5 lb/A rate of dicamba in early postemergence applications to corn from the spike stage of growth to 5 inches tall caused no apparent corn injury in experiments at the five locations. At twice the recommended rate of dicamba, 1.0 lb/A, corn injury in the form of severe malformation and stunting occurred on some, less than 5 percent, of the corn plants. From the results it seems probable that early post-emergence applications of dicamba at 0.5 lb/A are safe to use on corn. However, it should be recognized that it is impossible for us to evaluate the dicamba tolerance of all of the hundreds of corn hybrids that are commercially available. Some may be more sensitive to dicamba than those included in our tests.

Research efforts were continued in 1984 to determine the effectiveness of atrazine or cyanazine treatments for postemergence control of foxtail species. Treatments were more effective on small grasses as has been reported previously. Split applications up to 10 days apart were usually more effective than the equivalent amount of these herbicides applied in a single treatment at the time of the first application. The addition of tridiphane (Tandem), or pendimethalin (Prowl) to postemergence atrazine or cyanazine treatments improved foxtail control. The combination of cyanazine with pendimethalin or tridiphane plus crop oil concentrate gave the best control of larger grasses but also caused more corn injury. Sequential drop nozzle applications of atrazine or cyanazine with tridiphane or pendimethalin and crop oil concentrate gave partial control of 6- to 10-inch grasses. At present, there are no label clearances for the use of cyanazine on corn beyond the 4-leaf stage or for the use of atrazine on grasses more than 1½ inches tall. However, based on this research, expansion of label uses of atrazine and cyanazine to allow later treatments on larger grasses are under consideration. Also, tridiphane (Tandem) combinations with atrazine and cyanazine (Bladex) have been submitted for EPA clearance. It is doubtful that the appropriate clearances will be received for 1985 but are likely for 1986. Pendimethalin (Prowl) is cleared for use in tank mixes with atrazine or cyanazine but usage is limited to very small corn and weeds.

The herbicide alachlor (Lasso) is now undergoing a Special Review by the U.S. Environmental Protection Agency (EPA) because tests show that tumors are caused when high levels of alachlor are fed daily to laboratory animals over long periods of time. In this Special Review, EPA is re-examining all health and safety tests and product benefits from alachlor usage. Recommendations from EPA on future uses of alachlor will be developed based on their estimates of these risks and benefits. As of November, 1984, it seems probable that alachlor will continue to be available in 1985 for use by Minnesota farmers.

AG-FO-0892 — REVISED FOR 1984

AGRICULTURAL EXTENSION SERVICE
UNIVERSITY OF MINNESOTA

Weed Control in Corn

Richard Behrens and Gerald R. Miller, Extension Agronomists

Weed control in corn should be based on an optimum combination of cultural, mechanical, and chemical practices. The ideal combination for each field will depend on several factors including crop being grown, kinds of weeds, severity of the weed infestation, soil characteristics, tillage practices, cropping systems, and availability of time and labor.

Cultural Practices

Cultural practices for weed control in corn include seedbed preparation, establishing an optimum stand, adequate fertility, and timely cultivations. Weeds that germinate before planting can be destroyed with tillage operations or herbicides. Killing weeds just before planting gives the young crop seedlings a competitive advantage and often improves performance of preplanting or preemergence herbicides.

Early cultivations are most effective for killing weeds and for preventing crop yield reduction due to weed competition or corn root damage. The rotary hoe or harrow works best if used after weed seeds have germinated and are in the "white stage" or just emerging. A rotary hoe, harrow, or cultivator should be used as soon as weeds appear, even if preplanting or preemergence herbicides have been applied, unless a properly timed postemergence herbicide treatment is planned.

Set cultivators for shallow operation to avoid pruning the corn roots and to reduce the number of weed seeds brought to the surface. Throw enough soil into the row to cover small weeds, but avoid excessive ridging that may encourage erosion or interfere with harvesting. Shallow cultivation should be repeated as necessary to control newly germinated weeds.

Herbicides

When selecting an appropriate herbicide or combination of herbicide treatments, consider carefully the following factors:

—Label approval for use
—Use of the crop
—Corn tolerance to the herbicide
—Potential for chemical residues that may affect later crops
—Kinds of weeds
—Soil texture
—Soil pH
—Amount of organic matter in the soil
—Climate

Table 1. Effectiveness of herbicides on weeds in corn[1]

	Preplanting							Preemergence								Postemergence								
	Alachlor (Lasso)	Metolachlor (Dual)	Atrazine + metolachlor (Bicep)	Butylate (Sutan +)	EPTC (Eradicane, Eradicane Extra)	Cyanazine (Bladex)	Atrazine (AAtrax, others)	Alachlor (Lasso)	Atrazine (AAtrex, others)	Atrazine + metolachlor (Bicep)	Dicamba (Banvel)	Metolachlor (Dual)	Propachlor (Ramrod)	Linuron (Lorox)	Cyanazine (Bladex)	2, 4-D	Dicamba (Banvel)	Atrazine and oil	Cyanazine (Bladex)	Bentazon (Basagran)	Bromoxynil (Buctril, Brominal)	Bentazon + atrazine (Laddok)	Pendimethalin (Prowl) + atrazine	Pendimethalin (Prowl) + cyanazine (Bladex 80W)
Corn tolerance —	G	G	G	G	G	F	G	G	G	G	F	G	G	F	F	F	G	G	F	G	G	G	F/G	F
Grasses —																								
Giant & robust foxtail	G	G	G	G	G	F	F	G	F	G	P	G	G	F	F	N	N	F	F	N	N	F	G	G
Green foxtail	G	G	G	G	G	G	G	G	G	G	P	G	G	F	G	N	N	G	G	N	N	F	G	G
Yellow foxtail	G	G	G	G	G	G	G	G	G	G	P	G	G	F	G	N	N	G	G	N	N	F	G	G
Barnyardgrass	G	G	G	G	G	F	F	G	F	G	P	G	F	F	F	N	N	F	F	N	N	F	G	G
Crabgrass	G	G	G	G	G	F	P	G	P	G	P	G	G	F	F	N	N	P	F	N	N	P	F/G	G
Panicum	G	G	G	G	G	F	P	G	P	G	P	G	F	F	F	N	N	P	F	N	N	P	F/G	G
Nutsedge	G	G	G	G	G	P	P	F	P	F	N	F	F	P	P	N	N	F	P	G	N	G	P	P
Sandbur	F	F	F	G	G	F	F	F	F	G	P	F	P	—	F	P	P	P	—	P	N	P	F	G
Quackgrass	N	N	P	N	F	P	G	N	G	P	N	N	N	N	P	N	N	G	P	N	N	P	P	P
Woolly cupgrass	G	G	G	F	G	P	P	G	P	G	P	G	F	P	P	N	N	F	F	N	N	P	F	F/G
Wild proso millet	F	F	F	F	F/G	P/F	P	F	P	F	P	F	F	P	P/F	N	N	P	P/F	N	N	P	F	F/G
Wild oat	P	P	G	F	F	F	G	P	G	G	N	P	P	P	F	N	N	G	F	N	N	G	G	G
Broadleafs —																								
Buffalo bur	P	P	P	F	G	P	P	P	P	P	P	P	P	P	P	P	P	G	F	P	—	G	G	F
Cocklebur	N	N	F	P	P	F	F	N	F	F	F	N	P	F	F	G	G	G	F	G	G	G	G	F
Kochia	P	P	G	P	F	G	G	P	G	G	F	P	P	F	G	F	G	G	G	—	G	G	G	G
Lambsquarters	F/P	F/P	G	P	F/G	G	G	F/P	G	G	G	F/P	P	G	G	G	G	G	G	F	G	G	G	G
Mustard	P	P	G	P	P	G	G	P	G	G	G	P	P	G	G	G	F	G	G	G	G	G	G	G
Eastern black nightshade	F	F	G	F	F	G	G	G	G	G	F	G	P	P	G	F	F	G	G	P	—	G	G	G
Pigweed	G	G	G	F	F	F	G	G	G	G	G	G	F	G	F	G	G	G	F	P	G	G	G	F
Ragweed	P	P	G	P	F	G	G	P	G	G	G	P	P	G	G	G	G	G	G	G		G	G	G
Smartweed	P	P	G	P	P	G	G	P	G	G	G	P	P	G	G	P	G	G	G	G	G	G	G	G
Velvetleaf	P	P	F	F	F	F	F	P	F	F	F	P	P	F	F	G	G	F	F	G	G	G	G	G
Wild sunflower	P	P	F	P	P	F	F	P	F	F	F	P	P	F	F	F	G	G	F	G	G	G	G	G
Canada thistle	N	N	P	N	N	P	P	N	P	P	N	N	N	N	P	F	G	F	P	F	N	F	P	P
Jerusalem artichoke	N	N	P	N	N	P	P	N	P	P	P	N	N	P	P	G	G	P	P	P	N	P	P	P
American germander	N	N	P	P	F	P	P	N	P	P	P	N	N	P	P	P	P	G	F	P	N	F	F	F

[1] G = Good, F = Fair, P = Poor, N = None

—Weather
—Formulation of the chemical
—Application equipment available
—Potential for drift problems

There are a number of herbicides available for use in corn. In setting up a weed control program for several years, it may be advisable to rotate a selection of herbicides from different chemical families, particularly in continuous corn.

Chemical rotations reduce the likelihood of a buildup of resistant weeds or of herbicide residues in the soil. Even if corn is being rotated to other crops, a chemical rotation can be planned for several years in the cropping system. Commonly used herbicides for corn in different chemical families are:

Acetamides—alachlor, metolachlor, propachlor
Benzoic acids—dicamba
Dinitroaniline—pendimethalin
Other—bentazon
Phenoxys—2,4-D
Substituted ureas—linuron
Thiocarbamates—butylate, EPTC
Triazines—ametryne, atrazine, cyanazine, simazine

This folder summarizes herbicide suggestions for corn, based on numerous experiment station and U.S. Department of Agriculture tests to determine their overall effectiveness. Herbicide labels should be followed.

Table 1 indicates corn tolerance to herbicides suggested for use in corn and relative effectiveness and reliability of these herbicides in controlling common weeds. This table shows general comparative control ratings based on field observations. Under unfavorable conditions, any of the herbicides may give unsatisfactory results. Under favorable conditions control may be better than indicated.

Preplanting Applications

Some herbicides may be applied to the soil before planting and incorporated 2 to 3 inches into the soil with a disk, field cultivator, or similar implement. The disk or field cultivator should be set to operate twice as deeply as the desired depth of incorporation. Use sweep shovels on the field cultivator to get more uniform mixing of the chemical and soil.

The field should be disked or cultivated twice, crosswise and lengthwise, after applying the chemical. If the soil is not too moist or rough and is in a good tilth condition, adequate incorporation may be achieved with one pass over the field with some combination implements. To avoid excessive loss of volatile chemicals like EPTC or butylate, the first tillage operation should follow immediately behind the sprayer.

Butylate (Sutan +) or EPTC (Eradicane, Eradicane Extra) applied preplanting and incorporated at 3 to 6 pounds per acre has given good control of annual grasses and fair control of a few annual broadleafs, but these chemicals do not control several annual broadleafs or most perennial weeds. Both chemicals are effective against nutsedge. EPTC may be used to control quackgrass, but trial results have been inconsistent. Butylate and EPTC are formulated with an antidote chemical to prevent corn injury. With repeated annual use, the weed control performance of EPTC may decline due to more rapid breakdown of EPTC in the soil.

Preplanting and disked-in applications of atrazine have resulted in weed control equal to or, under dry conditions, better than preemergence applications without incorporation. Broadcast applications, necessary when preplanting treatments are used, may increase the potential of atrazine carryover, compared to banded preemergence applications.

Mixtures of butylate or EPTC (Eradicane) and atrazine or cyanazine (Bladex) applied preplanting and incorporated have controlled both annual grasses and broadleafs. These mixtures improve broadleaf control compared to butylate or EPTC alone. Cyanazine does not carry over to the following year, and the lower rate of atrazine used in the mixtures reduces carryover problems from atrazine compared to those caused by the higher rates used when atrazine is applied alone. Cyanazine with butylate is not recommended for use on coarse-textured soils with less than 1 percent organic matter because of potential corn injury.

Preplanting, incorporated applications of alachlor (Lasso) at 3 to 4 pounds per acre or metolachlor (Dual) at 2 to 3 pounds per acre have controlled nutsedge effectively. Under dry conditions, control of annual weeds usually has been improved over preemergence applications by shallow preplanting incorporation of alachlor or metolachlor. Atrazine or cyanazine may be tank mixed with alachlor or metolachlor to improve broadleaf control.

Preemergence Applications

Atrazine at 1 to 3 pounds per acre has given good control of annual weeds with no injury to corn. A 3-pound-per-acre rate of atrazine should be used on fine-textured soils or those high in organic matter. One to 2 pounds per acre of atrazine is adequate on sandy soils that are low in organic matter.

Atrazine sometimes affects small grains, flax, sugarbeets, sunflowers, soybeans, other legumes, vegetables, and other sensitive crops planted the following spring. The label recommends that small grains, flax, sugarbeets, vegetables, and small-seeded legumes or grasses not be planted in the year following atrazine application.

Soybeans may be injured the year following atrazine use if the rate of atrazine application was more than 2 pounds per acre of active ingredient in western Minnesota or 3 pounds in eastern Minnesota, or if application was made after June 10. However, in some years, soybean injury has occurred following use within these restrictions, especially on highly alkaline soils of western Minnesota.

Residue can be minimized by using the lowest rate of chemical consistent with good weed control, using band rather than broadcast applications, and plowing or thoroughly tilling the soil before planting soybeans. Atrazine residues are more likely to persist if soil moisture or temperatures are low.

Cyanazine (Bladex), chemically similar to atrazine, has given good control of annual grasses and most broadleafs when applied preemergence. There has been no soil residue the following season except from granules following dry years. Weed control is not as good under dry conditions as under moderate to heavy rainfall. Within the suggested rates of 1.25 to 4.75 pounds per acre, the higher rates are required on soils higher in organic matter and finer-textured soils. Corn injury may occur on sandy soils. Granular formulations of cyanazine have been less effective than sprays under limited rain conditions.

Propachlor (Ramrod) has given good annual grass control when applied preemergence at 4 to 6 pounds per acre. Propachlor does not consistently control most broad-leaved or perennial weeds, but it may be used in mixtures with atrazine or linuron for annual grass and broadleaf control. Corn is very tolerant to propachlor.

Alachlor (Lasso) and metolachlor (Dual) control annual grasses in corn. Both chemicals also have given good control of redroot pigweed, but control of other broadleafs has been erratic. Preemergence applications have controlled nutsedge on coarse soils that are low in organic matter, but on finer-textured, dark soils, preplanting incorporated applications have controlled nutsedge better than preemergence treatments. Corn has good tolerance to alachlor and metolachlor. Suggested rates for alachlor are 2¼ to 4 pounds per acre in the liquid formulation and 2.4 to 3.9 pounds per acre in the granular formulation (Lasso II). Metolachlor is labeled for preemergence application at 1.5 to 3 pounds per acre in the liquid and granular formulations. Corn, soybeans, sorghum, root crops, potatoes, pod crops, buckwheat, or small grains may be grown the year after using metolachlor; other crops should not be planted for 18 months after application of metolachlor. Any crop may be grown the year following alachlor use.

Pendimethalin (Prowl) may be used alone at ¾ to 2 pounds per acre or in mixtures at ¾ to 1½ pounds per acre for preemergence control of most annual grassy weeds and some broadleafs such as common lambsquarters, pigweed, smartweed, and velvetleaf in corn. In Minnesota trials, preemergence applications of this compound have been somewhat less effective on grasses but more effective on broadleafs than alachlor. Tank mixes with atrazine, cyanazine, or dicamba provide a broader spectrum of weed control.

Corn root injury and lodging have sometimes occurred from preemergence applications of pendimethalin. Corn injury may occur on sandy soils. With dicamba, do not use it on sandy soils or on loams, silts, and silt loams with less than 3 percent organic matter. Incorporating pendimethalin or ridging soil along the row when cultivating may increase corn injury.

Preemergence Herbicide Mixtures

Mixtures of atrazine with alachlor, linuron, metolachlor, pendimethalin, or propachlor are registered for preemergence application on corn to control annual grasses and broadleafs. Soil residues of atrazine are reduced by using these mixtures since application rates are lower than if atrazine is used alone. These mixtures are less effective than atrazine alone on quackgrass. Do not apply the mixture with linuron after corn is up, or severe corn injury may occur.

A 1:1 ratio of active ingredients of an atrazine-linuron mixture has given weed control comparable to an equivalent rate of atrazine alone on soils low in organic matter. Using linuron in combination with atrazine reduces the likelihood of corn injury and usually improves weed control, compared to using linuron alone. Rates vary from ½ to 1½ pounds per acre of each chemical according to soil type. Corn tolerance to this mixture is not as great as to atrazine alone. Corn injury may occur on coarse-textured soils that have low organic matter content.

The mixtures of atrazine or cyanazine with alachlor, metolachlor, or propachlor control broad-leaved weeds better than alachlor, metolachlor, or propachlor alone and give more consistent control on high organic matter soils or with limited rain than atrazine or cyanazine alone. Corn has good tolerance to these mixtures.

Using mixtures of linuron and propachlor or alachlor reduces the potential for corn injury compared to using linuron alone since lower rates of linuron are used. These mixtures control broadleafs better than propachlor or alachlor alone. Suggested rates are 1 to 1½ pounds per acre of linuron, with 3 pounds per acre of propachlor or 1 to 3 pounds per acre of alachlor. Do not use these mixtures on sandy soils because of possible crop injury from linuron.

A preemergence mixture of alachlor or metolachlor with dicamba (Banvel) improves broadleaf control compared to alachlor or metolachlor alone and improves grass control and reduces corn injury compared to dicamba alone. Dicamba

Table 2. Suggestions for chemical control of weeds in corn

Method of application Chemical-common name (Trade name[1])	Rate—lb/A of active ingredient or acid equivalent broadcast[2]	EPA registration limitations on crop use	Remarks[3]
PREPLANTING INCORPORATED			
Alachlor (Lasso)	2 to 4	None	Preplanting application of alachlor or metolachlor at the high rates is suggested if nutsedge is a problem, but for annual grasses only, shallow incorporation or preemergence application is preferred. Incorporate butylate or EPTC immediately after application. Do not use butylate or EPTC on corn
(Lasso II)	2.4 to 3.9		
Atrazine (AAtrex, others)	2 to 3	Do not graze or feed forage for 21 days after treatment.	
Butylate (Sutan+)	4 to 6	None	
Cyanazine (Bladex)	2 to 4	None	
EPTC (Eradicane or Eradicane Extra)	3 to 6	None	
Metolachlor (Dual) (Dual 25G)	1½ to 3	None	
Atrazine + alachlor	1 to 2 + 1½ to 2½	Do not graze or feed forage for 21 days after treatment.	
Atrazine + butylate (Sutazine or tank mix)	1 to 1½ + 3 to 4	Do not graze or feed forage for 21 days after treatment.	
Atrazine + EPTC	1 to 1½ + 3 to 4	Do not graze or feed forage for 21 days after treatment.	
Atrazine + metolachlor (Bicep or tank mix)	1 to 3 + 1¼ to 3	Do not graze or feed forage for 21 days after treatment.	
Cyanazine + alachlor	1 to 2.2 + 2 to 2½	None	
Cyanazine (Bladex) + butylate	1½ to 2 + 3 to 4	None	
Cyanazine + EPTC	1½ to 2 + 3 to 4	None	
Cyanazine + metolachlor	0.8 to 2½ + 1¼ to 2½	None	
PREEMERGENCE			
Alachlor (Lasso)	2 to 3½	None	Atrazine may carry over and affect crops the next year. Other chemicals do not carry over. Because of potential crop injury, do not use preemergence applications of cyanazine, dicamba, or linuron on sandy soils. Linuron is suggested for use only on soils between 1 and 4 percent in organic matter. Use dicamba only on medium- and fine-textured soils with more than 3% organic matter. Propachlor does not persist long enough in sandy soils to give satisfactory weed control.
(Lasso II)	2.4 to 3.9		
Atrazine (AAtrex, others)	1 to 3	Do not graze or feed forage for 21 days after treatment.	
Cyanazine (Bladex)	2 to 4	None	
Metolachlor (Dual)	1½ to 3	None	
Propachlor (Ramrod)	4 to 6	None	
Atrazine + alachlor	1 to 2 + 1½ to 2½	Do not graze or feed forage for 21 days after treatment.	
Atrazine + metolachlor (Bicep or tank mix)	1 to 3 + 1¼ to 3	Do not graze or feed forage for 21 days after treatment.	
Atrazine + propachlor	1 to 1½ + 2 to 3-3/4	Do not graze or feed forage for 21 days after treatment.	
Cyanazine + alachlor	1 to 2.2 + 2 to 2½	None	
Cyanazine + metolachlor	0.8 to 2½ + 1¼ to 2½	None	
Cyanazine + propachlor	1 to 1.8 + 2½ to 6	None	
Dicamba (Banvel) + alachlor	½ + 2 to 2½	Do not graze or feed silage prior to milk stage.	
Dicamba + metolachlor	½ + 2 to 2½	Do not graze or feed silage prior to milk stage.	
Linuron (Lorox) + alachlor	½ to 1½ + 1 to 3	Do not graze or harvest immature corn for feed within 12 weeks after treatment.	
Linuron + propachlor	1 to 1½ + 2 to 3	None	
POSTEMERGENCE			
Atrazine (AAtrex, others) + oil	1.2 to 2	Do not graze or feed for forage for 21 days after treatment.	Apply atrazine when weeds are less than 1½ inches tall.
Bentazon (Basagran)	3/4 to 1	None	Apply bentazon when weeds are 2 to 6 inches. Earlier application is more effective on most weeds.
Bentazon + atrazine (Laddok) + oil concentrate	½ to 3/4 + ½ to 3/4 + 1 qt/A	Do not graze or feed for forage 21 days after application.	Controls only broadleafs. Apply when weeds are less than 2 to 4 inches and corn has 1 to 5 leaves.
Bromoxynil (Brominal, Buctril)	¼ to ½	None	Apply before weeds are 6 inches and corn 14 inches tall.
Cyanazine (Bladex 80W)	2	None	Apply cyanazine when weeds are less than 1½ inches tall and before corn has more than 4 leaves. Use vegetable oil or surfactant under acid conditions only. See label.
Pendimethalin (Prowl) + atrazine	3/4 to 1½ + 1 to 1½	None	Apply spike to 2-leaf stage of corn and up to 1-inch weeds.
Pendimethalin + cyanazine 80W	3/4 to 1½ + 1 to 2	None	
Dicamba (Banvel)	¼	Do not graze or harvest for feed before milk stage.	Apply dicamba before corn is 2 feet tall and not within 15 days of tasseling. Follow drift control precautions on label.
Dicamba + 2,4-D amine	¼ + ¼	Do not graze or harvest for feed before milk stage.	
2,4-D amine	¼ to ½	Do not forage or feed fodder for 7 days following 2,4-D application.	Apply 2,4-D at these rates when corn is 4 inches to 3 feet tall. Use drop nozzles after corn is 8 inches tall. Earlier applications on small weeds are more effective.
2,4-D ester	1/6 to 1/3	Do not forage or feed fodder for 7 days following 2,4-D application.	
2,4-D amine	½ to 1	Do not forage or feed fodder for 7 days following 2,4-D application.	Apply 2,4-D at these rates only after corn is 3 feet tall. Use drop nozzles so only base of stalk is sprayed. Do not apply between tasseling and dough stage of corn.
2,4-D ester	1/3 to 2/3	Do not forage or feed fodder for 7 days following 2,4-D application.	

[1] See table on herbicide names. Trade names are used to identify the herbicide discussed. Omission of other trade names of similar herbicides is unintentional. The inclusion of a trade name does not imply endorsement and exclusion does not imply nonapproval.

[2] These rates will need to be properly interpreted for the formulation you use and for band width and row width if the chemicals are not applied broadcast. See AG-FS-0917, *How to Calculate Herbicide Rates and Calibrate Herbicide Applicators*. The proper rate depends on such things as soil characteristics, kinds of weeds, size of weeds and crop, temperature, and moisture conditions.

[3] Read labels for detailed use instructions and restrictions on crop use.

should be applied preemergence only on medium- or fine-textured soils with more than 2.5 percent organic matter. Do not incorporate this mixture prior to corn emergence. Harrowing or dragging before corn emerges may increase corn injury.

Early Postemergence Sprays

Postemergence sprays of atrazine effectively control most annual weeds in corn. Broad-leaved weed control is especially good. Grass control is less consistent. It is important to apply early postemergence treatments at the proper time or results may be poor. Apply atrazine while the weeds are less than 1½ inches tall. Application may be made until corn is 30 inches tall. Drop nozzles should be used to keep the spray out of the tops of the corn and to give better spray coverage on the weeds.

Adding 1 gallon per acre of special oils with an emulsifier or ¼ to ½ gallon per acre of special adjuvant-oil emulsions to the spray increases the effectiveness of early postemergence applications of atrazine. Labeled emulsions of either vegetable or petroleum oils are satisfactory.

Various formulations of surfactants and detergents used with atrazine have not improved weed control as much as using oils. Suggested atrazine rates for postemergence application with oil are 1.2 pounds per acre for broadleafs and 2 pounds per acre for annual grasses.

When atrazine is used, early postemergence treatments are preferred to preemergence if the soil is high in clay or organic matter and in western Minnesota, where rainfall is less certain. These are the areas where preemergence applications of atrazine have given less satisfactory weed control.

Severe corn injury has resulted from adding 2,4-D to this mixture. Corn injury has occurred also when atrazine and oil were applied to corn growing under cold, wet conditions, or if frost occurred shortly before or after application.

Cyanazine (Bladex 80W) is effective on annual grasses and broadleafs as an early postemergence herbicide. It is cleared for use through the 4-leaf stage of corn and before weeds are more than 1½ inches tall. Pigweed and lambsquarters have shown some tolerance. Oils or surfactants added to the spray increase the potential for corn injury and have resulted in severe corn injury and stand reduction under conditions of heavy rains or dews, cool temperatures, and cloudiness.

Under dry conditions, vegetable oils or certain surfactants may be used to improve weed control. Use only the wettable powder or dry flowable formulations for postemergence application. Do not use on sands with less than 1 percent organic matter.

Bentazon (Basagran) may be applied alone or in a mixture with atrazine as a postemergence treatment in corn to control certain annual broad-leaved weeds, Canada thistle, and nutsedge. Corn has good tolerance to bentazon, but do not apply it when corn is stressed from adverse growing conditions. Apply when annual weeds are less than 2 inches tall, but some species may be controlled up to 10 inches tall. Rain within 24 hours after application will reduce the effectiveness of bentazon. Do not mix bentazon with fertilizers. A non-phytotoxic oil concentrate or crop oil may be mixed with bentazon or with a combination of bentazon and atrazine for applications in corn to improve weed control.

Alachlor (Lasso) may be applied postemergence in a mixture with dicamba (Banvel) to corn less than 3 inches tall. Alachlor or metolachlor (Dual) may be applied with atrazine on corn that is no more than 5 inches tall to control weeds in the two-leaf stage or smaller. Weed control may be less consistent than that from preemergence applications. Propachlor (Ramrod) alone or mixed with atrazine may be applied after corn has emerged to control grasses up to the two-leaf stage.

Table 3. Herbicide names and formulations

Common name	Trade name	Concentration and commercial formulation[1]
Alachlor	Lasso Lasso II	4 lb/gal L 15% G
Alachlor + atrazine	Lasso/atrazine	2½ + 1½ lb/gal F
Atrazine	AAtrex, others	80% WP, 4 lb/gal F 90% WDG
Atrazine + metolachlor	Bicep	2 + 2½ lb/gal F
Bentazon	Basagran	4 lb/gal L
Bentazon + atrazine	Laddok	1.66 + 1.66 lb/gal F
Bromoxynil	Brominal, Buctril	2 or 4 lb/gal L
Butylate and protectant	Sutan+	6.7 lb/gal L, 10% G
Butylate + atrazine	Sutan + atrazine, Sutazine	18% + 6% G 4.8 + 1.2 lb/gal L
Cyanazine	Bladex	80% WP, 15% G, 4 lb/gal F, 90% DF
Dicamba	Banvel	2 or 4 lb/gal L
EPTC and protectant	Eradicane	6.7 lb/gal L
EPTC + protectant + extender	Eradicane Extra	6 lb/gal L
Linuron	Lorox	50% WP, 4 lb/gal F
Metolachlor	Dual	8 lb/gal L, 25% G
Pendimethalin	Prowl	4 lb/gal L
Propachlor	Ramrod	65% WP, 20% G, 4 lb/gal F
Propachlor + atrazine	Ramrod and atrazine	48.1 + 20.9% WP
2,4-D	several	various

[1] G = Granular, L = Liquid, WP = Wettable Powder, WDG = Water Dispersible Granule, F = Flowable.

Pendimethalin (Prowl) in mixtures with atrazine or cyanazine wettable powder may be applied after corn emergence, but not later than when corn is in the two-leaf stage and when weeds are no more than 1 inch tall. These mixtures have been effective against annual grasses and broadleafs. The early postemergence application of pendimethalin and cyanazine used following a preplanting application of EPTC has improved the control of wild proso millet and woolly cupgrass.

Bromoxynil (Brominal, Buctril) applied at ¼ pound per acre as an early postemergence spray controls some annual broad-leaved weeds, including annual smartweeds, wild buckwheat, cocklebur, kochia, common lambsquarters, pigweed, common ragweed, Russian thistle, wild sunflower, and wild mustard. Bromoxynil does not control grasses or perennial weeds. To be most effective, bromoxynil must be applied when weeds have 2 to 4 leaves and corn is less than 6 inches tall. Corn leaf burn may occur, especially under conditions of high temperature or high humidity. Follow specific label information.

Postemergence Applications

Annual broad-leaved weeds can be controlled with broadcast postemergence applications of ¼ to ½ pound per acre of 2,4-D amine when the corn is 4 to 8 inches tall. More severe onion leafing may occur from 2,4-D applications made in the 2- to 3-leaf stage of the corn.

The ¼-pound rate has been adequate for susceptible weeds and is less dangerous to corn. The ½-pound rate has been satisfactory for moderately resistant weeds, but corn usually has been injured by this rate. Rainfall within 8 hours after application reduces the effectiveness of 2,4-D amines more than the effectiveness of 2,4-D esters. About 1/3 less acid equivalent of 2,4-D esters is needed than of the 2,4-D amines.

Spray drift from either amines or esters of 2,4-D will injure susceptible plants. Since the ester forms are volatile, vapor injury to nearby susceptible crops is a possibility. Low volatile esters should be used rather than high volatile esters. Using amines eliminates the danger of vapor injury because amines are not very volatile.

To reduce the danger of 2,4-D injury when the corn is more than 8 inches tall, avoid spraying the upper leaves and leaf whorl of corn by using drop nozzles between the rows. However, adequate spray coverage of the tops of the weeds is necessary for maximum weed control. If nozzles are directed toward the row from both sides, the herbicide concentration must be reduced to compensate for the double coverage. Do not use spray additives with 2,4-D as corn injury may be increased.

Some injury may result when corn is sprayed with 2,4-D. Brittleness, followed by bending or breaking of stalks, is the most serious type of injury, and it may result in severe stand losses when applications of 2,4-D are followed by a storm or careless cultivation.

Several factors influence the degree of injury resulting from 2,4-D. Hybrids vary in tolerance to 2,4-D. Corn growing rapidly is more susceptible than corn developing under less favorable growth conditions. When temperatures exceed 85°F. just before or at the time of 2,4-D application, the corn is more likely to be injured.

At the rates of application commonly used, the stage of growth at which treatment is made during the period from emergence to tasseling is less critical than the effects of environmental factors.

If broad-leaved weed control is necessary after the last cultivation, 2,4-D ester at ½ pound per acre or 2,4-D amine at 3/4 to 1 pound per acre may be applied using drop nozzles. Do not apply 2,4-D from tasseling to dough stage, or poor kernel set may occur. 2,4-D can be applied at ½ to 1 pound per acre after the dough stage if necessary, but it is more beneficial to control weeds earlier.

Dicamba (Banvel) as a postemergence spray in corn has given better control of Canada thistle and smartweed than 2,4-D with less effect on the corn. Dicamba also controls other broad-leaved weeds except mustard, but it does not control grasses. But when used, dicamba drift has often affected soybeans in the vicinity of treated cornfields.

Dicamba may be used in corn at ¼ pound per acre, either alone or in mixtures with 2,4-D amine at ¼ to ½ pound per acre. The lower rate of dicamba has given satisfactory weed control with less crop effect than the higher rate. Applications can be made until corn is 2 feet tall or until 15 days before tassel emergence, whichever occurs first. Do not use on corn grown for seed. Later applications, especially when corn is tasseling, may result in poor kernel set. Use drops after corn is 8 inches tall. Do not use additives with dicamba.

Mixtures of dicamba and atrazine or cyanazine are cleared for use on corn as early postemergence treatments. These mixtures have given good broadleaf control, but grass control has been erratic. Oils and other additives should not be used.

Caution: Soybeans and other broad-leaved plants are very sensitive to dicamba. In recent years, there were many instances in which dicamba drift affected soybeans. Users of dicamba must take special precautions to avoid spray drift at the time of application or vapor drift for several days after application. Spray drift can be minimized by reducing sprayer pressure, increasing water volumes with larger nozzles, and using drop nozzles to keep the spray release as low as possible and still give weed coverage. Drift potential is greater with windy or high temperature conditions.

Applications are not recommended at temperatures above 85°F. Spray and vapor drift effects on soybeans can be reduced by spraying corn early in the season when temperatures are lower and before soybeans have emerged, or when they are small. Do not graze or harvest for dairy feed prior to the milk stage of the grain if corn is treated with dicamba.

Directed Sprays

These cannot be used on small corn. Therefore, early season weed growth must be controlled by some other means (rotary hoe, harrowing, herbicides, or cultivation) to prevent yield losses from early weed competition. Directed sprays are considered emergency measures to control heavy weed stands within corn rows.

Specially designed equipment has been developed to make directed spray applications in corn. When applying directed sprays, the nozzles should be mounted so that wheels, skids, cultivator shanks, or similar devices control the nozzle height. To minimize spray contact with corn leaves, use attachments to lift the corn leaves and direct the spray to the base of corn plants and onto weeds in the row.

Directed sprays of linuron at 1½ pounds per acre can be applied when the corn is not less than 15 inches tall. Ametryne (Evik) is cleared for use as a directed spray at 1.6 to 2 pounds per acre after corn is 12 inches tall. Do not apply ametryne later than 3 weeks prior to tasseling. Ametryne should not be used on sandy soils. Adding a wetting agent is necessary for effective weed control with linuron or ametryne.

Care must be taken in application to minimize spray on the corn leaves while covering most of the weed foliage with the spray. Either chemical will kill the corn leaf tissue it contacts and, if leaf kill is extensive, corn yields may be reduced.

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Read the pesticide label and follow the instructions as a final authority on pesticide use.

CORN ROOTWORM INSECTICIDE PERFORMANCE IN 1984

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INTRODUCTION

The combined strategies of crop rotation and soil insecticide use in continuous corn usually limit corn rootworm damage effectively. Each year farmers report the poor performance of soil insecticides. During 1984, these reports of poor performance were unusually abundant and involved all soil insecticides. During recent years, the apparent failure of some soil insecticides with continuous use (e.g. carbofuran, isofenphos) has generated concern about the continued performance of all soil insecticides. Are the widespread reports about poor performance in 1984 related to enhanced microbial breakdown? What other factors affect the performance of soil insecticides? What can a farmer do to improve or maintain the performance of soil insecticides?

SOIL INSECTICIDE PERFORMANCE

Poor insecticide performance, per se, does not indicate enhanced microbial breakdown. Rather, various factors affect the performance of soil insecticides against the CRW. Soil insecticides applied at planting need to be present in sufficient amounts and in the right place to provide control of larvae that hatch 30 to 50 days later. Any factors that affect the timing of corn planting and larval hatch, the placement and amount of insecticide applied, or the degredation of the insecticide in the soil can alter the insecticides performance. In the next few paragraphs I'll highlight some of the factors that affect soil insecticide performance.

Proper application

Proper application is the most important factor the farmer has within his control. For optimum performance, each granular applicator should be calibrated to insure the proper rate is applied. Calibration should be repeated each year because wear can increase flow rate. The insecticide should be applied in a 6-8" band as close to the soil surface as soil conditions and equipment will allow. Dropping insecticide from greater heights will allow wind drift to occur. Wind can dramatically alter the application pattern, shifting the band up to 8" from its intended center over the row. Finally, shallow incorporation, ca. 1/2", is necessary for proper movement of some less-soluble insecticides into the root zone.

Rainfall

Rainfall can affect insecticide distribution and persistence. Heavy rains that produce extensive sheet and rill erosion just after planting can dramatically alter the distribution of insecticides. Erosion can be particularly heavy in the press wheel track, depending on row orientation and slope. Percolating rain can leach the more-soluble insecticides further into the soil profile. Finally, moisture can enhance the degradation of insecticides by chemical reaction (hydrolysis) or by promoting the growth of insecticide-degrading soil microflora.

Delayed CRW egg hatch

Soil insecticides applied at planting are constantly degraded in the soil environment. Proper control of CRW larvae depends on a sufficient residual of the insecticide present in the soil when the larvae hatch in late June. Cool soil temperatures that occur through cooler than normal air temperatures, cloudiness, and/or rainfall may retard CRW development and egg hatch. This delay would permit additional insecticide degradation and could result in reduced insecticide performance.

Population pressure

Insecticides rarely kill an entire insect population. The proportion of the population killed varies with the insecticide concentration in the environment. Assume the effectiveness of an CRW insecticide is 90% under normal field conditions, planting dates, and CRW hatching dates. Damage resulting from a CRW population would depend on the size of the egg population in the soil. If 100 eggs occurred in each quart of soil, 10 larvae would be expected to survive. If 10 eggs occurred in each quart, only 1 larvae would survive. In both cases, the insecticide performed equally well yet the damage in the first case would be greater than in the second case. Thus, the size of the egg population in the soil can affect insecticide performance, in terms of crop damage.

Tillage

Preliminary data indicate tillage may affect the resulting level of damage. Data from Iowa and Minnesota suggest that some tillage systems (no-till, chisel plow) suffer greater damage than other tillage systems (conventional, ridge-till). The data are not definitive at this point. Considerable research is underway on this topic and on the effects of residue and incorporation on insecticide performance.

Resistance

At this point there is no evidence to suggest that resistance mechanisms are involved in recent examples of poor performance.

Enhanced biodegradation

Repeated use of some soil-applied insecticides and herbicides can lead to enhanced biodegradation. Some soil microorganisms can adapt to feed on the soil insecticide as a food source. Repeated use of an insecticide can favor the proliferation of these microrganisms. Under these conditions the insecticide concentration in the soil declines more rapidly and insufficient amounts are left at CRW hatch to provide control. Laboratory studies have demonstrated that soils can become agressive degraders of organophosphate and carbamate insecticides in as little as 1 to 2 applications. Field documentation of enhanced biodegradation has been demonstrated for both carbamate and organophosphate insecticides. Cross reactivity between insecticides with the same chamical class has also been demonstrated. These findings suggest that we exercise caution in the use of soil insecticides. Rapid degradation of soil insecticides could become a major problem affecting both carbamate and organophosphate insecticides. The problem of micorbial degradation is a complex one requiring more research. Rapid breakdown of insecticides does not occur in every field with a continuous use pattern. The factors which promote enhanced degradation in some cases but not in others need to be understood.

PERFORMANCE OF SOIL INSECTICIDES IN 1982 TRIALS

The performance of CRW insecticides was evaluated at three locations, Waseca, Lamberton, and Morris. Both Lamberton and Morris experienced excellent pressure from CRW populations, receiving root ratings of 3.40 and 4.00, respectively, in the untreated checks. CRW pressure at Waseca was greatly reduced, as compared to previous years, with the check receiving a root rating of only 1.82 Table 1 presents the results of these trials for labelled compounds and compounds with an experimental use permit (Lance 20G). Please note that Amaze 20G is no longer marketed.

Table 1. Performance of soil insecticides on the corn rootworm in Minnesota during 1984, as measured by root damage ratings (Iowa 1-6 rating scale).

	Average Root Ratings		
Treatment	Morris	Lamberton	Waseca
Lance 20G	1.98 f	1.63 c	1.15 d
Lance 20G *	2.18 ef	1.68 c	1.13 d
Counter 15G	2.68 de	1.80 c	1.13 d
Amaze 20G	2.55 e	2.33 b	1.63ab
Thimet 20G	2.65 de	2.38 b	1.30 cd
Broot 15G	3.18 cd	2.63 b	1.13 d
Dyfonate 20G	3.38 bc	2.85 b	1.25 d
Mocap 15G	4.03a	2.35 b	1.28 d
Furadan 15G	3.73ab	2.68 b	1.53 bc
Lorsban 15G	3.68abc	2.85 b	1.68ab
Untreated Check	4.00a	3.40a	1.81a

*All treatments applied at 1.0 lbs ai/acre with the exception of one Lance treatment at 0.75 lbs ai/acre. All treatments applied as a 7" surface band behind the presswheel, with the exception of Lorsban 15G which was applied ahead of the presswheel. Planting dates: Morris - May 11, Lamberton - May 22, Waseca - May 17. Roots rated: Morris - Aug. 1, Lamberton - Aug. 2, Waseca - July 26.

The poor performance of some compounds may be related to extensive rainfall which leached more soluble compounds deeper into the soil than desired, promoted degradation, and delayed CRW hatch about 7-10 days later than normal.

CONSISTENCY OF CRW INSECTICIDE PERFORMANCE

Corn rootworm insecticides vary in the consistency of their performance. Consistency may be measured in two ways. First, a root rating of 3.00 is considered the threshold of economic damage. Consistency can be measured as the proportion of time the insecticide produces a damage rating less than 3.00. Second, insecticide performance can be judged relative to the best insecticide in each trial. In this case, consistency is measured as the proportion of trials where the insecticide produced a root rating statisitically comparable to the best insecticide. Consistency of CRW insecticide performance during recent years (1977-1984) is presented in Tables 2 and 3 respectively.

Table 2. Corn rootworm insecticide performance in Minnesota, 1977-1984, as measured by root ratings < 3.0.

Compound	# Ratings < 3.0 / # Trials	%
Counter 15G	19/20	95
Thimet 20G	18/19	95
Broot 15G	16/17	94
Amaze 20G	17/19	89
Dyfonate 20G	15/19	79
Furadan 15G	15/20	75
Mocap 15G	13/19	68
Lorsban 15G	10/19	53
Check	4/20	25

Table 3. Corn rootworm insecticide performance in Minnesota, 1977-1984, as measured by statistical equivalence to best insecticide.

Compound	Times equivalent to best compound	%
Counter 15G	14/15 *	93
Thimet 20G	13/14	93
Amaze 20G	14/15	93
Broot 15G	10/12	83
Furadan 15G	9/15	60
Dyfonate 20G	8/14	57
Mocap 15G	7/14	50
Lorsban 15G	4/14	29
Check	2/15	13

* Number of times statistically equivalent to best compound divided by the total number of trials containing the compound. Trials where check root rating did not exceed 3.00 were excluded.

SITUATION FOR 1985

Results of the adult corn rootworm survey conducted by the Minnesota Department of Agriculture - Plant Industry Division are presented in Table 4. Adult beetle numbers declined in the WC, SC, and SE districts. Despite this decline from 1983 levels, the beetle counts in each district exceeded 2.0 beetles per plant. With these population levels the potential clearly exists for economic damage in continuous corn fields. The ratio of northern CRW (*Diabrotica longicornis*) to western CRW (*D. virgifera*) remains the same as last year 91:9.

Table 4. Corn rootworm adult survey (Aug. 6-15) in Minnesota.

District	Fields	Corn plants per acre	CRW beetles/acre 1983	CRW beetles/acre 1984	Percent lodging
WC	35	20,736	70,898	41,324	2.1
C	43	21,927	43,533	42,428	0.8
EC	25	21,917	9,255	42,451	0.0
SW	29	21,321	54,892	54,346	1.6
SC	30	22,878	52,318	46,866	3.1
SE	23	23,211	67,310	51,522	4.0

RECOMMENDATIONS FOR 1985

The best management strategy against CRW injury is crop rotation. For those growers who need to grow continuous corn for livestock or economic reasons, the use of soil insecticides is recommended if no scouting for CRW adults was done during August, 1984. If fields were scouted in 1984 and bettle counts averaged more than 1.0 beetle per plant, treatment with a soil insecticide is recommended. No treatment is necessary if beetle counts averaged less than 1.0 beetle per plant.

The continuous use of any soil insecticide has the potential to encourage enhanced biodegradation and poor performance. We do not know how frequently soil insecticides should be changed or the pattern of use that should be followed. However, the following recommendations seem prudent:

1. Make sure that your equipment is applying insecticides correctly. Check the calibration, application pattern, and incorporation. Do not plant under extremely windy conditions to avoid wind drift.
2. Avoid the continuous use of one soil insecticide. Rotate insecticides, especially if poor performance occurs. A rotation between insecticide classes, carbamates (Broot, Furadan, Lance) and organophosphates (Counter, Dyfonate, Lorsban, Mocap, Thimet) may be advisable.

EUROPEAN CORN BORER SITUATION IN 1984

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INTRODUCTION

European corn borer populations reached record infestation levels in 1983. Statewide, economic losses attributed to the ECB through physiological loss, harvest loss, and chemical application costs exceeded $200 million. Infestation levels for the second generation and resulting harvest losses for 1983 are summarized in Table 1 (Data courtesy of the Minnesota Dept. of Agric. - Plant Industry Division). Based on historical patterns in the fall ECB survey, we projected that statewide infestation levels should decline in 1984. What was the ECB situation in Minnesota during 1984? Did infestation levels decline, as measured by the fall survey?

Table 1. Minnesota European corn borer fall survey results, Sept. 26-30, 1984. Data supplied by Minn. Dept. of Agric. - Plant Industry Division.

District	% Plants infested	# ECB larvae/ 100 plants	% shanks infested	# ears on ground
WC	90	241	44	7.2
C	79	178	40	4.6
EC	78	149	37	1.1
SW	95	295	64	1.5
SC	89	181	57	1.6
SE	92	241	59	1.6
State Average	87	214	50	2.9

THE EUROPEAN CORN BORER IN 1984

Spring surveys by the Minnesota Dept. of Agric. - Plant Industry Division revealed higher-than-normal levels of overwintering larvae, 11.3 larvae per 100 stalks. Despite high overwintering populations, the infestation potential of the population was not realized. Lighttrap captures of emerging adult moths remained within normal levels. Infestation levels were quite variable with treatment levels in some areas of SE, SC and NW Minnesota reaching 65-75% while treatment levels in some areas of SW Minnesota only reached 3-5%. Generally, infestation levels during first generation increased from west to east in southern Minnesota. Earlier planted, taller corn fields were hardest hit by ECB infestations.

The variability in infestation and poor realization of infestation potential seems related to heavy spring rains. These rains presumably reduced adult survival directly. Indirectly, these rains may have reduced larval survival. The extensive rains during May and June interrupted corn planting and retarded corn development. Consequently, this "young" corn possessed higher levels of a resistance factor, called DIMBOA, that disrupts or prevents normal larval feeding. Low larval survivorship was commonly noted by consultants in SW, WC, and SC Minnesota.

Adult flights in northern Minnesota were comparable to last year at Crookston. As in southern Minnesota, the tallest and most advanced corn was more attractive for oviposition. Infestation levels were extremely high in some areas, reaching nearly 100% infestation and up to 8 larvae per plant. Infestation levels were highly variable but reduced from 1983. A partial second flight was observed at Crookston but all corn was sufficiently advanced to be unattractive for oviposition.

The second adult flight in 1984 was greatly reduced throughout WC, SW, and SC Minnesota. Infestation levels were reduced from 1983. The 1984 fall survey results are presented in Table 2. Generally, infestations were more severe in C, SC and SE Minnesota. Infestation levels, larval abundance, shank infestation, and ear droppage in SE Minnesota remained equivalent to 1983 levels. Except for the SE, infestation levels declined throughout Minnesota.

Table 2. Minnesota European corn borer fall survey results, Oct. 8-19, 1984. Data supplied by the Minn. Dept. of Agric. - Plant Industry Division.

District	% plants infested	# ECB larvae/ 100 plants	% shanks infested	# ears on ground
WC	63	84	15	0
C	75	111	20	1
EC	54	38	17	0
SW	36	38	5	<.5
SC	81	156	42	2
SE	93	224	52	2
State Average	67	108	25	1

TO TREAT OR NOT TO TREAT?

Economic thresholds presented in extension literature vary in form, depending on the quantity and quality of research used to derive them. First, if no research or experience exists for a particular pest situation, there are no thresholds. Second, a nominal threshold may be established from the learned opinion of an expert based on limited data. Third, a calculated threshold may be established from the following data:

1. the amount of damage expected from each pest individual,
2. the relationship between crop damage and yield loss,
3. the market value of the crop (yield x price), and
4. the cost of control and its efficacy.

Finally, weather effects on the crop, pest, and the yield-loss relationship can be incorporated into comprehensive economic thresholds.

Currently, most growers are familiar with older nominal thresholds for the ECB. These thresholds recommend treatment for first generation larvae when 50% of the whorls exhibit shotholing. Nominal thresholds are convenient because they remain fixed. However, nominal thresholds do not vary with crop price, yield expectations, or control costs. Consequently, they provide only an approximation of when it is economical to treat. Calculated thresholds are much more desirable, if data are available, because they are sensitive to economic factors. During 1983, new yield-loss data were released in a revised regional publication, entitled "Management of the European corn borer" - NCR publication no. 22, that made calculated thresholds for the ECB possible. These yield-loss values for various corn growth stages are presented in Table 3.

Table 3. Corn yield loss, expressed as percentage loss per borer, caused by European corn borer larvae for various corn growth stages. Adapted from Iowa and Kansas data presented in NCR publication no. 22.

Plant stage	% yield loss per borer per plant
Early whorl	5.5%
Late whorl	4.4
Pre-tassel	6.6
Pollen shedding	4.4
Kernels initiated	3.0

Economic thresholds for the ECB can be calculated from the following formula:

$$ET = \frac{\text{Control Costs}}{(\text{Expected yield x crop price x \% loss/borer x insecticide efficacy})}$$

where expected yield and crop price can be tailored to the specific farm operation, % loss per borer can be obtained from the previous table, and insecticide efficacy can be determined from insecticide trials. For the 1984 growing season, insecticide efficacy was set at 70% for first generation and 50% for second generation, pending generation of data specific to Minnesota.

WHERE'S THE MINNESOTA DATA?

Tailoring calculated economic threshold to Minnesota's ECB situation will require two types of research data, insecticide efficacy and yield loss per borer. This research problem is further complicated by Minnesota's climatic and cropping diversity. Two generations occur in southern Minnesota, which typically infest corn during the whorl stages (first generation) and during pollen shed and kernel initiation (second generation). In contrast, in northern Minnesota, the first generation infests corn during pretassel and tassel stages. To generate realistic economic thresholds, efficacy trials and yield-loss experiments should be conducted in each of these situations. Research during 1984 focused on efficacy trials against the first generation in both southern and northern Minnesota and on the yield-loss relationship in northern Minnesota. Research plans for 1985 include the expansion of yield-loss studies to southern Minnesota for both generations and the expansion of efficacy trials to include the second generation. Within the efficacy trials, data will be generated on the relative performance of individual insecticides and formulations (granules vs liquid sprays), and on the appropriate timing of applications for optimal effectiveness.

INSECTICIDE PERFORMANCE DURING 1984

During 1984, three insecticide trials were established against first generation larvae. The first trial, located at the Southern Experiment Station in Waseca, explored the performance of all labelled granular materials under field conditions. All insecticides were applied with a Gandy airblast applicator mounted on a hi-boy sprayer on July 6. At the time of application, ca. 48% of the plants were infested with 2.85 larvae per infested plant, producing a field average of 1.4 larvae per plant. Corn was at the 13 leaf stage and ECB larvae ranged from first to fourth instar. All granular insecticides performed well, averaging 90.9% and ranging from 83.1% to 97.4% (Table 4).

Table 4. First-generation European corn borer control by granular insecticides. Waseca Co. - Southern Expt. Stn.

Treatment	Rate (lbs ai/A)	Tunnels per 20 plants	% control
Furadan 15G	1.00	0.67 b	97.4
Dipel 10G	1.00	1.00 b	96.1
Lorsban 15G	1.00	2.00 b	92.2
Dyfonate 20G	1.00	2.33 b	90.9
Diazinon 14G	1.00	3.67 b	85.7
Counter 15G	1.00	4.33 b	83.1
Untreated check	----	25.67a	

The second and third trials were located near Crookston at the Northwest Expt. Stn. and near Thief River Falls at the Bob Wald farm, respectively. These trials, involving a matched set of compounds, explored the performance of all labelled and soon-to-be labelled compounds. At both locations treatments were applied by hand on July 23 to corn which was just tasseling. The infestation level at Crookston averaged 73% with 3.8 larvae per infested plant for a field average of 2.8 larvae per plant. The infestation level at Thief River Falls averaged 58% with 4.2 larvae per infested plant, for a field average of 2.4 larvae per plant. At both sites, larvae ranged from first to third instars. The performance of compounds in these trials, revealed by the number of tunnels, is presented in Table 5. Insecticide effectiveness varied considerably from 17.1% to 76.8%. Efficacy for granular insecticides averaged 64.0% while efficacy for liquid sprays averaged 41.0%. Thus, granular formulations seem to provide slightly better control than liquid sprays, even on tasseling corn.

Table 5. Effectiveness of granular and liquid-spray insecticides on first-generation European corn borer in northern Minnesota. Polk Co. - Northwest Expt. Stn. and Pennington Co. - Bob Wald farm.

Treatment	Rate (lbs ai/A)	Tunnels per 5 plants TRF *	Tunnels per 5 plants Crookston	Tunnels per 5 plants Average	% Control
Granules					
Pounce 1.5G	0.15	4.00 g	4.75 c	4.38	76.8
Diazinon 14G	1.00	4.50 fg	6.00 bc	5.25	72.1
Furadan 15G	1.00	5.50 efg	6.50 bc	6.00	68.2
Lorsban 15G	1.00	6.75 defg	6.75 bc	6.75	64.2
Counter 15G	1.00	7.75 defg	6.25 bc	7.00	62.9
Dyfonate 20G	1.00	6.00 defg	9.50 bc	7.75	58.9
Thimet 20G	1.00	8.00 defg	8.25 bc	8.13	56.9
Dipel 10G	1.00	7.25 defg	11.00 b	9.13	51.6
Liquid sprays					
Furadan 4F	1.00	9.63 cde	8.75 bc	9.19	51.2
Penncap-M 2E	0.50	8.75 def	10.25 bc	9.50	49.6
Pounce 3.2E	0.15	10.00 cd	9.00 bc	9.50	49.6
Pydrin 2.4E	0.15	12.88 bc	10.75 b	11.82	37.3
Lorsban 4E	1.00	14.00ab	17.25a	15.63	17.1
Untreated check	----	17.75a	19.94a	18.85	

* TRF designates Thief River Falls.

CONCLUSIONS FROM 1984

1. Labelled granular insecticides provide effective control of first-generation ECB larvae in southern Minnesota. Efficacy ranged from 83% to 99%. These data suggest that a conservative value of 85% should be used in 1985 economic threshold calculations.
2. Both granular and liquid insecticides provide reasonable control of first generation larvae in northern Minnesota. Efficacy ranged from 17.1% to 76.8%. On the average, granular insecticides outperformed liquid insecticides by ca. 20%, 64% vs 41%, respectively. Results of these trials suggest that efficacy values of 60% and 45% be used for granular and liquid insecticides respectively, in economic threshold calculations.
3. Shotholing provides a poor criteria for treatment decisions in northern Minnesota. Egg laying and egg hatch occurs when corn is

in the late whorl to tassel stages. Leaf feeding damage at these stages is very subtle and leaf collar feeding is very difficult to detect. Treatment decision criteria, at a minimum,should include both shotholing and egg masses. Alternatively, close examination of leaf collars and tassels can yield an accurate determination of larval abundance. This approach offers the distinct advantage of providing a reliable indicator of larval development and feeding position, necessary information to insure timely insecticide application.

Cutworm Control

Our interest continues in comparing newer chemicals against those which have performed well in cutworm control. In past years our trials have included control of dingy, darksided and redbacked cutworms. Populations of these three species were low in 1983 and 1984. However, the PIK program apparently contributed to huge local populations of sandhill cutworm (Euxoa detersa Walker) in Morrison County. Such a local outbreak permitted a trial against this cutworm species at the Sundvahl farm (Table 1) near Royalton.

The cutworm itself prefers to oviposit in grains in the fall. The Morrison county outbreaks were associated with rye planted PIK acres. On one farm we visited with the county agent, the cutworm destruction of corn following PIK was exactly to the edge of the 1983 rye planting. Eggs hatch in the fall, larvae winter and were in the third and forth instars when these plots were established on May 30, 1984. The literature reports this species as a subterranean feeder but this has to be incorrect as evidenced by our trial results. The larvae are pale colored and translucent so stomach contents are visible.

Table 1

SANDHILL CUTWORM CONTROL - MINNESOTA 1984
Morrison County - Sundvahl Farm
David M. Noetzel

Treatment	Dosage in pounds ai/A	Average number dead larvae/6 rows: post treatment
Lorsban (4E)	1.0	19.0
Baythroid (2E)	0.025	15.7
PP321 (1E)	0.01	14.6
Pay-Off (2.5E)	0.05	6.7
Pydrin (2.4E)	0.1	4.0
Ammo (2.5E)	0.05	4.0
Pounce (3.2E)	0.1	3.7
Sevin XLR (4E)	2.0	2.3
Dyfonate (4E)	4.0	1.7
Dyfonate (4E)	2.0	1.7
Untreated	-	0

The main portion of this field was from 30 to 80% destroyed by the sandhill cutworms. The grower had to replant and used granular Lorsban 15G at one pound actual per acre. We examined this field a week later (June 8, 1984) when portions of it again had stand reduction in excess of 50%. Cutworm feeding was going on everywhere in the field at that time. This convinced us that granulars are not effective enough to recommend for cutworm control. In most cases a broadcast spray appears the preferred, and possibly only, choice.

Our cutworm trials were placed in this corn field. We have always broadcast the treatments in about 10-15 gallons of water per acre. Plots were 9 rows x 30' in length and replicated three times. We did not disturb the soil surface following application. Readings were taken twenty four hours following treatments.

It was apparent at 24 hours post treatment that feeding had essentially ceased in the Lorsban, Baythroid and PP321 plots. This continued so corn stands had not changed between May 31 and June 8 in these plots in contrast to the "failure" in the main field.

We have had better performance of Pydrin and Pounce in years past on other cutworm species. This was our first work with the sandhill cutworm and also our first trials on sand. We cannot tell from these data why performance of these compounds was unacceptable.

I would like to acknowledge the excellent cooperation of Hal Sundvahl and the early call from James Carlson and Ken Olson which permitted these trials.

Armyworm 1984 and Control Trials

Armyworm provided considerable excitement again in 1984. The 1983 outbreak, although smaller in size, suggested that there was maldistribution of insecticide in Minnesota and some areas of the state had inadequate numbers of applicators. We also were slow to diagnose infestations "on the ground" in 1983 even though light trap collections suggested potential problems.

In 1984, an augmented light trap analysis by the Minnesota Department of Agriculture (Dr. Dharma Sreenivasam) and the Area Extension Agents-Integrated Pest Management (Rick Gauger and Carlyle Holen) gave an early indication of problem potential. Adult armyworm counts were exceedingly high in the southeastern and south central parts of the state. On the basis of these trap catches we indicated almost to the day when feeding damage should first be observed.

In the meantime, in view of the apparent lack of availability of insecticide in 1983, we contacted the Minnesota Department of Agriculture indicating we would request a special exemption for Lorsban 4E. If it did not come before the anticipated armyworm problem we would make a crisis request to insure adequate availability of insecticide. Such a request was possible in view of our work with Lorsban the past 8 to 10 years.

A third, and perhaps fortuitous event, was the rainy period during weed spraying. The Department of Agriculture permitted licensing of additional applicators to cope with this need. More importantly, weed spraying provided work for our locally based applicators and held them here continuously until the armyworm outbreak surfaced. (Fig. 1)

County agents, area agents and private consultants were able to detect early "on the ground" numbers of armyworm larvae that exceeded 50 per square foot in some fields. Indeed, these early observations led to the contacting of extension specialists and permitted some excellent insecticide trials (Tables 2 and 3).

In my fourteen years at Minnesota this is the first time that treating was begun when larvae were second and third instar and was largely completed before armyworm migration was observed. My hat is off to the entire industry for early detection, availability of chemical and expedient application. We estimate that these preparations and prompt action led to a saving for Minnesota producers of approximately 20.6 million dollars. This is based on 575,000 infested acres of which 350,000 were treated.

Fig. 1 ACRES INFESTED BY ARMYWORM 1984

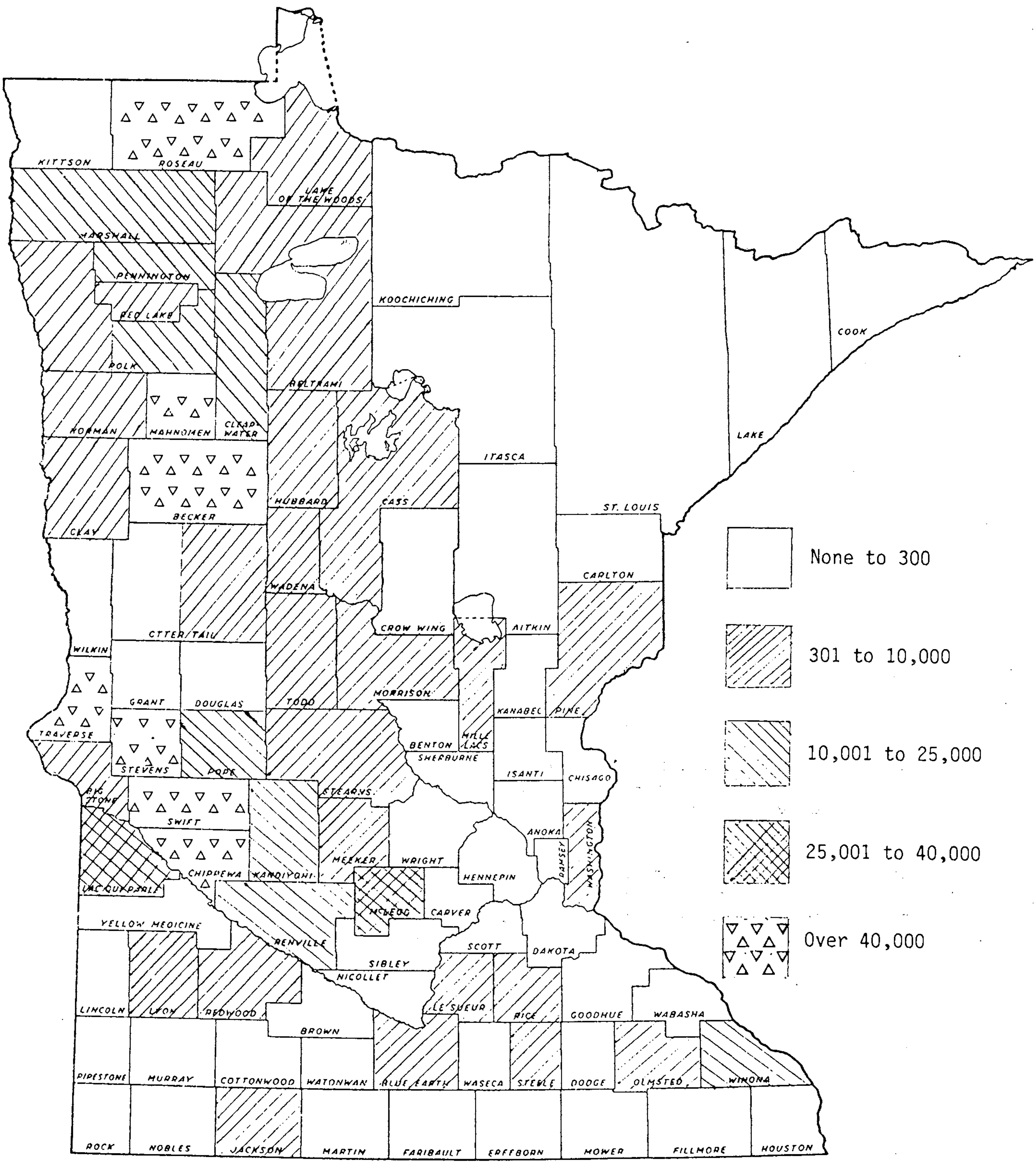

Table 2

ARMYWORM CONTROL - MINNESOTA 1984
Chippewa County - Norm Bosch Field
David M. Noetzel

Treatment	Dosage in lbs. ai/A	Average per cent control
Penncap-M (2E)	0.5	100
Pounce (3.2E)	0.1	100
PP321 (1E)	0.1	97.1
Pydrin (2.4E)	0.1	95.7
Cymbush (3E)	0.04	95.7
Pay-Off (2.5E)	0.04	92.9
Baythroid (2E)	0.04	92.9
Lorsban (4E)	0.5	92.9
Sevin XLR	1.5	91.4
Spur (2E)	0.04	78.6
SN 415	2 pts.	64.3
ABG 6162A	2 pts.	4.3
Untreated	-	0

Table 3

ARMYWORM CONTROL - MINNESOTA 1984
Becker County - Les Hanson Field
David M. Noetzel

Treatment	Dosage in pounds ai/A	Average per cent control
Pounce (3.2E)	.1	99.3
PP321 (1E)	.04	96.7
Pay-Off (4E)	.04	95.3
Lorsban (4E)	.5	94.7
Baythroid (2E)	.04	92.7
Pydrin (2.4E	.1	86.7
Cymbush (3E)	.04	84.3
Sevin XLR (4S)	1.5	80.0
Dyfonate (4E)	4.0	74.7
Spur (2E)	.04	45.3
ABG 6162A	4 pts	28.7
SN 415	4 pts	6.3
Untreated	-	3.7

Insecticide trials against armyworm were set out in Chippewa and Becker counties. The larval counts were 46/sq. ft. and 25/sq. ft. respectively in the two tests. We included two biologicals (SN415 and ABG6162A) along with several pyrethroids, one phosphate and one carbamate. Materials were broadcast on plots 30' square at the rate of 10-15 gallons of total material per acre. Larval counts were taken pre and 24 or 48 hours post-treatment. Results are expressed in per cent control.

Its our impression that growers will not accept less than 90% or better control. Our trials suggest that Sevin XLR, Spur, Dyfonate and the biologicals tested will not provide larval reduction acceptable to producers.

We would make the observation that when larval counts, or evidence (feces) thereof, equal or exceed 5 armyworm larvae per square foot one should not wait to see what damage is going to occur. Daytime counts of 4 to 5 larvae per square foot will almost certainly have nighttime larval numbers much higher than the 5 larvae per square foot action level. Do not wait to treat such a field with the recommended insecticide.

Finally, we have not yet been informed of a regular label for Lorsban use against armyworm. We know it performs equal, or superior to, presently labeled compounds (Penncap M, Lannate, and Dylox) for armyworm control. When Dow obtains this label we will let the industry know.

Sunflower Beetle Larval Control

Sunflower beetle populations collapsed in 1984. This unpredictability alone should discourage preventive soil systemic treatments for this insect. (Data supporting this observation will be discussed under soil systemic trials.) In fact, beetle populations were so low that we spent considerable effort in locating fields with larval numbers over 5 per plant for our trials.

Two (Table 4 and 5) of four 1984 sunflower beetle control trials are reported here. All applications were broadcast in 10 to 15 gallons of total material per acre. Plots are 2 or 4 rows and 25 feet in length replicated four times. In addition, but not included here, was an aerial trial at Benson using 1/100 lb of Pydrin in 3 gallons of total material per acre. Counts were taken at 24 and 96 hours and control is reported as per cent reduction based on the untreated check in each replicate.

In Table 4 insecticide effectiveness of 9 pyrethroids, 5 phosphates, 4 carbamates, 2 biologicals and 1 chlorinated hydrocarbon are compared. In most cases much lower then registered dosages were used. Note the excellent performance of all the pyrethroids at these lower rates.

Table 4

SUNFLOWER BEETLE LARVAL CONTROL - MINNESOTA 1984

Norman County - Moen Field

David M. Noetzel

Treatment	Dosage in lbs ai/A	Average per cent control
Ammo (2.5E)	.005	99.3
Cymbush (3E)	.005	98.6
PP321 (1E)	.005	97.5
Supracide (2E)	.25	97.5
Pounce (3.2E)	.01	97.1
Furadan (4F)	.125	95.0
Baythroid (2E)	.005	94.6
Pydrin (2.4E)	.01	92.9
Pay-Off (2.5E)	.005	91.8
Spur (2E)	.005	91.4
Ambush (2E)	.01	90.4
BAS 263 (40 oz/liter)	.125	88.9
Thiodan (3E)	.25	85.0
Sevin XLR (4E)	.5	82.5
Larvin (3.2E)	.25	68.2
Lorsban (4E)	.25	54.3
Dylox (80wp)	.25	43.2
Cygon (4E)	.125	41.1
Penncap M (2E)	.25	38.9
ABG 6162A	4 pts.	30.7
San 410	1 pt.	22.1
San 410	2 pts.	21.4
San 410	4 pts.	12.5
Untreated	-	0

Pydrin, which has a sunflower label for 1985, provided excellent broadcast control (92%) at 1/100 of a pound actual per acre. This has been consistent for the last three years as well as in several 1984 (see also Tables 5, 6, and 7) tests. We will recommend Pydrin at somewhere between 0.03 and 0.01 lbs ai/A for sunflower beetle larval control in 1985. For growers who can apply Pydrin for sunflower beetle control at last cultivation (plant height 8-15 leaves) a directed spray over the row should permit rate reductions even greater than this.

Of the insecticides presently registered on sunflower Pydrin at 0.03-0.01 lbs/A, Furadan at 0.125 lbs/A and Supracide at 0.25 lb/A all provide excellent sunflower beetle larval control. Control rates for these compounds at the above rates has been above 90% in all trials the last three years.

In addition, we remain interested in as economical and predictable control as we can obtain. In examining this concept we lowered dosages still further (see Table 5) in a trial in Swift county in a field with about 62.5 larvae per plant. The percentage reduction for each date (one day and four day post treatment) are based on the number of living larvae per plant in untreated plots (62.5 and 38.4 respectively) on the day of the reading. Note that in all cases per cent control increases over the 96 hour period following treatment. And note especially how Pydrin performs at 0.01 and 0.005 lb ai/A.

Table 5

SUNFLOWER BEETLE CONTROL - MINNESOTA 1984

Swift County - Carruth Field

David M. Noetzel

Treatment	Dosage in lb. ai/A	Average per cent control at: 1 day	4 days
Pydrin 2.4E	.01	94.4	99.8
	.005	93.1	100.0
	.0025	81.2	88.6
	.00125	52.1	82.6
	.0005	35.0	64.3
PP321	.005	94.1	100.0
	.0025	88.4	98.0
	.00125	84.1	98.0
	.0005	81.5	97.9
Cymbush	.005	93.3	97.0
	.0025	85.5	98.6
	.00125	79.1	95.5
	.0005	62.4	91.7
Pounce	.01	84.0	95.8
	.005	53.7	88.2
	.0025	38.2	76.4
	.00125	43.1	72.0
	.0005	25.2	59.7
Untreated		0	0

Soil Systemic Trials on Sunflower

Considerable publicity regarding the effectiveness of soil systemics, notably Furadan, for grasshopper, sunflower beetle and spotted sunflower stem weevil control developed in 1982 and 1983. In view of the unpredictability of most of these pests and the ease and low cost for control when they are present we were unsure this soil systemic "insurance" was worth the price. In addition, we can easily monitor (IPM methodology) for grasshopper and sunflower beetle. We rarely, if ever, see spotted sunflower beetle in our major Minnesota sunflower production area.

We had examined this concept in 1976-77 and found no yield benefit whatever. However, growers seemed to need additional information with which to make judgements about the concept.

We set out nine trials in Minnesota and North Dakota to compare soil systemics with foliars for, especially, defoliator control. Two trials are reported here (Tables 6 and 7). They were selected because of the uniformity of the sites upon which they were established and the uniformity of management by the grower. One, the Cote field, was high oil, and the other, the Flaskerud field, was low oil.

Neither field had economic defoliation from sunflower beetle in the untreated plots. There were significant differences in defoliation in each field however. Foliar sprays, even at very low dosages are significantly superior to soil systemics in reducing defoliation.

Spotted sunflower stem weevil was not present in either field. There are differences however in other stem infesting insects versus treatments. There were no differences in stem breakage so that was not reported. (Incidentally it is only stem breakage that reduces yield from stem insects.)

Table 6

SOIL SYSTEMIC TRIALS - MINNESOTA 1984
Red Lake County - Cote Field
David Noetzel - David Kabes

Treatment	Dosage in lbs ai/A	Average per cent defoliation	Average number tunnels/5 plant	Yield in lbs/A
Untreated	-	7.0	8.0	2176
Counter 15G (layby)	0.5	4.25	5.75	2081
Furadan 4F (foliar)	0.5	<1.0	6.25	2051
Furadan 15G (layby)	1.0	3.75	4.75	2024
Furadan 15G (layby)	0.5	2.75	3.75	2006
Pydrin (2.4E) (foliar)	0.01	<1.0	8.0	1984
Furadan 4F (Planting time)	0.5	<1.0	2.0	1944

Table 7

SOIL SYSTEMIC TRIALS ON SUNFLOWER - MINNESOTA 1984
East Polk County - Flaskerud Field
David Noetzel - Howard Person

Treatment	Dosage in lbs ai/A	Average per cent defoliation	Average number tunnels/5 plant	Yield in lbs/A
Pounce (32E) (foliar)	0.005	1.0	7.0	2255
Temik (15G) (layby)	0.5	7.25	10.5	2216
Counter (15G) (layby)	0.5	7.5	8.75	2170
Temik (15G) (layby)	0.25	8.0	8.75	2117
Untreated	-	7.0	10.0	2096
Furadan (4F) (foliar)	0.5	0.75	5.75	2047
Furadan (4F) (foliar)	0.125	1.0	7.5	1983
Furadan (15G) (layby)	0.5	7.0	10.5	1962
Baythroid (2E) (foliar)	0.0025	0.75	11.5	1961
Pydrin (2.4E) (foliar)	0.01	1.0	7.5	1927
Furadan (15G) (layby)	1.0	2.75	3.5	1882

We have not statistically analyzed the yields. It is unlikely there will be a statistical difference in yields from the Cote field. I am not sure that will be the case with the Flaskerud field.

We applied granulars at "layby" (2 to 4 leaf stage) for our comparisons. The plants without Furadan (ie. our plots) at planting were three or four days ahead of those treated with liquid Furadan at planting. We did not observe differences in bloom, etc. between planting time treatments and our plot area.

In Table 8 we have included average values of all soil treated Furadan plots and all untreated plots from our 1984 trials. We did not include planting time treatments by growers. As you can see yields were less from plots treated with Furadan (0.5 to 4 lbs ai/A) than when no treatment was applied. It is unlikely this difference is statistically significant.

To summarize we believe the insects one would use a soil systemic to control are either not present in economic numbers in Minnesota or if they (grasshoppers and sunflower beetle) are in economic numbers integrated pest management (ie. monitoring, etc.) provides by far the most effective, economical and safe control.

Table 8

SUMMARY OF ALL SOIL SYSTEMICALLY TREATED PLOTS VS. UNTREATED PLOTS MINNESOTA 1984

David M. Noetzel

Treatment	Dosage in lbs ai/A	Total Number plots (N)	Average yield in lbs/A
Furadan	0.5 - 4.0	80	1576
Untreated	-	120	1640

Sunflower Seed Insect Control

Banded sunflower moth has become a major pest of the Minnesota sunflower crop. Early surveys (1980-81) indicated it to be more important than seed weevil in west central Minnesota. In 1984, nearly every field in the state suffered some loss from this insect. 1984 plots at the Southwest Experiment Station (results not included) had 45% of the seeds infested. In Mahnomen and Norman counties (see Table 9) over 60% of the seeds show larval feeding. We also observed feeding which destroys developing florets leaving little evidence of damage. Thus we are speculating that total damage is higher than these data suggest.

We do not have a valid action level for determining when a field should be treated. We feel that if adult moths are readily visible along field margins it will usually be economically beneficial for the grower to treat. The presence of such adults, however, is rather transitory. Once a week visits to monitor can miss entirely the peak of adult flight. The peak of adult flight in the Mahnomen - Norman county area was between July 20-25, 1984. It was difficult to find adults toward the end of July in the same fields.

Observations and sampling in 1983 and again in 1984 suggest it is futile to treat field margins and expect any appreciable control of banded sunflower moth. Much of our earlier trials suggested timing of applications to the whole field based on sunflower phenology (ie. 10% bloom) to be successful. In 1984 we dissected heads a week or more prior to bloom and found hundreds of larvae in some of these plants. This evidence suggests earlier treatment may further improve control.

The need for insecticide applications for banded sunflower moth larval control were based on the observation of adult abundance around field margins. Timing of application was again related to the stage of bloom (eg. 1 to 3 plants in 10 with male florets open: equals 10-30% bloom) in the sunflower field. Results are reported in Tables 9 and 10.

The seed infestation in Norman County (Moen field) was nearly 100% banded sunflower moth larvae. The infestation in Wilkin County (Nordick field) was approximately 70% banded sunflower moth and 30% seed weevil.

Table 9

BANDED SUNFLOWER MOTH CONTROL - MINNESOTA 1984

Norman County - Moen Field

David Noetzel, Ken Pazdernik, Jim Martin

Treatment	Dosage in ai/A	Average number infested seeds/100 seeds	Yield in lbs/A
PP321	0.05	12.3	1743
SAN 415	2 pts.	16.3	1720
Penncap-M	0.5	20.3	1569
Lorsban	0.5	20.7	1742
SAN 415	1 pt.	22.7	1380
Furadan 4F	0.5	23.0	1532
SAN 415	4 pts.	23.3	1680
Larvin	0.5	24.0	1468
Pydrin	0.1	25.0	1398
Baythroid	0.05	26.7	1631
Supracide	0.5	27.0	1563
Dipel	2 pts.	28.0	1274
Pay-Off	0.05	29.0	1344
Ammo	0.05	30.7	1310
Furadan (field)	0.5	31.3	1454
Pounce	0.1	31.7	1399
Dipel	1 pt.	36.3	1285
Thiodan	0.5	36.7	1221
Dipel + ABG 6162A	1/2 + 1/2 pt.	37.0	965
ABG 6162A	1/2 pt.	45.7	886
Spur	0.05	49.0	1047
ABG 6162A	1 pt.	54.0	756
Pydrin (field)	0.12	55.7	767
Untreated	-	59.7	778
ABG 6162A	2 pts.	73.3	626
ABG 6162A	4 Pts.	59.7	465

Table 10

BANDED SUNFLOWER MOTH AND SEED WEEVIL CONTROL - MINNESOTA 1984

Wilkin County - Nordick Field

David Noetzel, Michelle Ricard

Treatment	Dosage in ai/A	Average number infested seeds/100 seeds	Yield in lbs/A
Ammo	0.05	3.7	1597
ABG 6162A	2 pts.	5.0	1652
PP321	0.05	6.0	1794
Baythroid	0.05	6.0	1575
Spur	0.05	7.3	1719
Penncap M	0.5	7.7	1458
Dipel	2 pts.	8.7	1436
ABG 6162A	4 pts.	9.0	1784
Thiodan	0.5	9.7	1636
ABG 6162A	1 pt.	12.7	1194
Furadan 4F	0.5	13.7	1429
ABG 6162A	1/2 pt.	15.0	1532
Supracide	0.5	16.0	1731
Pydrin	1.0	17.0	1388
Lorsban	0.5	19.0	1359
Dipel	1 pt.	19.0	1262
Larvin	0.5	19.3	1244
Pounce	0.1	21.0	1585
SAN 415	4 pts.	21.3	1451
SAN 415	1 pt	21.7	1204
Untreated	-	23.3	1419
SAN 415	2 pts.	29.3	1384
Pay-Off	0.05	31.3	1259
Dipel + ABG 6162A	1/2 + 1/2 pt.	33.0	962

We are obtaining something above 60% reduction of banded sunflower moth larval feeding damage in our tests. Probably significant differences in yield (from 400 to over 800 lbs/acre) were found in four sets of trials in 1984.

Among labelled compounds Lorsban, Furadan and parathion perform acceptably. It appears that several pyrethroids (PP321, Baythroid and Ammo-Cymbush) appear superior to the above three products but are not presently labeled.

Acknowledgements

The Department of Entomology would like to express special thanks to Dow, ICI, Mobay, Shell, Stauffer and Zoecon companies for Grants-in-Aid in support of this research.

In addition, we are most appreciative of grower cooperation in providing land, crop and insects for these trials. Of necessity we need to place plots where high insect populations exist. In many cases growers must apply controls and yet avoid our test site. Cooperating growers in the above trials include Hall Sundvahl, Norm Bosch, Les Hanson, Sanford Moen, Dale Cote, George Flaskerud and the Nordick family. Their help was absolutely essential for the excellence of the 1984 trials.

ALFALFA WEEVIL UPDATE

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INTRODUCTION

Although alfalfa weevils (A.W.) have been present for at least 14 years in SE Minnesota and roughly 10 years in much of central and SW Minnesota, with their range gradually spreading north (see Fig. 1a), they have rarely been abundant enough to be a problem in this State. In 1984 a fortuitous sequence of favorable weather conditions was probably at least partially responsible for unusually high densities of larvae, and associated with this some economic damage, and on some farms, severe losses.

THE 1984 SEASON - SPRING

Heavy early snow and continuous snow cover which would have protected the ground from freezing for most of the winter of 1983/84, probably contributed to higher than usual overwinter survival of adult A.W. Normally A.W. eggs do not survive the winters in Minnesota. By late May A.W. adults and some larvae had been reported from several areas in the S & W of the State, and a warning was issued in the Plant Pest Control Newsletter alerting scouts to the possibility of a build up and advising them to start sampling alfalfa if they had not yet done so. Much of the first 2 1/2 weeks of June were rainy and overcast, delaying the first cut on many farms. By the 3rd week of June damage due to A.W. larval feeding, both on uncut alfalfa and on stubble regrowth, was being reported from a wide area (Fig 1b), with the most severe and widespread damage occurring in Dakota, Scott and Rice counties. Severe damage, skeletonizing the leaves of uncut hay, so that the crop has had a silvered appearance from a distance, and severely delaying regrowth after harvest, also occurred on a few farms in the other affected counties. Some farmers cut their hay early, before the rains, and in some cases desiccation and starvation reduced the numbers of A.W. larvae to non-economic levels. More frequently, the rain followed too soon after cutting for the farmers to pick up their hay, or else it prevented cutting altogether. Either way, young larvae were provided with a continuous supply of food in a moist and often sheltered environment, so they survived till later, less vulnerable stages, eating all the while. An unusually high number of farmers were forced to spray their stubble regrowth - a few also had to spray the standing crop, when it was too far ahead ($>$10 days) of the planned harvest to cut the hay. This was the first time that A.W. damage to regrowth after the first harvest in Southwestern Minnesota had ever been severe enough to warrant chemical treatment. By the end of June the need for chemical treatment had largely passed, as the bulk of the larvae were pupating. When the new adults emerge, they normally feed for only a few days to a week or so before leaving the alfalfa for the summer.

PARASITES

Both parasites that attack the larvae (*Bathyplectes curculionis*) and others that attack the adults (*Microctonus aethiopoides*) of A.W., have been released in the U.S. *B. curculionis* probably spread to Minnesota when the weevils came here, and its distribution now matches that of the weevils. USDA has released further *B. curculionis* in recent years to supplement the numbers. *M. aethiopoides* was released in SE Minnesota in the late 1970's but its establishment was not well documented. DUring spring 1984 Craig Krueger, a MS student with Dr. E.B. Radcliffe in the Department of Entomology, University of Minnesota, undertook a survey, sampling A.W. populations in Southern and East Central MN (Fig. 1b) to determine the distribution of the parasite *M. aethiopoides*. He brought samples of A.W. back to the laboratory and held them until the parasites emerged. He found that although the level of parasitism in about 1/2 the counties he surveyed is quite low, the parasites are now almost as widespread as the weevils. It appears, however, that more may have spread into Minnesota from Iowa or Wisconsin rather than from the local release.

1984 SEASON - FALL

Alfalfa weevil larvae are usually rare after about mid-July in Minnesota, there normally only being one generation a year here. In some years a very few larvae have been found in the fall, but not damaging numbers. A high (though variable) proportion of the adults produced from spring larvae leave the alfalfa fields in summer and neither feed nor reproduce until they return in the mid-to-late fall or next spring. The proportion leaving is influenced by condition of the alfalfa. We do not know what proportion of those that stay in the fields can reproduce without this 2-3 month physiological delay (called diapause). But this year, perhaps because of the exceptionally high numbers of weevil larvae in the spring, A.W. larvae were found in moderate abundance in some fields in Dakota and Goodhue counties during September. In one small field in Goodhue county numbers were so high that they caused damage well in excess of the spring treatment threshold. These larvae can only have been produced by weevils that did <u>not</u> diapause. There was not enough time (in terms of the day-degrees they require for development) for them to be the progeny of diapausing adults, even if the latter had by then returned to the alfalfa, which we do not know.

DISEASE

Larvae were collected from both the University of Minnesota Agricultural Experiment Station at Rosemount (September 6) and the severely damaged field mentioned above (September 14). A few of the former and all of the latter died of disease in the lab., and were found to be infected with a fungus *Erynia* that more often infests spring populations of alfalfa weevil. A number of the larvae had appeared sickly when collected. Workers in Champaign, IL are studying this disease organism but as yet we have no way to determine for sure whether it has any potential to be useful against A.W. in Minnesota - it is probably usually too rare here.

QUESTIONNAIRE

If we are to be better prepared for, and so more efficiently and economically handle problems with, alfalfa weevil in Minnesota in future we need a better understanding of the changes in its distribution and abundance, and the factors influencing these changes. Firstly, however, we need to document what those changes were. In an attempt to collate all available information (albeit mostly qualitative rather than quantitative), in mid-October I sent a questionnaire style letter to County Agents, Area Agents and private consultants. Only about 15-20% of responses have been returned to date, with less than half of these coming from counties where alfalfa weevil damage was at its most severe and widespread. Consequently it is premature to draw conclusions from the replies at this stage. Nevertheless, it appears that the occurrence of relatively high numbers of A.W. larvae in the fall was much more localized than in the spring. Questionnaire responses have shown that A.W. is now present in 3 northern counties where the Minnesota Dept. of Agriculture (MDA) had not yet recorded it: Beltrami, Clearwater, and Cass. Likewise, Craig Krueger's samples showed that A.W. is present in Pine Co., also not recorded by MDA.

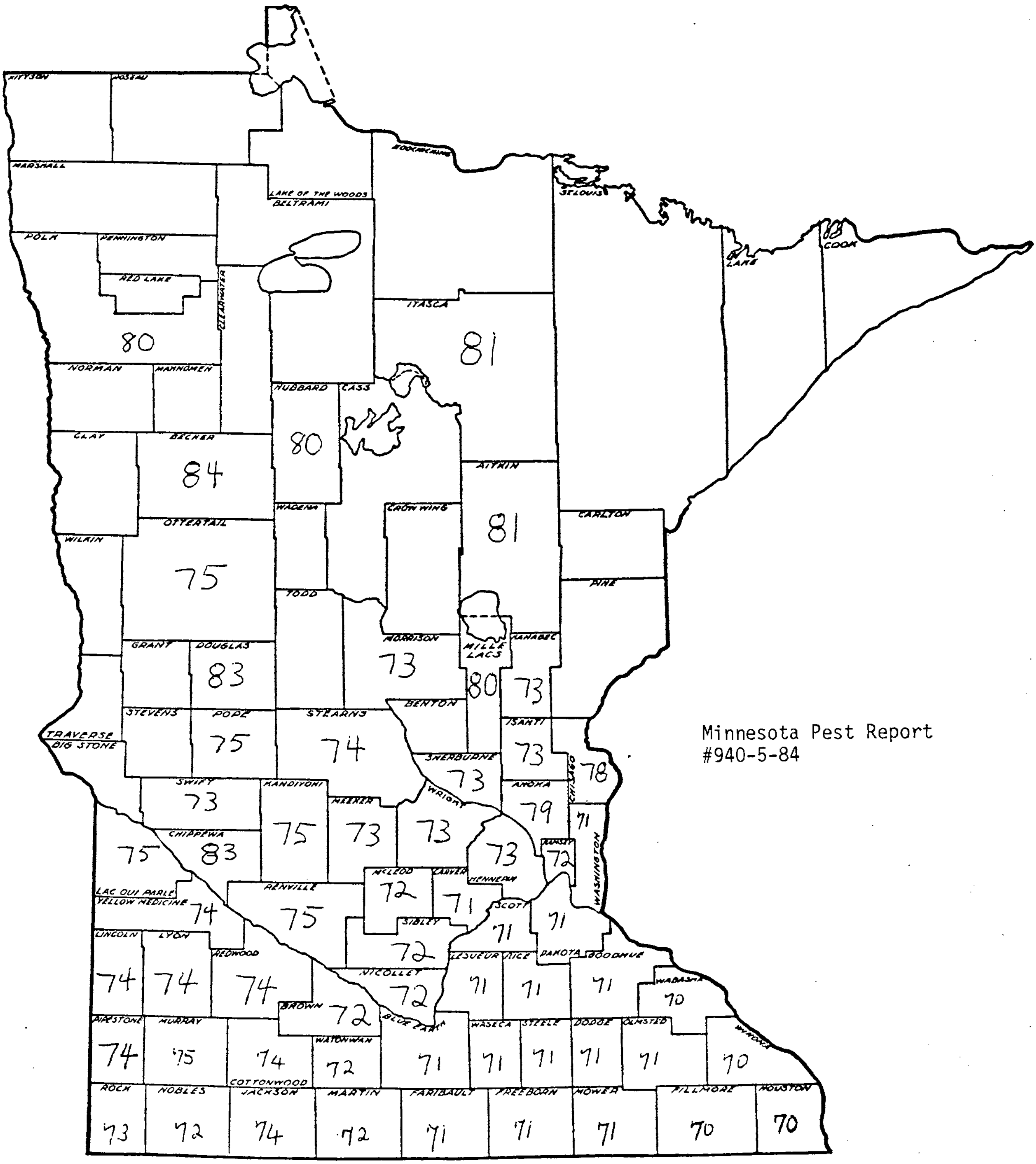
It is really important that all of us who have information on the alfalfa weevil collate it, so I am hoping for a high return rate on the questionnaires, once agents and consultants become less busy as the fall progresses. If any participants at this meeting feel they could provide information on the occurrence of the A.W. in Minnesota this season, I would welcome them contacting me for a copy of the questionnaire. The Extension Service fact sheet on the alfalfa weevil AG-FS-1026 will be updated before next spring.

CAPTION FOR FIGURES

Fig. 1a. Minnesota Dept. of Agriculture map showing years when they first recorded alfalfa weevil in each county of Minnesota.

Fig. 1b. Area in south and east central Minnesota sampled by Krueger for alfalfa weevil and parasite Microctonus aethiopoides. X's mark the counties from which calls regarding alfalfa weevil problems were received - one X for few calls, 2 X's for many.

Figure 1(a)



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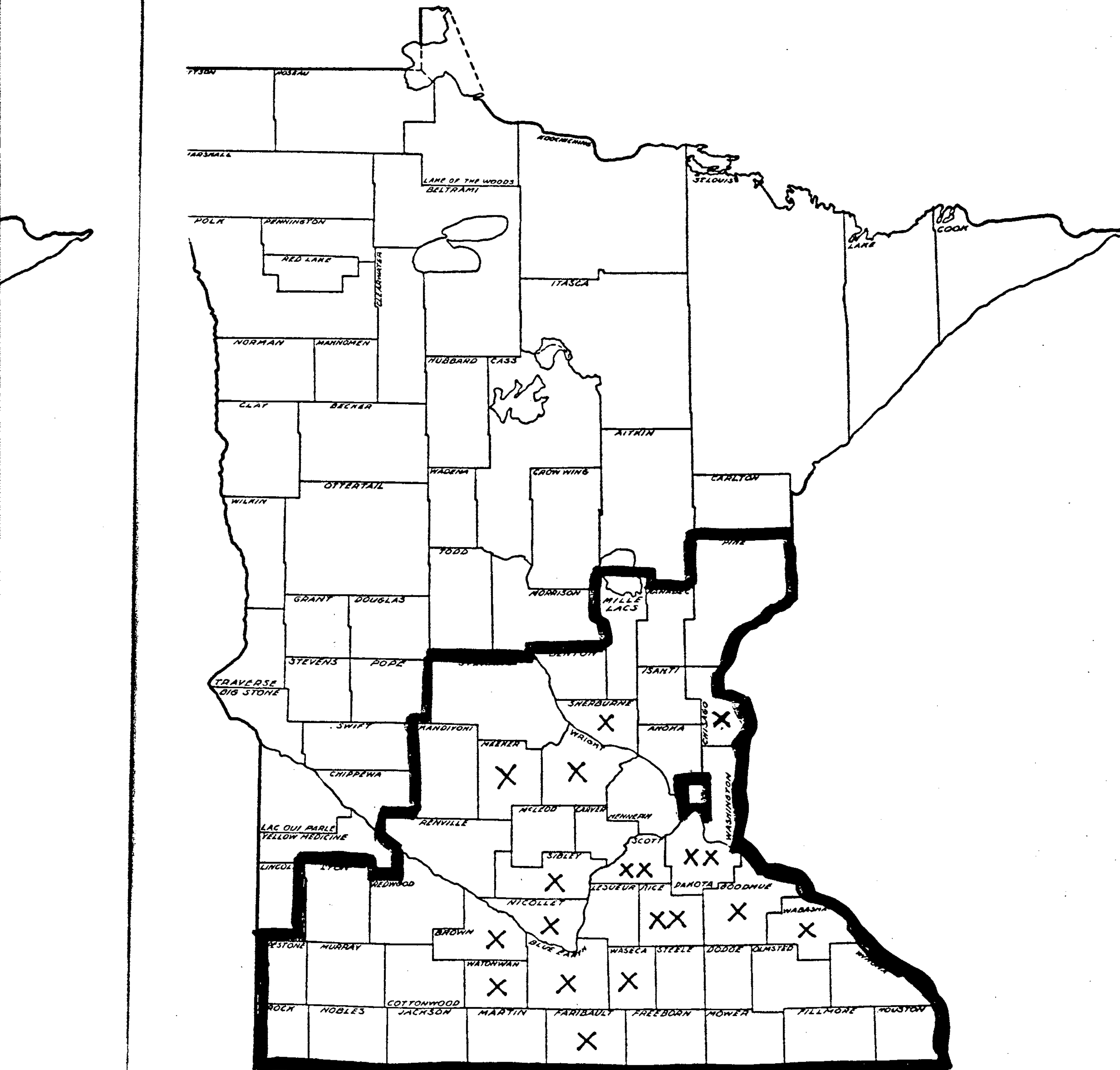
#940-5-84

Figure 1(b).



ROSEAU
MARSHALL
LAKE OF THE WOODS
BELTRAMI
KOOCHICHING
ST LOUIS
LAKE
COOK
POLK
PENNINGTON
RED LAKE
CLEARWATER
ITASCA
NORMAN
MAHNOMEN
HUBBARD
CASS
CLAY
BECKER
AITKIN
WADENA
CROW WING
CARLTON
WILKIN
OTTERTAIL
TODD
PINE
MORRISON
MILLE LACS
GRANT
DOUGLAS
STEVENS
POPE
ISANTI
TRAVERSE
BIG STONE
SHERBURNE
SWIFT
KANDIYOHI
ANOKA
CHISAGO
MEEKER
WRIGHT
CHIPPEWA
WASHINGTON
McLEOD
CARVER
HENNEPIN
RENVILLE
LAC QUI PARLE
YELLOW MEDICINE
SCOTT
SIBLEY
LINCOLN
REDWOOD
LESUEUR
RICE
DAKOTA
GOODHUE
NICOLLET
WABASHA
BROWN
MURRAY
BLUE EARTH
WASECA
STEELE
DODGE
OLMSTED
WATONWAN
COTTONWOOD
ROCK
NOBLES
JACKSON
MARTIN
FARIBAULT
FREEBORN
MOWER
FILLMORE
HOUSTON

SAMPLING METHODS & ACTION LEVELS FOR ALFALFA WEEVIL IN MINNESOTA.

A monitoring and decision making method has been devised in Illinois that takes into account crop growth stage, intensity of infestation with alfalfa weevil, and progress of the infestation. As yet, however, this procedure has not been validated under Minnesota conditions. Until this has been done the following sampling methods and action levels are advised:

Sample Unit	# per Location	# of Locations	Action Level	Action Advised
(a) PRE - HARVEST				
Alf. stems collected at random	20	At least 5 per decision area	30-35% of stems show feeding damage in tip & larvae still active	If 10 days or less till planned harvest, & is possible to cut very soon, do so. Otherwise, spray with recommended insecticide (immediately if possible)
(b) POST - HARVEST - ON STUBBLE REGROWTH				
(i) Examine windrow areas:				
		5 per decision area	If regrowth is being retarded by feeding & A.W. larvae present	Spray as soon as possible with a recommended insecticide
(ii) If regrowth not being retarded take samples from both windrow & non-windrow areas				
Random square-ft. samples	2 wr & 2 non-wr	5 per decision area	8 larvae per square foot	" " " " " " " "

EFFECT OF RONILAN, BENLATE AND MERTECT 340-F ON THE CONTROL OF WHITE MOLD IN PINTO BEANS

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University of Minnesota

Pinto bean growers have recognized for a long time that White Mold, caused by Sclerotinia sclerotiorum can be especially detrimental to pinto bean yields. Chemicals such as Benlate have been important tools in the control of White Mold epidemics. The following study was designed to evaluate the effectiveness of different rates and formulations and timing of Ronilan and Mertect as compared to the label rate of Benlate.

The Ronilan and Benlate treatments were successful in controlling White Mold, as noted by the percentage of wilted canopy and the resulting plot yields (Table 1). The plot treated with Ronilan WP and Benlate had the highest yields. The plots treated with Ronilan Fl, on the average, did not yield as high as the ones treated with Ronilan WP or Benlate. Mertect 340-F at either rate was the least effective against controlling White Mold.

The data collected in this experiment indicates that Benlate, when properly applied, still has the ability to control White Mold in Minnesota. Ronilan, when the Federal label is obtained should also be a treatment of choice. Competitive price and availability along with effectiveness will be the factors which will keep our chemical tools a viable option in the fight against White Mold.

Chemical control, however, is just one method of keeping White Mold under control. Three year rotations with non-host crops such as corn and small grains will do a lot to prevent serious build-up of White Mold in the soil. Crops like sunflowers, which are very susceptible to White Mold, should be avoided in a dry bean rotation. Planting tolerant varieties such as Bonsi (Ex Rico 23) Neptune + C-20 navies is another way to help keep the disease to a minimum. When selecting other classes of Dry beans, select varieties with upright growth habits which will encourage good air circulation in the canopy.

When considering when to spray, remember that fields which have been wet for a long extended time before blossoming are good candidates for White Mold infection. The odds for White Mold greatly increase when bean foliage covers the row. When these conditions are present, and the farm has a White Mold history and the outlook is for continued damp weather the present recommended sprays are Benlate and Topsin M at 1.5 - 2 lbs/acre at about 100% bloom. Spraying a second time has show to reduce the disease but may not be economically feasible.

White Mold spray program will not control 100% of the disease but in most cases should be cost effective. Coverage is very important. Since these chemicals are systemic and only travel upward in the plant it is important to get adequate canopy penetration. Ground sprayers with more than 1 nozzle/row and high pressure (20-40 gal H_2O, 75-125 lbs.) will give the most consistent results.

Predictive programs for White Mold development have been worked out in New York and Michigan. The New York model is 90% correct in telling growers not to spray and 45-50% correct when telling growers to spray. We will be watching these programs as they develop and be trying them experimentally in Minnesota as they develop further.

TABLE 1. White Mold Control Trial - Yields, White Mold Levels and Anthracnose Levels

	Treatments				White Mold Levels			
	First Application	Second Application	Yield (lb./A)		8/13	% Wilted Canopy	8/22	
Ronilan WP (.075 lb ai/A)	70% bloom	10 days later	2581	a	0	a	2	a
Ronilan WP (0.75 lb ai/A)	peak bloom	11 days later	2364	ab	2	a	12	ab
Benlate (2 lb prod./A)	70% bloom	10 days later (peak bloom)	2364	ab	3	a	15	abc
Ronilan WP (1.0 lb ai/A)	70% bloom	10 days later	2362	ab	0	a	0	a
Ronilan Fl (1.0 lb ai/A)	70% bloom	10 days later	2323	abc	0	a	1	a
Ronilan WP (1.0 lb ai/A)	peak bloom	11 days later	2229	abc	3	a	8	a
Ronilan Fl (0.75 lb ai/A)	70% bloom	10 days later	2193	abcd	0	a	10	a
Ronilan Fl (0.75 lb ai/A)	peak bloom	11 days later	2035	abcd	5	ab	27	bcd
Ronilan Fl (1.0 lb ai/A)	peak bloom	11 days later	1932	abcd	9	ab	30	bcd
Mertect 340-F (32 Fl oz/A)	70% bloom	10 days later (peak bloom)	1786	bcd	21	c	38	d
Mertect 340-F (16 Fl oz/A)	70% bloom	10 days later (peak bloom)	1665	cd	10	abc	37	cd
Unsprayed Check			1529	d	16	bc	42	d
LSD .05 =			650.5		11.1		21.8	

SCAB OF CEREALS AND OTHER MORE SERIOUS DISEASE PROBLEMS IN CROP PRODUCTION

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In todays production agriculture with it's acronems, buss-words, and top down decision making process, Head Blight or Scab makes a very good subject to explore the importance of understanding the problem before solving it.

Cereal growers may be more familiar with Scab by the name "Tombstone". When a grower delivers his crop for sale, the price may be subjected to a deduction - identified as Tombstone. The market can not utilize grain with very many scabby kernels. The bread won't rise, some livestock are even smart enough not to eat such feed.

Scab is a disease primarily of the head of the cereal plant. Several species of the Fusarium fungus are known to incite the disease. These same fungi can also cause seedling blights, leaf spot on cereals and stock rot of corn. As with many fungus pathogens these fungi overwinter on infected plant debris. Infected kernels when used for seed may also be a method of overwintering.

In reference to Minnesota, the southern half of the state experiences a serious cereal scab problem in one out of every 3 or 4 years. The disease problem is evidenced by a Tombstone deduction - or reduced yield when the crop must be "shrunk", heavily cleaned, to take out the scabby, shrivelled kernels.

The fungi survive on infected debris from previous crops, mostly cereals and corn. When cereal crops are planted into field with surface debris the environment is the only limiting factor controlling the occurrence of scab on a new crop. The fungus spores on the old debris are exposed to wind dissemination. Free water and/or humid conditions allow the spores that come into contact with the wheat leaf or head to germinate and penetrate the plant. Thus, a new disease cycle is started. The Head Blight phase of this disease is the most destructive. Usually the disease is most common at the time of flowering. When the head or flower parts of the plant are thus infected, the result is shrunken scabby kernels.

Unfortunately, most of our varieties of wheat, spring, winter and Durum, are not resistant. However, there is a very good possibility that resistance may be available, it has been identified and will have to be selected and transferred into acceptable new varieties.

So where is the Minnesota wheat grower now? Like the grower, you are searching for new research, new ideas that will solve the problem without pain. The hard fact is that we have not utilized what is already known. One might almost conclude that we are going backwards.

In the case with scab, we are promoting reduced tillage methods to leave crop debris (infected?) on the soil surface. Crop rotations have been shortened, even to the point of mono-cropping. Susceptible crop may follow susceptible crop. Is it any wonder why scab or for that matter other leaf spotting diseases continue to be a loss factor. Maybe certain crops such as wheat and corn should not be grown together.

In the major spring wheat area of the state, the Northwest, corn is being successfully introduced. Scab already is present on the cereals, so to make the disease more successful growers are providing another host for the pathogen, corn.

Tan Spot and Septoria Leaf Blotch diseases of wheat crop follow in the same tracks. The fungus survive on the old infected debris from previous seasons. So some growers plant these wheat crops in wheat stubble, leave debris on the field surface, reduce rotation time, and give all advantages to the diseases. Keep in mind that with many diseases the environment can be a limiting factor for plant disease development. When the environment is favorable for good plant growth, it is usually favorable for these fungus diseases. When drought conditions occur, usually leaf spotting diseases are not a problem.

Plant disease control practices will not totally eliminate the occurrence of plant diseases. However, practicing what is already known can make it make much more difficult for diseases to continue to be a crop loss factor.

Sanitation, removed or burying infected crop debris can reduce the potential disease inoculum that can reach a susceptible plant. However, such practices should be a universal practice amongst growers, not a one farm trial. Crop rotation with crops not susceptible to the same pathogens will slow-up the development of the pathogen population. Lengthening of the rotation time between susceptible crops will also work against the pathogen build-up.

By all means, where resistant varieties of a crop are available they should be grown. Clean seed (disease-free) if available should be used. When adequate fungicide practices exist, e.g. seed treatment and foliage application, such practices should be used. Even though such practices are good, and can reduce crop loss, they are not fool-proof, neither are weed control chemicals, or fertilizer applications.

To be successful all the "tools" of crop production must be used. One of the most important may be knowledge.

One may have gotten the impression that erosion-control is not important. Without our soil all of our production practices may be for nought. The type of erosion control practice is what is important. I believe that where the diseases that we have covered are important factors, then other methods of erosion control must be developed. Even to the point that some presently cultivated lands should not be cultivated.

Plant diseases are indeed shifty enemies.

PHYTOPHTHORA

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University of Minnesota

This disease was first seen in NE Indiana in 1984 and NW Ohio in 1951. In the early 50's this disease was the cause of significant root and stem rot in Canada and the eastern soybean belt of the U. S. The fungus Phytophthora megasperma was quickly recognized as a disease that would persist and increase as the crop was planted widely. In 1964 this root disease was found in a commercial field near Mankato. It was relatively "easy" to take the several resistant soybean varieties already developed elsewhere and incorporate into Minnesota production soybeans. The original race "Race 1" of Phytophthora began to change rapidly and in the Ohio/Indiana area growers could no longer depend on "Race 1" resistant varieties. In Minnesota the development of a new race, "Race 3" occurred in 1979 on a farm near Faribault where a "Race 1" resistant variety was being grown. In Minnesota the magnitude of threat is believed to be less and several years passed before other locations reported increased Phytophthora root rot problems. In 1982 and especially in 1983 many soybean growers recognized this old disease. Race identification, not a simple process, revealed 15 counties are known to have a race other than "Race 1" and some locations have several races present in one field.

The 1984 crop had its share of Phytophthora Root Rot and additional locations were found to have races other than the standard "Race 1" commonly found. Sixty-five percent of isolations in 1984 for race determination were not "Race 1". The importance of the 1979 "Race 3" find is now becoming clearer. The rate of development of new races is not predictable but the fact that new races will occur is predicted. Experience in the Ohio/Indiana soybean fields indicates a period of 8 to 10 years for race specific resistance failure is needed. Minnesota is now 6 years into the race change cycle and we presently also find "Race 4" and "Race 5".

Soybean growers who have Phytophthora Root problems with "Race 1 & 2" resistant soybeans can plant an alternate crop or choose a soybean variety with Multi-Race-Resistance. The chemical seed treatment material Apron (Gustafson) is also a possibility. "Race 1" resistance soybean varieties are still effective in many fields of Minnesota and many remain a viable choice for many growers. However, other growers should consider the use of Multi-Race-Resistant soybean varieties such as Corsoy 79, Wells II, Vickery and other soybean varieties with resistance to "Race 1, 2, 3, 6, 7, 8, & 9". The Multi-Race-Resistant soybean varieties are damaged less compared to Race 1 resistant varieties in fields where Phytophthora has been a problem. This mix of race specific resistance will serve the producer well until "Races 4 & 5" or others (?) become more dominant in the population. Some Minnesota fields are known to have "Race 4" and "Race 5", therefore, Multi-Race-Resistant varieties will not always be an adequate answer. This approach should be satisfactory in most locations.

An alternate method of disease control is the use of highly tolerant varieties. The highly tolerant soybean variety has the ability to survive and yield well under mild to moderate disease conditions. This ability is not lost when a new race of Phytophthora occurs. Tolerance is general and broad rather than selective and specific. The major weakness of "Tolerant" varieties occurs at germination when the tolerance is not expressed. Stand establishment has been a serious problem for "tolerant" varieties and has required replanting for many soybean growers. The replanting costs and reduced yields from delays in planting when using "tolerant" varieties will require the use of chemical seed treatment when severe Phytophthora rot is expected. Captan or Vitavax 200 are not effective in controlling Phytophthora rot - damping off stage. Apron has shown promise and is recommended for highly tolerant soybean varieties when planted in areas with a history of this disease. Apron has shown a benefit when used with Race specific varieties i.e. "1 & 2" when planted in fields with additional races present. No yield improvement with Apron is found if race resistance is adequate. The only label use of this product on soybeans for the forseeable future is as a seed treatment. It was expected that a soil application of Ridomil (Ciba Geigy), the same active ingredient as Apron by another name, would be available in 1984 and now in 1985. At this time no firm date for label clearance is projected. The active ingredient for these materials, Apron and Ridomil is called Metalaxyl. The use of Apron as a seed treatment will be beneficial in locations where Phytophthora is expected and usually severe and race specific resistant is not adequate.

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