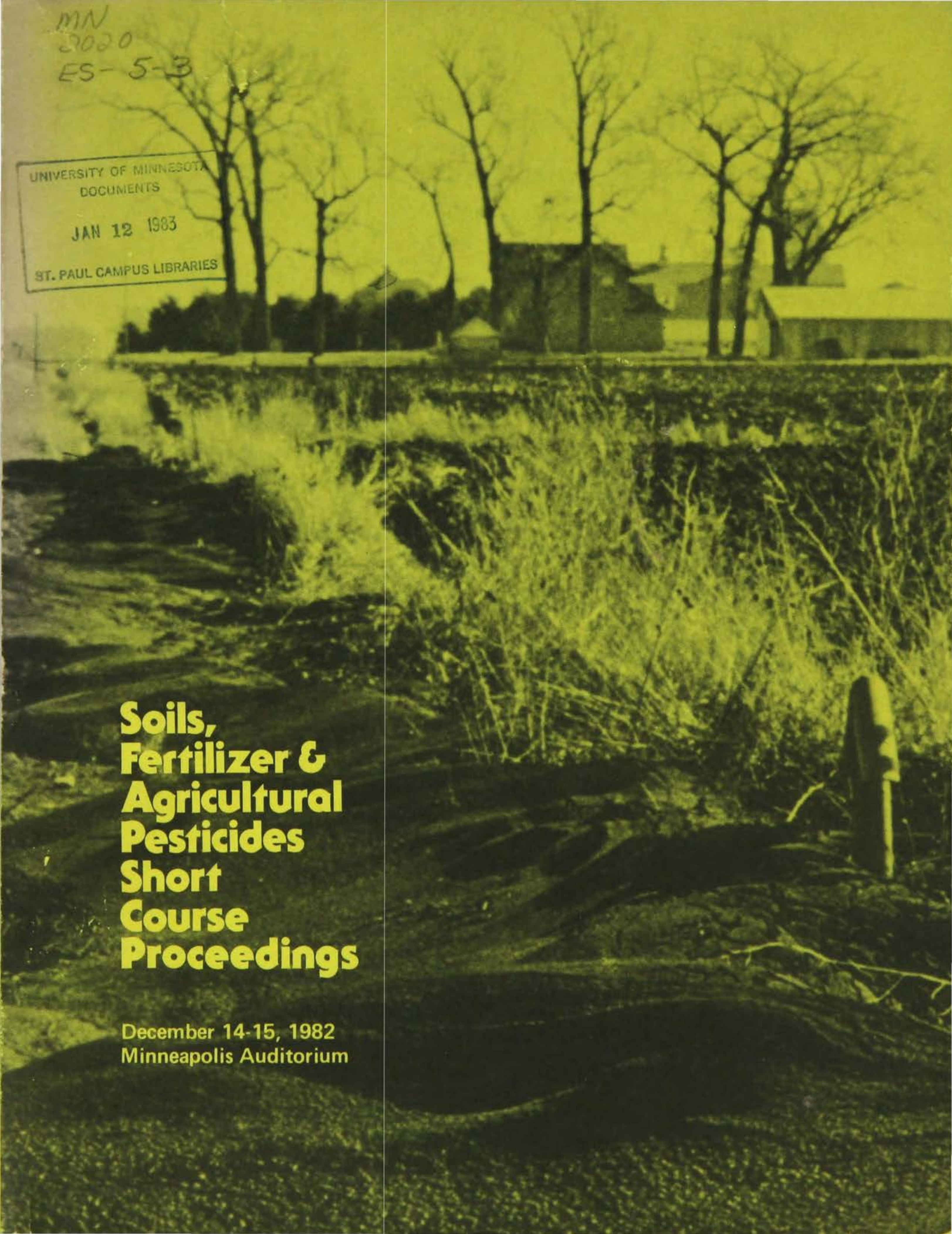

Soils, Fertilizer & Agricultural Pesticides Short Course Proceedings

December 14-15, 1982
Minneapolis Auditorium

PROCEEDINGS

SOILS, FERTILIZER AND AGRICULTURAL PESTICIDES
SHORT COURSE

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DO FERTILIZER RECOMMENDATIONS CHANGE WITH CHANGES IN TILLAGE?

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Conservation tillage systems for corn production have become increasingly popular in recent years because of the possibility of short term gains resulting from reduced inputs such as time, labor, and energy. The more important consideration is the potential for soil and water conservation in the long term. If conservation tillage is to be an acceptable alternative in troubled economic times, however, grain yields must be as high as those obtained with conventional tillage.

Changes in tillage to manage crop residues for erosion control can result in changes in soil physical properties such as temperature, moisture, aeration, and compaction. These changes can affect root distribution and metabolic activity as well as soil microbial activity. In some instances these effects manifest themselves as a reduction in nutrient availability. In most cases this reduction can be overcome by choosing the correct fertilizer source, method of placement, and time of application.

SOIL DENSITY, MOISTURE AND AIR

Tillage imposed differences in soil density, moisture and air from a Wisconsin study are shown in table 1.

Tillage had a marked influence on bulk density of the upper 3 in. of soil measured in late summer. Compaction with the no till system regardless of traffic and the till plant system under traffic was greater than the other systems at both locations. The bulk density in the row under the till plant system was similar to the chisel and moldboard plow systems under traffic. The chisel and moldboard plow systems had similar bulk densities in the row at both locations. These trends in bulk density increases with conservation tillage were also supported by penetrometer data (Moncrief et al., 1979; Moncrief and Schulte, 1980).

There are significant increases in soil moisture associated with tillage reduction. This coupled with increases in bulk density markedly reduced the volume of soil occupied by air in the no till and till plant systems, thereby also reducing aeration. This could result in N losses due to denitrification with these two systems (especially in wet years or in high rainfall areas). It is important to note that the chisel and moldboard plow leave similar soil densities. Although there is a modest increase in soil moisture with the chisel plow the decrease in soil air isn't as dramatic as with the till plant and no till systems.

Table 1. The effect of tillage on bulk density and percent pore space occupied by air and water at the 0-3 in. depth[+] (Moncrief et al.)

Tillage system	In row			Under traffic		
	D_b	H_2O	Air	D_b	H_2O	Air
	g/cm^3	-- % by vol.--		g/cm^3	-- % by vol.--	
No till	1.42a	35.6	10.8	1.39a	35.7	11.8
Till plant	1.24b	25.2	28.0	1.45a	31.8	13.5
Chisel						
Arlington	1.14c	22.0	35.0	1.22b	23.9	30.1
Lancaster	1.14c	25.3	31.7	1.28b	32.8	18.9
Moldboard						
Arlington	1.18c	19.8	35.7	1.22b	22.9	31.1
Lancaster	1.15c	26.2	30.4	1.28b	23.8	27.9

[+] Means in the same column followed by the same letter are not significantly different at $\alpha = 0.10$.

NITROGEN

Nitrogen can take many different forms in the soil, some of which are subject to loss or are unavailable to plants. Tillage imposed soil microclimate can influence microbial populations responsible for N transformations.The results of a Wisconsin study illustrating tillage effects on nitrogen availability are shown in tables 2 and 3. Nitrogen was applied broadcast preplant as ammonium nitrate.

Table 2. The effect of tillage on 95% of maximum yield (Moncrief et al).

Tillage system	Arlington, WI				Lancaster, WI			
	1978	1979	1980	Avg.	1979	1980	1981	Avg.
	Bu/A							
No till	---	---	---	---	144	156	135	145
Till plant	126	171	166	154	---	---	---	---
Chisel	118	158	155	144	131	138	136	135
Moldboard	127	164	177	156	131	139	147	139

It is interesting to note that the no till system resulted in a significant yield increase over chisel or moldboard plow tillage in two of the three years at the Lancaster site. This was due to a moisture advantage with this system during a 7 to 10 day period at silk emergence.

Table 3. The effect of tillage on the level of applied N at which 95% of maximum yield was found (Moncrief et al., 1981).

Tillage system	Arlington, WI				Lancaster, WI			
	1978	1979	1980	Avg.	1979	1980	1981	Avg.
	lbs/A							
No till	---	---	---	---	130	>293	237	>220
Till plant	154	>300	>300	>251	---	---	---	---
Chisel	115	130	130	125	45	36	93	58
Moldboard	109	130	102	119	54	73	150	92

It took more applied N to realize the moisture advantage of these tillage systems, however. It took in excess of an additional 125 lbs/A to meet the need for this nutrient under the till plant and no till systems.

There are several important points to consider, however. This is a "worst case" example for these two systems. A rotation with a low residue crop (soybeans, potatoes, sunflowers, etc.) would result in less of a reduction in N availability with the till plant and no till systems. Rotation is a valuable tool in managing crop residues for erosion control (optimum soil cover) without imposing extremes in soil physical environment which could lead to reductions in nutrient availability.

The first year results of a study in Goodhue County, Minnesota are shown in table 4. In this study anhydrous ammonia was applied preplant on continuous corn. There is a significantly higher yield with no N applied under a chisel plow system. With N applied there is no difference in grain yields due to tillage.

Table 4. The effect of tillage on corn grain response to applied N, Goodhue County, MN, 1982 (Moncrief et al., 1982).

N lbs/A	No till	Till plant	Chisel plow
	Tillage		
	Bu/A		
0	106	110	124
75	130	128	132
150	136	130	132
300	130	134	131

In most cases reductions in N availability seem to be associated with systems that leave large amounts of crop residue on the soil surface. A study was initiated in 1981 at Waseca, MN to explore the effects of N source and time of application with a till plant system. The results of the first two years of this study are shown in table 5. It appears that the preplant treatment is better when averaged over the two years.

Table 5. The effect of N source and time of application on corn grain yields with till plant tillage +. Nitrogen was applied at 150 lbs/A (Randall).

	1981			1982		
	PP	EM	SD	PP	EM	SD
Nitrogen Source	Bu/A					
Urea-Ammonium Nitrate Solution	171	157	168	162	164	155
Urea	174	174	168	167	164	148
Anhydrous Ammonia	175	160	169	166	142	162

+PP = Preplant, EM = Emergence, SD = Sidedress

It is interesting to note that the preplant treatment shows a 3 to 6 Bu/A advantage over sidedress in 1981 and 4 to 7 Bu/A in 1982. This is most likely due to a dry mid season in 1982. This is also supported by the advantage of anhydrous ammonia at sidedress because it is placed deeper in more moist soil (although all sidedress treatments were shallowly incorporated). Preplant treatments were made one day prior to planting,preventing volatilization losses of urea sources (the planting operation with this system provides for incorporation). The performance of the emergence treatment is dependent on source. Injection of anhydrous ammonia at this time was difficult because of shallowly incorporated trash between the row and the relatively narrow 30 inch rows. Poor retention and stand damage resulted. Due to the absence of incorporation there may have been some volatilization of the urea sources at emergence. In areas of the state with higher rainfall sidedress may prove to be an attractive option.

POTASSIUM

There are many contradictions in the literature suggesting that under certain conditions K availability is reduced with conservation tillage. There has been a sizable body of research suggesting that increased levels of soil K, and especially row-applied K, can be effective in attenuating availability problems associated with conservation tillage. Bower et al., (1945) found a reduction in K availability in corn to be associated with tillage on three Iowa soils--Fayette silt loam, Clarion loam; and Webster clay loam. Moldboard plowing resulted in higher K uptake than hard ground listing, disking, and subsurface tillage (20 in. sweeps operating at a depth of 4 to 5 in.). There were also grain yield differences associated with tillage-induced reductions in K availability. Bower et al., (1945) were able to overcome reductions in uptake and grain yields associated with tillage with applications of fertilizer. No differences in soil test K as a result of tillage were found in the soils under study. The Fayette silt loam and Webster clay loam soils used in the study had high levels of soil test K. They speculated, therefore, that differences in K availability were due to tillage-imposed soil aeration differences. In a follow-up study by Lawton (1946), K availability was shown to be more sensitive to aeration than was the availability of N, P, Ca, or Mg on Clarion loam and Clyde silt loam soils.

It is noteworthy that the reduction in K availability can be overcome effectively with increased bulk soil solution K levels from fertilization and especially so with a relatively small amount of row-applied fertilizer. Lawton (1946) cited tillage studies in northeastern Iowa on a Clyde silt loam soil where 50 Bu/A increases in corn grain yields were obtained with 20 lbs/A row application of K. Schulte (1980) reported a corn grain yield increase of 45 Bu/A with 12 lbs/A of row-applied K with a till plant tillage system on a Plano silt loam soil. Less than half of this response occurred with moldboard plow tillage. The response to row-applied K under till plant tillage was reduced from 45 to 3 Bu/A when average soil test K (Bray 1) values were raised from 135 to 300 lbs/A.

In split-root experiments, Classen and Barber (1977) have shown that about 50% of the corn roots must be supplied with K to maximize yield. This is more than the proportion of roots usually within the influence of the starter band. However, the response to row-applied K with conservation tillage suggests that if a moderate level of soil K is supplied to the rest of the root system, it is possible to meet the needs of the crop for this element by row fertilization.

A study at Wisconsin not only illustrates the effect of tillage and K availability but also the problem of soil sampling with a till plant system. The effects of tillage, row-applied fertilizer and soil K on grain yields at Arlington, WI are shown in Figs. 1a-c for 1978, 1979 and 1980, respectively. It is apparent for all three years of study that as the tillage intensity decreased at this site the starter K response increased. It is interesting to note the decrease in range of soil K with time in the till plant system. In 1980, the disk hillers and tractor speed were adjusted to maximize ridge formation during the cultivation operation. This resulted in abruptly lower soil test K values as a result of both sweeping surface accumulated K into the row area and soil sampling at a deeper depth in the furrow between rows. Initially (1978) applied K was incorporated throughout the surface 6 inches. Soil test interpretations should be made with this consideration for this tillage system. With the chisel and moldboard tillage systems, only a moderate response to soil K occurred with the use of a small amount of row-applied K. Corn grown under conservation tillage with high fertility at this site equaled yields of the moldboard system. The chisel plow system required a soil test K level higher than that of the moldboard plow system all three years. Although plant tissue data show that K availability is reduced with the till plant system, the response to soil test K in 1980 would not seem to support this unless consideration to K distribution relative to the row is included in the interpretation.

First year results from a tillage-potassium study in Goodhue County, Minnesota also illustrate the effect of tillage on K availability (Fig. 2). At 95% of maximum yield (165 and 150 Bu/A for a no till and chisel plow system respectively) soil test K is about 200 and 150 lbs/A. It is interesting to note that to realize a 15 Bu/A yield response to conserved moisture under no till, soil test K had to be greater than 200 lbs/A. It is probable that this K problem associated with conservation tillage will be apparent only in areas of the state with low to medium native soil K.

SUMMARY

1. Tillage affects both soil physical properties and subsequently nutrient availability. Soil moisture is increased with conservation tillage. Bulk density is similar with chisel and moldboard plowing.

2. Nitrogen response is similar for chisel and moldboard plowing. Nitrogen rates should be increased with a no till or till plant system if used with a continuous corn cropping system.

3. Corn grown with a till plant system responds best to preplant applications of N regardless of source (allows for incorporation of urea sources during planting). In parts of the state with higher rainfall or in wet years sidedress applications may perform as well.

4. Conservation tillage systems require higher levels of soil K (if soil is medium to low in native K - southeastern part of state).

5. It is crucial that starter fertilizer be used with conservation tillage. Phosphorus is always important in starter fertilizer but in areas of the state with low native K a balanced P-K starter should be used.

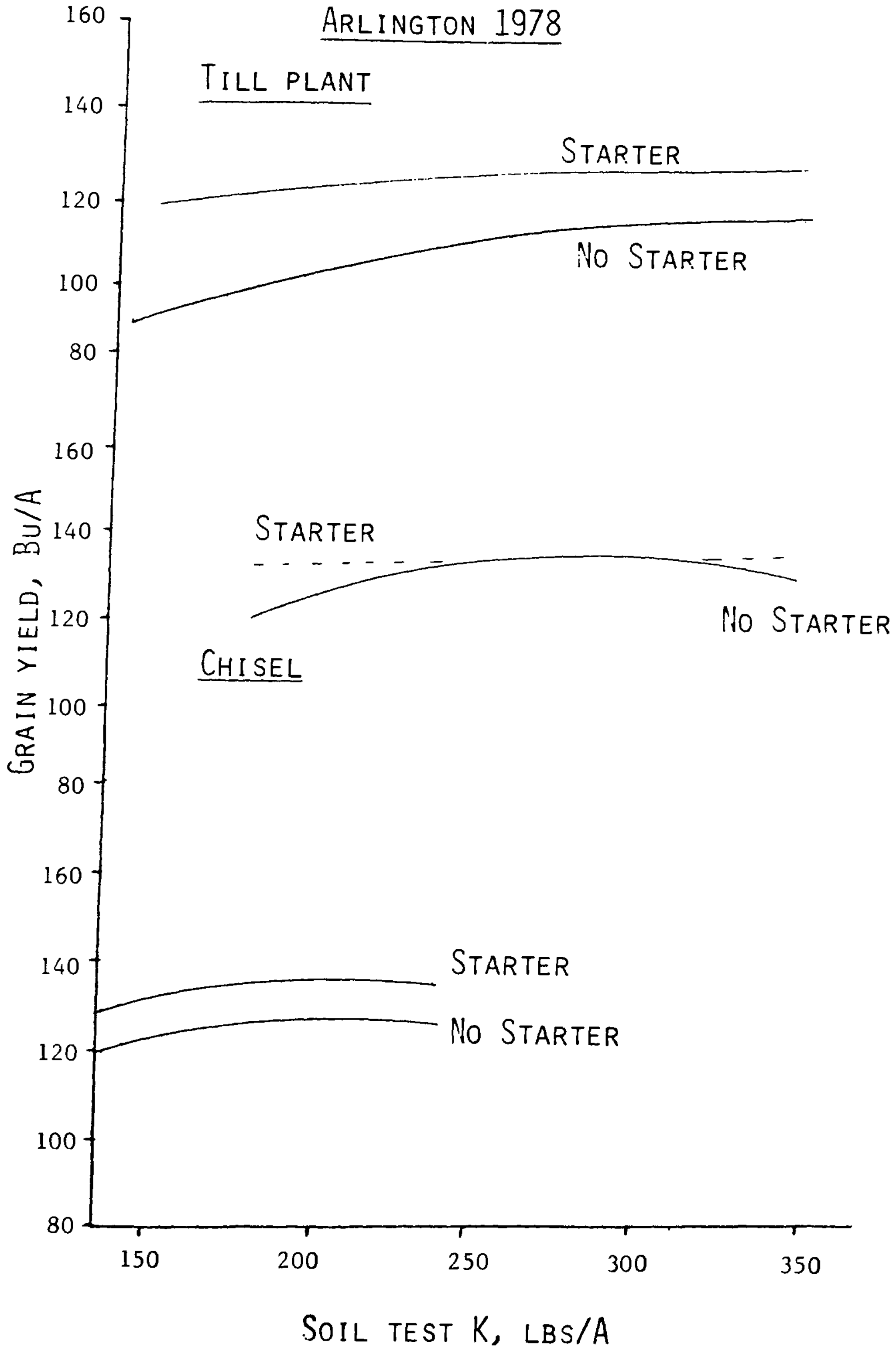

FIG. 1A EFFECT OF STARTER K, SOIL TEST K, AND TILLAGE ON GRAIN YIELDS AT ARLINGTON, 1978.

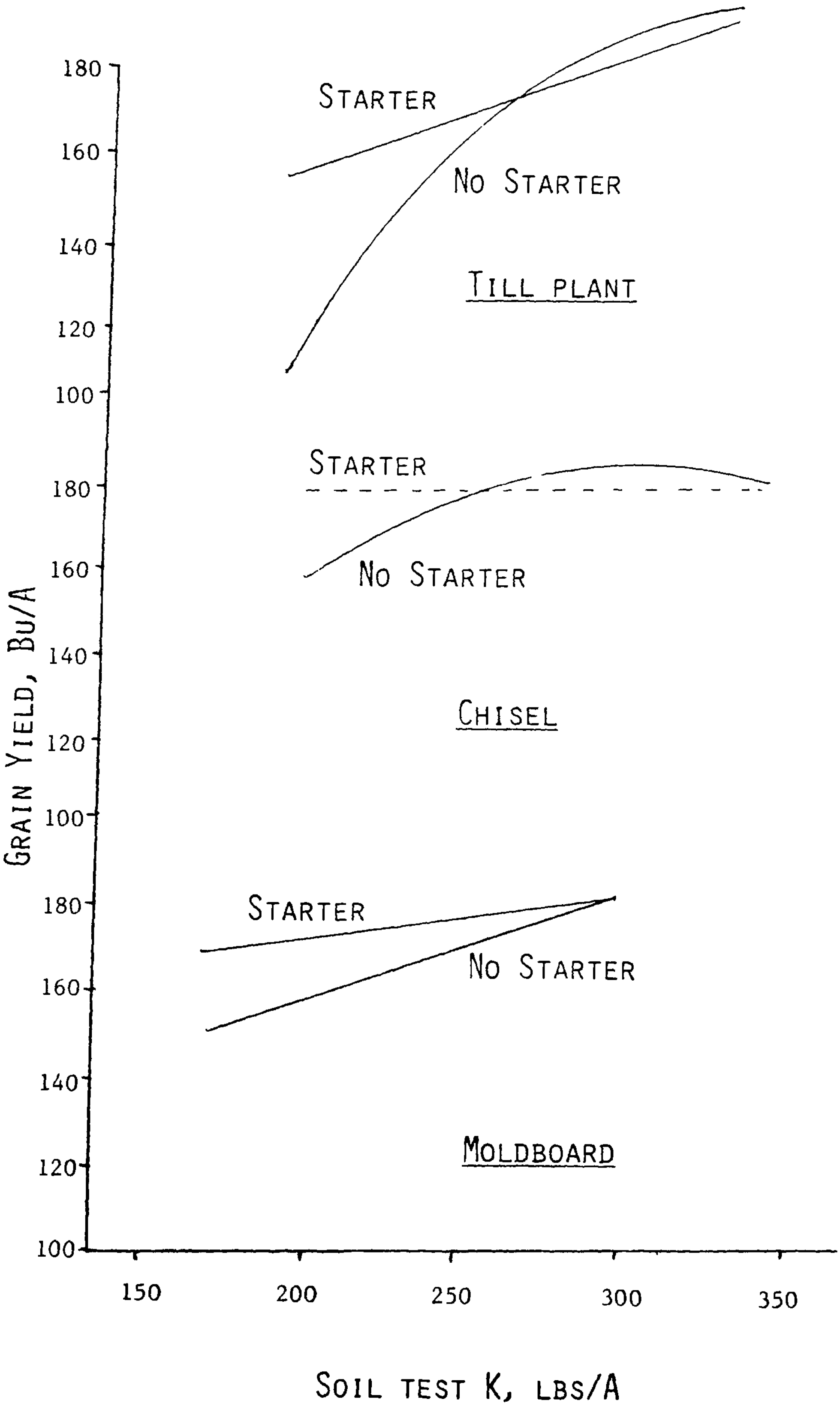

Fig. 1b Effect of starter K, soil test K, and tillage on grain yields at Arlington, 1979.

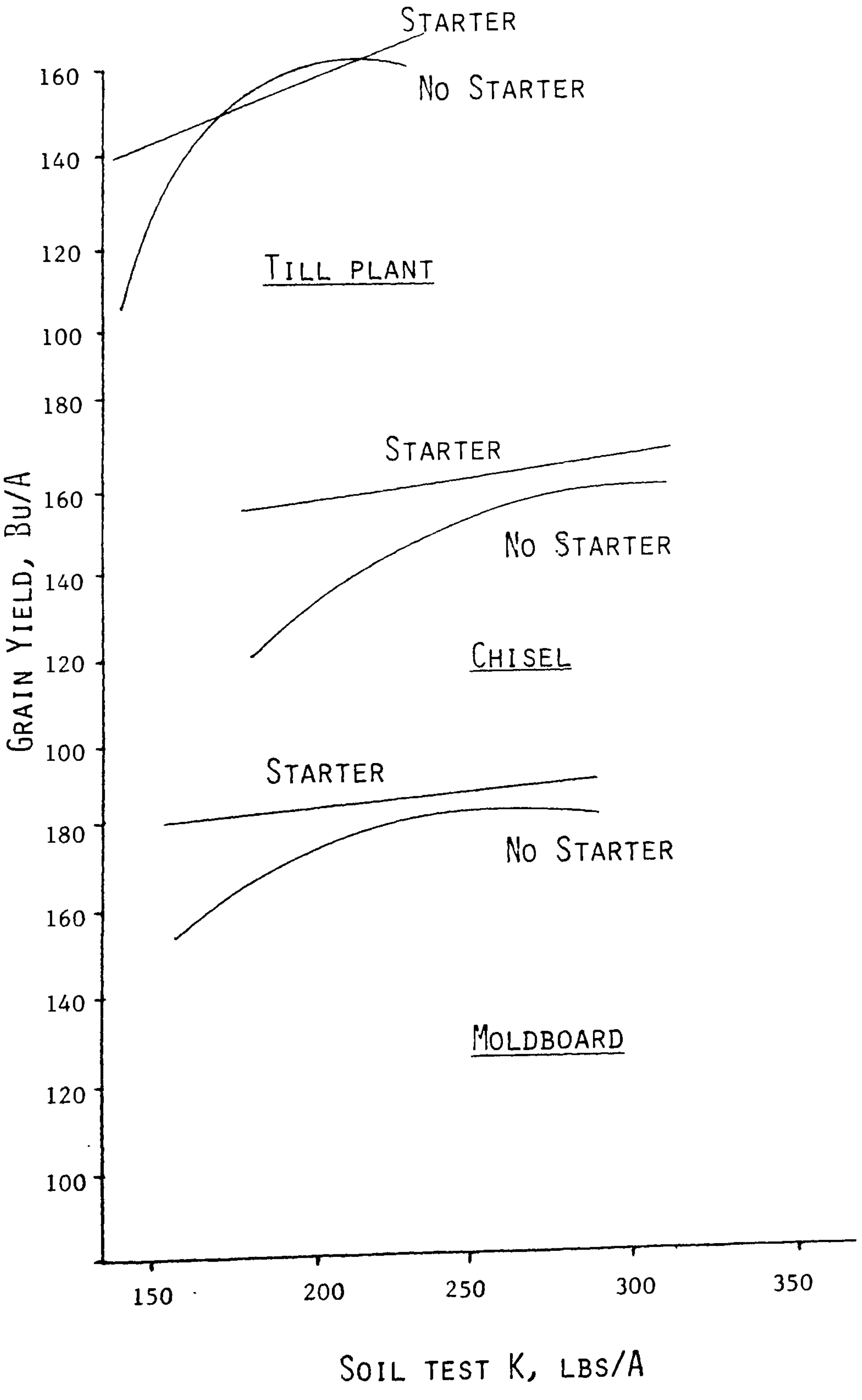

Fig. 1c Effect of starter K, soil test K, and tillage on grain yields at Arlington, 1980.

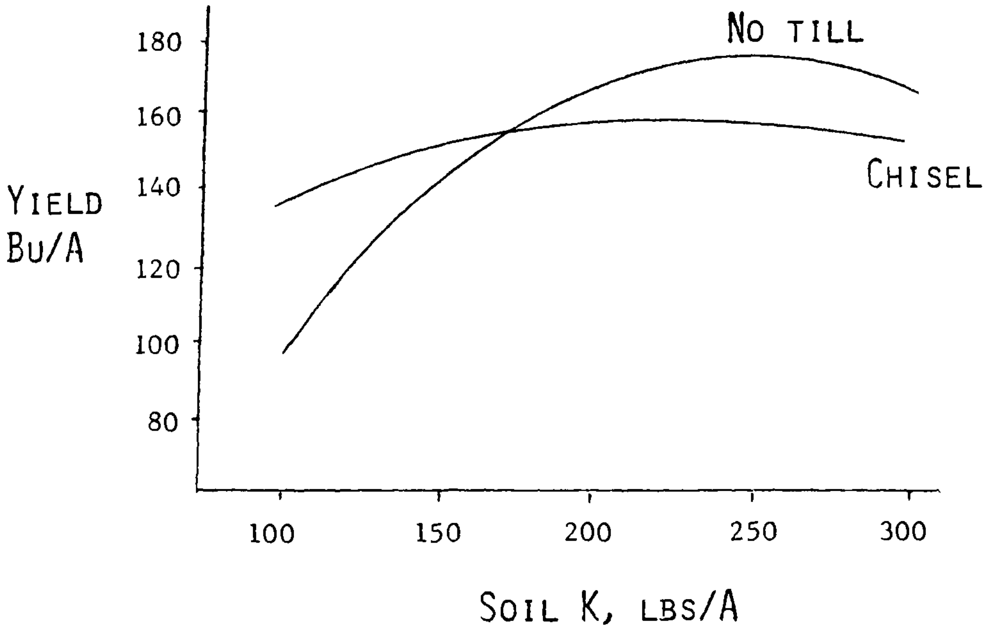

FIG. 2 THE EFFECT OF TILLAGE ON POTASSIUM RESPONSE (GOODHUE COUNTY - MN., 1982, SWAN ET AL.)

DUAL OR DEEP PLACEMENT OF FERTILIZER

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INTRODUCTION

In general, there are two basic methods of supplying the major portion of fertilizers needed by our crops -- band and broadcast. As the price of fertilizer and other inputs has increased, producers are interested in methods of increasing fertilizer use efficiency. One of the methods being studied by researchers and tried by farmers is dual, deep placement of fertilizers. This method is generally described as pre-plant placement of fertilizer nitrogen (N), phosphorus (P), and/or potassium (K) in bands 4-8 inches deep on a 12-20 inch spacing. Workers in Kansas, Montana, North Dakota, and Alberta have found positive results under some conditions from placing N and P in a common deep band as compared to separate placement in deep bands or broadcast application. It is my intent today to present some information on why dual, deep banding might increase fertilizer use efficiency and then present results of some trials in the upper midwest.

BACKGROUND

As all of you know, the fertilizer that is applied is not totally available to the crop to which it is applied. In some cases such as with N, losses thru leaching and denitrification reduce the availability of the N to only 50-60%. However, in the case of P, only about 20% of the fertilizer P applied in a given year is available to the crop grown that year. The remaining 80% goes into increasing the P soil test and/or into relatively "unavailable" forms of P in the soil.

Research has shown that restricting the soil-fertilizer contact, such as in a band, may increase the available P and thereby increase fertilizer use efficiency. This theory is used in making fertilizer recommendations where the amounts suggested for broadcast application are reduced when application is made in a row or band. It has also been shown that the application of an ammonium-N source with the P fertilizer increases the fertilizer use efficiency of both nutrients.

In the past few years there has been a renewed interest in reduced soil tillage. In some cases soil samples taken after extended periods of reduced tillage show a layering effect of P and K levels with high values in the surface layers and a gradient to lower levels at the bottom of the former plow layer. Dual, deep banding would enable farmers to put P and K into the soil at deep depths with some reduced tillage systems without reverting to moldboard plowing.

There have also been some pieces of equipment developed that combine tillage and fertilizer application. Various implements are available which will apply liquid, gaseous, and/or solid fertilizer sources in a subsurface band with the primary tillage operation.

METHODS OF FERTILIZER APPLICATION

I. BROADCAST

- Usually prior to primary tillage
- Material mixed with the entire tillage zone with some implements (plow) or about one-half of the tillage zone with other implements (disk)
- Rates are not limited and labor requirement is low

II. BAND OR ROW

- Usually applied at planting time
- Close to the seed
- Rates limited by amount of N & K to avoid salt damage and/or ammonia toxicity
- Possibly better fertilizer response than when same rate broadcast
- Takes extra time at planting when time is already short
- When soil conditions are dry, fertilizer availability may be reduced

III. DEEP, DUAL BAND

- Usually applied in combination with a tillage operation
- Material placed deep in the soil where moisture conditions are usually better
- Usually N & P are placed together so availability of both nutrients may be higher than when placed separately
- Rates are not limited

EXPERIMENTAL RESULTS

I. WEST CENTRAL MINNESOTA

Trials were started at Morris in the fall of 1980 using a Wil-Rich air seeder with chisel points on a 12-inch spacing. The materials were applied in early November to grain stubble that had already been chisel plowed once. Soil samples taken prior to fertilizer application indicated a very low NO_3-N level, a medium P level, and a pH of 8.0. Materials used were urea (46-0-0) and triple superphosphate (0-46-0). Results of the 1981 study are shown in Table 1.

Table 1. The Effect of Methods of N & P Application on Spring Wheat at Morris in 1981.

	Whole Plants at Soft Dough Stage				
Treatment	D.M. Yield	P Uptake	N Uptake	Grain Yield	Grain Protein
	------------	lb/A	------------	Bu/A	- % -
Check (no fertilizer)	4324	8.6	48	34	12.0
Broadcast	7198	12.3	71	57	12.7
Drill	7415	13.3	93	61	13.0
Dual, deep band	6722	10.8	64	55	12.0
BLSD(.05)	1442	4.3	29	11	NS

Note: Total rates of fertilizer applied were N at 70 lbs/A and P_2O_5 at 40 lbs/A. With the drill application 10 lbs N and 40 lbs P_2O_5/A were applied with the drill and the remainder was broadcast.

The 1981 results on wheat show a good response to fertilizer, but no significant difference between methods of placement. However, in most variables measured, the most efficient placement was the drill application.

In 1982 a different experimental applicator was put together so that anhydrous ammonia and liquid 10-34-0 could be applied in deep bands. The 1982 treatments were spring applied on an area that had been fall plowed. Soil samples taken prior to fertilizer application indicated a very low NO_3-N level, a medium P level, and a soil ph of 8.0. The knife spacing was 12 inches. The results of the 1982 study are shown in Table 2.

Table 2. The Effect of Methods of N & P Application on Spring Wheat at Morris in 1982.

	Whole Plants at Soft Dough Stage				
Treatment	D.M. Yield	P Uptake	N Uptake	Grain Yield	Grain Protein
	----------- lb/A	-----------	-----------	Bu/A	- % -
Check (no fertilizer)	2345	5.5	22	27	12.5
Broadcast	6719	13.4	93	60	13.7
Drill	7506	15.5	112	64	14.6
Dual, deep band	6936	12.6	99	62	13.5
BLSD(.05)	743	2.1	15	5	1.4

Note: Total rates of fertilizer applied were N at 100 lbs/A and P_2O_5 at 40 lbs/A. All N was applied in the broadcast and deep band treatments as anhydrous ammonia. Broadcast P was applied as 0-46-0. With the drill treatment 10 lbs N/A and 40 lbs P_2O_5/A were applied with the drill and the remaining N as anhydrous ammonia.

As in 1981 the results indicate no significant difference between methods of application although there was a very significant response to fertilizer. Again the drill was the most efficient method of placement.

In both wheat trials at Morris, the dual, deep band treatment was not greatly different from broadcast; so, this method of placement was satisfactory. Rainfall and soil moisture conditions in 1981 and 1982 were favorable for crop growth throughout most of both seasons. Results may have favored dual, deep placement under drier conditions.

As a sidelight to the 1982 study, we were interested in determining if these subsurface bands could be picked up by soil tests. During application we marked the bands and kept track of them during the growing season. In early September, about one month after harvest, we sampled the band and interband areas in the dual, deep band treatment and took random samples in the check and broadcast treatments. The results of the P soil tests are given in Table 3.

The soil tests show a definite difference between the band and interband areas in the deep banding treatment. On a practical basis it would be impossible to sample the bands in a field; so, you would actually be getting an average of the band and interband areas. The broadcast treatment did not show a significantly different P level from the check at the end of the growing season.

Table 3. The effect of Method of P Application on P Soil Tests at Morris in 1982.

Treatment	P Soil Test Olsen	Bray #1
Check	9	18
Broadcast	8	17
Dual, deep band -- band area	16	27
Dual, deep band -- interband area	6	14

II. NORTH DAKOTA

Since 1979 researchers in North Dakota have had trials on various crops investigating deep banding. Gregorie et al. (1981) reported significant benefits from deep banding on barley yields (Table 4).

Table 4. Effect of N & P Placement on Glenn Barley Yields, 1979, North Dakota.

Fertilizer -- lb/A -- N	 P	Yield bu/A Check	 Surface	 5" Deep
0	0	44	--	--
60	34	--	58	68

Soil tests averaged 12 lbs/P and 57 lbs/N per acre
N source 28-0-0, P source 10-34-0

Deep placement of N and P increased barley yields 10 bu/A as compared to broadcast application. Surface application of N and P increased yields 14 bu/A over the check.

Additional trials have been carried out in the period 1980-1982 on many crops with variable results. North Dakota State University summarizes their results as follows:

1) A deep (6-8") band placement of P is a very good method of fertilizer application on small grains.
2) It is not necessary that P and N be applied in the same band.
3) Deep band placement of fertilizer will often result in larger yield responses than broadcast application of P on soils testing low in available P. On soils testing high in P the method of P application is not important.

In most cases the North Dakota data shows a greater benefit from deep application under drier and cooler weather conditions.

COMPARISON OF APPLICATION METHODS

I. BROADCAST

A. Large amounts of fertilizer can be applied without danger of crop injury.
B. Material can be applied quickly thus reducing both cost and labor.
C. Material is mixed with more soil so crop yields may be lower if soil tests are low and low P rates are applied.

II. BAND AT SEEDING

A. Crop availability is improved because of proximity of fertilizer to young plants.
B. Soil-fertilizer contact is reduced and thereby there is possibly less P fixation.
C. Extra time and labor is required at seeding time when time may be critical.
D. Rates must be limited to reduce salt damage and/or ammonia toxicity.
E. An accurate fertilizer applicator is required on the planter or drill.

III. PRE-PLANT DEEP, DUAL BAND

A. Fertilizer can be applied when the farmer is not rushed.
B. Application may be combined with a tillage operation.
C. Fertilizer is placed deeper in the soil where soil remains moist for a longer part of the growing season.
D. P uptake is possibly stimulated when applied together with an ammonium-N source.
E. P fixation is possibly reduced.
F. Special attachments or equipment is required for proper application.

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Gregorie, T. and C. Fanning. March 1981. Application of nitrogen and phosphorus fertilizer products. North Dakota State University Cooperative Extension Service Circular SF-370. March 1981.

NITRIFICATION INHIBITOR RESULTS WITH N FERTILIZERS AND MANURE

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INTRODUCTION

Nitrogen (N) is the nutrient required in the largest amount for producing corn. Some available N is released from soil organic matter each year, however, most of the N taken up by corn is applied as inorganic fertilizers (i.e., anhydrous ammonia, urea, or 28% nitrogen solution). In this period of rising fertilizer prices, swine manure represents a potentially valuable resource if effectively used as a fertilizer. However, studies have shown that a significant proportion of the plant-available N is lost from the rooting zone of soils when manure is incorporated into soil during the fall or early spring prior to planting. Leaching and denitrification are thought to be the processes largely responsible for N losses from manure-treated soils. Surface application of manure may also result in N losses through ammonia volatilization during the first few days after waste addition.

A number of field trials conducted at Purdue and other universities in the midwest have shown that N losses are often markedly reduced if a nitrification inhibitor such as N-Serve, (N-Serve is the registered trademark of the Dow Chemical Company, Midland, Michigan) is applied with inorganic fertilizers (Huber et al., 1977; Nelson and Huber, 1980; Warren et al., 1975). These compounds stop or slow down the nitrification process (which is the biological conversion of ammonium N to nitrate N) when applied at a rate of 0.5 to 1 pound per acre. Ammonium is not generally lost from soils, but nitrate is subject to loss through leaching and denitrification. Because swine manure primarily contains ammonical forms of N, nitrification inhibitors may be useful in reducing N losses following waste application to soil. Preliminary studies showed that addition of N-Serve to band-applied liquid swine manure delayed nitrification for 15 weeks. Most of the inorganic N was lost from manure bands not receiving the inhibitor within 11 weeks of application, but high levels of inorganic N were present in N-Serve treated bands for 24 weeks (McCormick et al., 1983). This report summarizes results of three field studies evaluating the agronomic effects of adding N-Serve to liquid swine manure used as a fertilizer for corn.

EXPERIMENTAL DESIGN

Three field experiments were conducted during the 1978, 1979 and 1980 growing seasons at the Purdue University Agronomy Farm, West Lafayette, Indiana to evaluate the usefulness of adding N-Serve in liquid swine manure used as the source of nutrients for corn. Corn was grown on tile drained plots of Chalmers silty clay loam soil (measuring 10 feet by 50 feet for the 1978 growing season and measuring 10 feet by 45 feet for the 1979 and 1980 growing season) that were fertilized with varying rates of liquid swine manure (obtained from an anaerobic manure pit at the Purdue University Baker-Purdue Animal Sciences Center). In the 1978 experiment treatments were applied only in the spring; however, in the 1979 and 1980 experiments both fall and spring applications of manure were included. During all experiments, the manure was treated with 0, 0.21 and 0.42 lbs N-Serve active ingredient (a.i.)/1000 gallons of waste. The appropriate amount of emulsifiable N-Serve (24E) was added to a 1100 gallon vacuum manure tanker before filling with manure. N-Serve 24E contains 2 lbs of a.i./gallon. After mixing the N-Serve with manure, the waste was injected into the soil at a depth of 8 inches. The tanker was weighed before and after manure application to determine the amounts of waste added to each plot. In the 1978 and 1979 experiments the soil was plowed and disked before manure application and disked again before corn planting. However, in the 1980 experiment, corn stalks were chopped, manure was injected, and the area was disked once before planting in the spring. Becks 65X corn seed was planted to give a final population of 22,000 plants/acre. Cultivation and/or herbicides were used for weed control. All treatments were replicated four times and the results given are averages of all replicates.

The rates of manure application used in the three studies are given below:

1978 Growing Season

Approximately 6 weeks before corn planting manure was applied at rates of 0, 22, and 49 tons/acre (0; 5,180; and 11,530 gallons/acre, respectively). These rates provided an average of 0, 168 and 374 lbs of plant-available N/acre. Available N in waste was assumed to be ammonium N plus 25% of organic N. Check (no application) and urea fertilizer (80, 120 and 160 lbs of N/acre) applications were also included.

1979 Growing Season

Six months before corn planting, manure was applied at rates of 0, 14 and 27 tons/acre (0; 3,300; and 6,350 gallons/acre, respectively). These applications provided an average of 0, 82 and 158 lbs of plant-available N/acre. Approximately 2 weeks before corn planting, manure was applied to other plots at rates of 0 and 28 tons/acre (0 and 6,600 gallons/acre, respectively). These applications provided an average of 0 and 177 lbs of plant-available N/acre. Check (no application) and anhydrous ammonia applications (150 lbs N/acre) with 0 and 0.5 lbs N-Serve a.i./acre were also included at both application times.

1980 Growing Season

Manure was applied at rates of 0, 17 and 27 tons/acre (0; 4,000; and 6,350 gallons/acre, respectively) six months before corn planting. These applications provided an average of 0, 93 and 148 lbs of plant-available N/acre. Approximately two weeks before corn planting manure was applied to other plots at rates of 0, 20 and 35 tons/acre (0; 4,700; and 8,240 gallons/acre, respectivley). These applications provided an average of

0, 124 and 255 lbs of plant-available N/acre. Check (no application) and anhydrous ammonia applications (150 lbs N/acre) with 0 and 0.5 lbs N-Serve a.i./acre were also included at both application times.

RESULTS

Data in Tables 1, 2 and 3 show that spring application of swine manure at rates of 20, 22, 28, 35, and 49 tons/acre significantly increased corn yields as compared to the check treatment. In 1978 application of swine manure at a rate of 49 tons/acre (Table 1) resulted in yields which were not different from plots receiving 160 lbs urea N/acre, and in other two years swine manure applied at rates of 28 and 35 tons/acre gave similar or greater yields than plots receiving 150 lbs N/acre as anhydrous ammonia (Tables 2 and 3). Furthermore, during the 1978 and 1980 studies, the addition of N-Serve (at a rate of 0.42 lbs/1000 gal.) to swine manure applied in the spring at rates of 22 and 20 tons/acre, respectively, resulted in increased corn yields. In the 1980 study, the addition of N-Serve (at a rate of 0.21 lbs/1000 gal.) to swine manure applied in the spring at a rate of 35 tons/acre also resulted in increased corn yields. However, in the 1978 and 1979 experiments the addition of N-Serve (at rates of 0.21 and 0.42 lbs/1000 gal.) to swine manure applied in the spring at high rates ($>$ 28 tons/acre) did not affect corn yields. Likewise, the addition of N-Serve at a rate of 0.42 lbs/1000 gallon to manure applied at a rate of 35 tons/acre in the spring of 1980 had no effect on corn yields.

Response of corn to N-Serve applications with spring-applied manure can be attributed to two factors: (1) timing of manure application and (2) amount of plant-available N applied. Yield increases from N-Serve will only be achieved if N losses are such that the level of plant-available N in the soil is insufficient to meet crop needs. When manure is spring-applied, the time interval between application and N uptake by corn plants is limited. Thus, there is less opportunity for N loss following manure application and less chance that N-Serve application will increase corn yields. Also the rate of N applied to corn is of considerable importance. If the amount of N applied greatly exceeds the amount required by the corn crop, a N deficiency will not develop even if there are large N losses. Under such conditions N-Serve application would not increase yields. Apparently, there were limited N losses following applications in the spring of 1979 (Table 2) because addition of N-Serve (0.5 lbs/acre) to anhydrous ammonia and manure did not increase corn yields.

Fall application of swine manure at rates of 14 to 27 tons/acre increased corn yields as compared to the control treatment. However, the yields obtained with fall applications of swine manure (without N-Serve) were much lower than those from applications of similar amounts of manure in the spring. This finding illustrates that high N losses may occur with fall applications of manure. Corn yields were significantly increased by the addition of N-Serve (0.21 and 0.42 lbs/1000 gal.) to swine manure applied in the fall at rates of 14 to 27 tons/acre (Tables 2 and 3). This finding suggests that N-Serve significantly reduced N losses by maintaining the applied N in the ammonium form over the winter. Fall application of swine manure (27 tons/acre) treated with N-Serve resulted in yields that were similar to those obtained with 150 lbs N/acre as anhydrous ammonia applied in the fall and with spring applications of manure.

Since fall-applied manure is present in the soil for a much greater length of time before corn planting than is spring-applied manure, greater N losses are likely. Thus, a greater crop yield response is expected from N-Serve addition to fall-applied as compared to spring-applied manure.

Other benefits obtained from applying nitrification inhibitor with swine manure are: (1) increased flexibility in field operations (i.e., manure may be applied in the fall with little N loss, when soil conditions are favorable and labor is available, (2) decreased incidence of corn diseases such as stalk rot (observed during one year of the study), and (3) decreased pollution of ground and surface water from nitrate leaching. Addition of N-Serve to manure also resulted in higher N concentrations in vegetative tissues and higher protein levels in grain of corn especially in experiments where grain yields were increased by the nitrification inhibitor (Tables 1, 2, and 3).

CONCLUSIONS

1. The use of liquid swine manure as a fertilizer for corn resulted in yields similar to those obtained with inorganic fertilizers, thus, providing livestock producers with an economically feasible alternative to the use of inorganic fertilizers.

2. The addition of N-Serve at a rate of 0.42 lbs/1000 gal. to spring-applied swine manure and at rates of 0.21 and 0.42 lbs/1000 gal. to fall-applied swine manure significantly increased corn yields as compared to applications of similar amounts of manure without the nitrification inhibitor.

3. The addition of N-Serve to fall-applied swine manure resulted in the greatest yield increase due to greater N losses occurring between time of application and corn planting. Very large losses of applied N occurred following swine manure applications without N-Serve in the fall.

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Table 1. Effect on corn yields and tissue nitrogen levels of adding N-Serve to swine manure applied in the spring of 1978.

Treatment	Manure application rate	Available N	N-Serve rate	Grain yield[†]	Ear leaf N[†]	Grain N[†]
	tons/acre	lbs/acre	lbs/acre	bu/acre	--------- %	-----------
Control	0	0	0	90 a	1.96 a	0.94 a
Swine manure	22	168	0	161 bcd	2.72 cd	1.15 bc
Swine manure	22	168	1.1	150 b	2.28 ab	1.01 ab
Swine manure	22	168	2.2	186 e	2.94 de	1.27 cd
Swine manure	49	374	0	186 e	2.94 de	1.29 cd
Swine manure	49	374	2.4	174 cde	2.98 de	1.29 cd
Swine manure	49	374	4.9	179 de	3.17 e	1.35 d
Urea	0.09	80	0	154 bc	2.53 bc	1.04 ab
Urea	0.133	120	0	167 bcde	2.79 cde	1.16 bcd
Urea	0.18	160	0	177 cde	2.91 cde	1.23 cd

[†] Values followed by the same letter are not statistically different ($p = 0.05$).

Table 2. Effect on 1979 corn yields and tissue nitrogen levels of adding N-Serve to fall- and spring-applied swine manure.

N Source	Application time	Available N	N-Serve rate	Grain yield[†]	Ear leaf N[†]	Grain N[†]
		lbs/acre	lbs/acre	bu/acre	-------- %	--------
Check	-	0	0	53 Aa	1.75 Aa	0.91 Aa
Swine manure	Fall 1978	82	0	75 a	1.98 ab	0.90 a
(14 tons/acre)		82	0.7	142 c	2.17 abc	0.98 ab
		82	1.4	122 bc	1.93 ab	0.93 a
Swine manure	Fall 1978	158	0	117 b	1.95 ab	0.92 a
(27 tons/acre		158	1.4	181 d	2.29 bc	1.20 d
		158	2.7	170 d	2.53 cd	1.06 bc
NH_3	Fall 1978	150	0	185 d	2.80 d	1.15 cd
(0.09 tons/acre)		150	0.5	189 d	2.75 d	1.15 cd
Swine manure	Spring 1979	177	0	186 B	2.44 B	1.06 BC
(28 tons/acre		177	1.4	178 B	2.65 BC	1.04 B
		177	2.8	196 B	2.62 BC	1.07 B
NH_3	Spring 1979	150	0	186 B	2.81 C	1.16 CD
(0.09 tons/acre		150	0.5	185 B	2.68 Bc	1.19 D

[†] Values followed by the same letter are not statistically different ($p = 0.05$).

Table 3. Effect on 1980 corn yields and tissue nitrogen levels of adding N-Serve to fall- and spring-applied swine manure.

N Source	Application time	Available N	N-Serve rate	Grain yield†	Ear leaf N†	Grain N†
		lbs/acre	lbs/acre	bu/acre	-------- %	--------
Check	-	0	0	56 Aa	2.02 Aa	0.92 Aa
Swine manure	Fall 1979	93	0	110 b	2.76 c	1.06 b
(17 tons/acre)		93	0.8	142 cd	3.00 d	1.18 bc
		93	1.7	158 d	2.96 d	1.17 bc
Swine manure	Fall 1979	148	0	124 bc	3.00 d	1.19 bc
(27 tons/acre)		148	1.4	145 d	2.98 d	1.23 c
		148	2.7	154 d	2.90 cd	1.16 bc
NH_3	Fall 150	150	0	114 b	2.38 b	0.93 a
(0.09 tons/acre)		150	0.5	115 b	2.56 b	1.05 b
Swine manure	Spring 1980	142	0	98 B	2.43 B	0.98 AB
(20 tons/acre)		142	0.8	97 B	2.37 B	0.96 AB
		142	1.8	124 C	2.41 B	1.07 BC
Swine manure	Spring 1980	255	0	146 CD	2.95 C	1.19 CDE
(35 tons/acre)		255	1.8	165 E	3.01 C	1.28 E
		255	4.0	156 DE	3.02 C	1.27 E
NH_3	Spring 1980	150	0	124 C	2.80 C	1.09 BCD
(0.09 tons/acre)		150	0.5	140 CD	2.82 C	1.22 DE

†Values followed by the same letter are not statistically different ($p = 0.05$).

IS REDUCED TILLAGE FOR EVERYONE?

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YES

With the newer machinery that has been produced and developed in the last several years, it is now possible to precisely place seeds under almost any seedbed conditions. With the new power units it is possible to pull almost any type of equipment. Along with this, we now have the fertilizers, the chemicals to control insects, diseases and weeds, and many other added items. One of the great concerns as we have moved to soybeans in the last 30 years and eliminated the small grains, is that we have developed into a row crop agriculture in southern Minnesota and the rest of the Corn Belt. Erosion has become a very real and critical issue. The question then is, is this the way to stop erosion and reduce costs in this time of a very competitive and narrow margined economy? The question that was not well defined is "what is reduced tillage?" To each individual this is a different concept.

BUT

the putting together of the whole crop production system under a continental climate,that to be normal would be very abnormal, is the key to the whole tillage operation.

There are many parts to fitting this system together, and they must be looked at and tampered with as we move into different tillage systems. One of the first areas that must be looked into is the land type or topography and how it lies. If we look at southwestern Minnesota, the southwest 16 counties which goes all the way over to Mankato, we find (Table 1) that 65% of our land area on 6.14 million acres in agricultural land is less than 2% slope. 30% of the land area is 2-6% slope. On less than 2% slope is it almost impossible to have water erosion so there we need to consider primarily wind erosion.

TABLE 1: DISTRIBUTION OF SOILS BY SLOPE GROUPS IN 16 SOUTHWEST MINNESOTA COUNTIES

% Slope	% of all Land
0-2	65
2-6	30
6-12	4
12+	1

Total acreage 6,143,073 of agricultural land

An additional 10% in non-agricultural land (urban,roads)

On the 5 percent over 6% slope should perhaps be very carefully tilled, if it is tilled at all. A majority of this land area is not subject to water erosion and it becomes a matter of water intake and drainage as a means of water control in these areas.

The soils in the Corn Belt, for the most part, are glacial tills that are very low in phosphorous and fairly heavy textured. They are also derived primarily from the prairies and thus have a fairly high organic matter content. With this combination the structure of the soil is fairly strong and so we get a lot of persistant cloddiness so that when tillage is done in the fall, we can create roughness that will last over the winter. From data that we have, the roughness and cloddiness can be substituted to a high extent for plant residue on these types of soils. This does not hold true, however, for sandy or peaty muck type soils that are found in isolated locations throughout this area. It appears that one of the last things we would want to over-winter with in the Corn Belt would be a smooth level field with little crop residue. Perhaps a good example of how to obtain this would be to disk the soybean field that had been droughty with little residue, leaving it very loose and smooth. Another example would be working down cloddiness and roughness after the primary tillage in the fall so that the surface would slake over from any hard precipitation that sometimes occurs.

The primary purpose of agricultural production, of course, is to produce high and economic yields, not necessarily the highest but those that give the greatest economic return. A great deal of work has gone into looking at this, and a series of tillage residue management studies as established at the Southwest Experiment Station at Lamberton with the ARS group from Morris since 1978. We find that there is very little yield difference between the residue and management if we use fall plow, fall chisel or disk, spring chisel, or till plant with the buffalo, where we had been ridge tilling. These normally are all put in at the same time. We have ample nitrogen, we have no concern for cost of herbicides, insecticides, etc., however, where we only cultivate and use a ripple coulter to prepare a flat seedbed we have normally reduced our yield, often times very considerably. These are small plots and we have hand weeded them and etc. so do not have that as a contributing factor.

TABLE 2: ARS TILLAGE - ROTATION STUDIES 1982
RESIDUE MANAGEMENT - CORN YIELDS

Treatment		Ave. Bu/A
Fall plow -	A. Cont. Corn	148.0
	B. Corn-Bean Rotation	145.7
Fall Chisel -	A. Cont. Corn	135.8
	B. Corn-Bean Rotation	137.1
Spring Disk -	A. Cont. Corn	124.9
	B. Corn-Bean Rotation	143.0
Till Plant -	A. Cont. Corn	151.1
	B. Corn-Bean Rotation	148.6
No Till -	A. Cont. Corn	123.7
	B. Corn-Bean Rotation	150.1

Lamberton

The soybean yields where we grow alternate corn and soybeans also have followed the same pattern as the corn.

TABLE 3: ARS TILLAGE - ROTATION STUDIES 1982
RESIDUE MANAGEMENT - SOYBEAN YIELDS
CORN - BEAN ROTATION

Treatment	Ave. Bu/A
Fall Plow	46.9
Fall Chisel	49.3
Spring Disk	47.8
Till Plant	45.9
No Till	37.0

Lamberton

In a new study established this year on soybean management with tillage being one of the variables, it appears level of tillage had little effect on soybean yields at Lamberton

TABLE 4: SOYBEAN MANAGEMENT TILLAGE 1982

SEED YIELDS BU./A

	Row Spacing		
Tillage	10 Inch	30 Inch	Ave.Yield Bu./A
Plow	47.9	45.5	46.7
Chisel	49.7	45.0	47.4
Disk	47.9	44.8	46.4
No Till	44.8	41.7	43.2
Average	47.6	44.3	45.9

Lamberton

and at Waseca.

TABLE 5: SOYBEAN MANAGEMENT TILLAGE 1982

SEED YIELDS BU./A

	Row Spacing		
Tillage	10 Inch	30 Inch	Ave Yield Bu./A
Plow	47.0	43.8	45.4
Chisel	46.3	43.6	45.0
Disk	47.3	44.4	45.8
No Till	46.2	44.4	44.7
Average	46.7	44.1	45.3

Waseca

One problem at planting time was getting the seed into the ground on the no till. This required some hand labor. If, with a wet fall and corn picked after freeze up, it would appear a minimum of preparation would be needed for soybeans next year. However, next fall, if there was a lot of compaction this fall and next spring, this should be considered in the tillage option.

There must then be many other factors that must be taken into consideration in determining what tillage operation to perform. The long term and historic use of various tillage systems have been to help control insects, plant diseases that harbored over on residue as well as weeds and weed seeds, With the advent of pesticides, some of these can be overcome without the use of tillage, however, there are a number of herbicides that must be incorporated if they are to be used. With a very reduced tillage system, this becomes very difficult. The further west in the Corn Belt one goes,with reduced rainfall and probability of rainfall after herbicide application, the more important it becomes to at times have incorporated herbicides which are more drought proof. Thus we have a Catch 22 in that the areas where we need to be most concerned about wind erosion is also the area where we need to perhaps use the incorporated herbicides most. On the other hand, in these drier areas, there is a greater probability, also due to climatic conditions, that there may be come carryover on herbicides applied. In 1981 a soybean field on which we had applied 3/4 pound DNA (Treflan) in the spring, we applied 3/4 pound DNA versus nothing in the fall. We then had four tillage systems and looked at the plant growth and injury etc. in 1982.

TABLE 6: TILLAGE & DNA EFFECT ON CORN GROWTH - INCHES
1982

Tillage	DNA	Fall Applied*
	0	3/4 #
No Till	92	
Plow	94	88
Disk	90	72
Chisel	90	71

*3/4# DNA used spring before on entire area

Lamberton

This indicates that there isn't a great deal of difference in the growth of the corn with no DNA applied in the fall of 1982, however, where 3/4 pound was applied in order to simulate a very large amount of carryover, there was a great difference in tillage effect on corn growth. With the plowing we apparently had almost normal growth,perhaps due to the additional mixing and dilution of the carryover chemical. There are times with various chemicals and climatic conditions where this practice may be of value and use to prevent injury from carryover.

The soil water, air contents of the soil along with compaction has many possible effects. However, one of the first ones we become concerned with is the utilization of nitrogen. With the higher organic matter level that we have, long term experiments at the Experiment Station indicate that we can produce approximately 65-70 bushels of corn with conventional tillage on a 22 year average without added nitrogen but only using the residual nitrogen from organic matter mineralization. In reality, this is a slow burning of the organic matter and this requires an adequate amount of air and as we tend the soil, we tend to increase this. Thus we have never been able to maintain the organic matter that was present at the time the prairies were broken due to the increased mineralization rate that occured.

In a study conducted with the ARS group we endeavored to look at the nitrogen tillage interaction.

TABLE 7: NITROGEN - TILLAGE - ARS - LAMBERTON
1980

Lb.N/a	Mod. Ridge Till	Fall Chisel	Fall Plow
14	46	74	99
54	79	90	108
96	104	111	125
140	116	126	125
180	115	124	124

Oleness - ARS Morris

TABLE 8: NITROGEN - TILLAGE - ARS - LAMBERTON

1981

Lb.N/a	Mod. Ridge Till	Fall Chisel	Fall Plow
14	68.4	86.5	82.2
54	76.2	95.6	87.6
96	91.5	111.7	108.8
140	103.7	105.7	100.0
180	103.1	102.5	96.2

Oleness - ARS Morris

TABLE 9: NITROGEN - TILLAGE - ARS - LAMBERTON

1982 - Hybrid 1

N. Fert.*			Mod		
Preplant	Side	Total	Ridge Till	Fall Chisel	Fall Plow
0	0	17	53.1	72.8	96.1
40	0	57	81.6	92.7	106.4
40	32	89	101.5	106.7	121.8
80	32	129	121.7	126.0	126.6
80	63	161	126.7	126.4	133.6

* 17 lb./a N as starter

Oleness - ARS Morris

TABLE 10: NITROGEN - TILLAGE - ARS - LAMBERTON

1982 - Hybrid 2

N. Fert.*			Mod		
Preplant	Side	Total	Ridge Till	Fall Chisel	Fall Plow
0	0	17	45.6	59.7	93.5
40	0	57	80.6	85.6	107.9
40	32	89	101.9	112.4	133.4
80	32	129	124.2	125.9	134.4
80	63	161	134.7	126.8	137.9

* 17 lb./a N as starter

Oleness - ARS Morris

In this experiment we used 0,40,80,120 and 160 pounds of N per acre along with a starter with three levels of tillage. One is a modified ridge till in which we cultivate and put up some ridges and plant in them; a fall chisel with normal cultivation, and a fall plow with normal other tillages. After 3 years and 2 hybrids in 1982, we come up with a relatively similar pattern. It appears that we can obtain near maximum yield with 80-100 pounds of nitrogen under fall plow, however, it takes approximately 40 pounds more to obtain this with reduced tillage methods such as modified ridge and fall chisel being intermediate. In looking at this, it appears as though there is little difference in tillage systems if adequate N is applied, however, it also indicates that it takes approximately 40 pounds more nitrogen to obtain yields comparable with more fall tillage. If this is the case, then this must be counted as a cost in a tillage system.

There has been a long time study on soil temperatures and moisture and it appears that the less fall tillage done and the more residue left on the surface that the colder the soil will be. During spring planting in the northern Corn Belt we are usually planting at the very edge of germinating temperatures and every degree or two makes a vast difference in growth. This is perhaps the reason that the ridge till is superior to no till this far north in that the ridges warm up faster and then the residue is skimmed off between.

There is also the matter of timeliness and the number of hours that it takes to get a job done. Time that is available, if one is to be on time 80% of the time, we would have to put all the corn and soybeans in in 7½ days. If the system that you use to put in the corn and soybeans is slower in the spring, then this will cut this down even more. In other words, your time is much more valuable at planting than perhaps any other time of the season. The other high value time is during harvest when you have approximately 15-18 days to get your crop out if you are going to get it out on time 80% of the time. The other times require less specialized help and high quality labor. Thus they are low value times and can be performed by a great number of people and at a lower cost in as much as the time frame is not nearly as critical.

It appears as though a variable tillage system where you can work out a number of the factors of the system to the best advantages is the more desirable.

In the end you must be a professional. You must adapt a PROfessional stance when you are doing tillage. The tillage performed must be the one that gets the highest score when all the factors in PRO-tillage are rated.

TABLE 11:

	TECTIVE	
	FITABLE	
	FESSIONAL	
PRO	ENVIRONMENTAL	TILLAGE
	FICIENT	
	GRESSIVE	
	SCRIPTION	
	SPER	

SHOULD WE ROTATE OUR CORN AND SOYBEANS?

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INTRODUCTION

Crop rotation has been a subject of popular discussion and debate by farmers, agronomists and the agricultural industry for years. For many years crops were routinely rotated to reduce pest problems, supply nutrients and provide a variety of livestock feed. As the cash grain farmer and livestock producer became large and more specialized, the traditional rotations involving forage legumes were often abandoned in favor of a corn/soybean rotation or a continuous corn monoculture system. Some farmers have been growing continuous soybeans also.

With the current crop price situation and the input costs associated with various crop rotations, does it benefit the farmer to rotate his corn and soybeans? The purpose of this discussion is to outline some of the most recent research results from our crop rotation studies and present the agronomic advantages and disadvantages of rotating crops.

RESULTS

Corn Yields

Studies were initiated in the mid-70's at Waseca to determine the long-term effects of crop rotations. One of these studies involved four crop sequences (continuous corn, corn-soybeans, corn-wheat and corn-wheat + alfalfa) and six rates of N (0, 40, 80, 120, 160 and 200 lb N/A) to determine the crop sequence effects as well as the optimum rate of N for corn in each one of these rotations. The N was applied as ammonia each spring prior to planting. Corn was planted in 30" rows at 26,100 ppA in early May each year. The hybrid was Pioneer 3709 in 1977 and Pioneer 3780 in 1978-80. All corn plots regardless of the previous crop received an insecticide at planting. Furadan was used in the even years and Counter in the odd years. Agate alfalfa was interseeded with the wheat (wheat + alfalfa) and was allowed to grow following harvest of the wheat. All plots were moldboard plowed each fall. Results from this study for 1977-1980 are presented in Table 1.

Table 1. Corn yield as influenced by crop rotation and N rate at Waseca from 1977-1980.

Crop rotation	N rate (lb/A) 0	120	160	200
	------Yield (bu/A)[1/] ----			
Cont. corn	84	136	143	146
CS	122	163	166	169
CW	115	160	164	168
CW+A	127	165	166	165

[1/] Each yield is an average of 16 values (4 years x 4 replications/yr.)

Continuous corn yields averaged 20-25 bu/A less than corn following soybeans, wheat or wheat + alfalfa even when N rates were more than adequate (Table 1). Corn yields following soybeans, wheat and wheat + alfalfa were similar. Within the statistical variations of the data, the N rate for corn was optimized between 160 and 200 lb/A following corn and between 120 and 160 lb/A following soybeans, wheat or wheat + alfalfa.

This experiment was modified substantially in 1981 and 1982 to include:

1) a comparison between continuous corn where only the grain is removed each year and continuous corn where all of the forage is removed as silage

2) a comparison of second-year corn vs first-year corn following soybeans

3) a comparison of two hybrids of different genetic background and relative maturity

4) the elimination of the wheat + alfalfa previous crop and

5) a fifth replication.

All other experimental procedures were the same as mentioned previously except that a planting population of 29,900 was used. The yields from the two hybrids (Pioneer 3901 and 3732) were not markedly different and have been combined in Table 2.

Table 2. Corn yield as influenced by crop rotation and N rate at Waseca in 1981 and 1982.

Crop rotation	N rate (lb/A) 0	40	80	120	160	200
	Yield (bu/A)[1/]					
1981						
Cont. corn (grain)	111	148	169	182	188	191
Cont. corn (silage)	132	160	180	184	189	191
CW	133	169	183	186	189	190
CS	153	174	189	197	197	196
1982						
Cont. corn (grain)	83	118	148	162	172	168
Cont. corn (silage)	108	140	161	173	170	177
CW	113	150	171	176	173	171
CS	115	148	173	174	182	180
CCS[2/]	73	112	154	169	179	178

[1/] Each yield is an average of 10 values (5 replications x 2 hybrids/plot).

[2/] Second year corn following soybeans.

Results from the past two years at less than optimum N rates indicate continuous corn yields following silage removal to be higher than when only the grain was removed. At optimum N rates (160 lb/A) differences in yield were not found between the two continuous corn systems. Corn following soybeans yielded slightly more than corn following wheat which yielded about the same as continuous corn at the higher N rates. Second year corn following soybeans showed a strong response to N but did not yield comparable to first year corn following soybeans until N rates of 160 or 200 lb/A were used.

Another long-term study involving different crop rotations was also started in the mid-70's. Nitrogen rates were optimized at 200 lb/A each year for all rotations. Pioneer 3780 was the hybrid used each year. Other crop management procedures (pesticides, population, etc.) have been used to maximize the yields reported in Tables 3 and 4.

Table 3. Corn yield as affected by pervious crop at Waseca.

Previous crop	Year 1977	 1979	 1981	 AVG.
	Yield (bu/A)			
Corn	146	140	172	153
Soybeans	154	146	181	160
Adv. for rotation	+8	+6	+9	+7

A consistent corn yield advantage was found for the corn-soybean crop sequence as compared to continuous corn (Table 3). Over the three years when direct comparisons could be made an average gain of 7 bu/A was obtained following soybeans.

Table 4. Corn yield as influenced by position in the crop rotation at Waseca.

Crop rotation	Year 1977	 1980	 1981	 AVG.
	Yield (bu/A)			
CS	156	100	174	143
CCS[1]	150	92	167	136
CCW[2]	145	75	163	128
Cont. corn	146	85	166	132

[1] Second year corn following soybeans.

[2] Second year corn following wheat.

Corn in the year following soybeans produced the highest yields in this study (Table 4). Yields from second year corn following soybeans were slightly less but were greater than second year corn following wheat or continuous corn; especially in the dry year (1980).

Soybean Yields

The influence of previous crop and crop rotation on soybean yields has not been studied as much as on corn. However, information has been gathered over the past few years in a couple of studies on the influence of previous crop on soybeans (Tables 5 and 6).

Table 5. Soybean yields as affected by the number of years of continuous soybeans following corn at Waseca.

Years of continuous soybeans after corn		Year 1980	1981	1981[1]
		------Yield (bu/A)-------		
CS	1st year	49.3	56.3	54.3
CSS	2nd year	41.5	54.3	----
CSSSSS	5th year	----	----	46.1

[1] From a tile line drainage study.

Consistent yield depressions were noted when soybeans were grown for two or more consecutive years following corn (Table 5). In 1980, a stress year, soybeans yielded almost 8 bu/A less when grown for two consecutive years. Yields in the same study in 1981, a non-stress year, only showed a 2 bu/A decline. However, in the same year an 8 bu/A depression occurred with the Hodgson variety when grown for five consecutive years.

Table 6. Soybean yield as influenced by the number of previous corn crops prior to soybeans at Waseca.

Crop rotation	Year 1978	1982
	-----bu/A------	
CS	55.6	35.7
CCS	57.9	44.0
Adv. for two-years corn	2.3	8.3

Although the data in Table 6 are from only two years, they do indicate a favorable trend (from a soybean standpoint) toward more than one year of corn previous to soybeans. In a non-stress year (1978) a yield advantage for two years corn of 2.3 bu/A was found in contrast to an 8.3 bu/A gain in the stress year (1982).

OTHER CONSIDERATIONS

Nitrogen fertilizer

The data in Tables 1 and 2 clearly show that N rates for corn can be reduced by rotating corn with soybeans or wheat. On the average this reduction equals about 35-40 lb N/A. Depending on the N price, source of N and perhaps application method, this can result in a savings from $5 to $11/A.

Insects

Compared to continuous corn rootworm activity following soybeans is generally not severe enough to cause yield reductions when no insecticide is used. Thus, a savings of $6-9/A can be achieved by omitting the corn rootworm insecticide when following another crop besides corn.

Diseases

Continuous corn has been known to provide a good environment for certain diseases, i.e., eyespot, head smut. On the other hand soybean diseases such as phytophthora and brown stem rot are known to be more prevalent where soybeans follow soybeans. Thus, from a disease standpoint crop rotation makes good sense.

Weeds

Crop rotation offers the farmer a wider spectrum of herbicides for controlling weeds than do the continuous monocultures. As an example, grasses such as wild proso millet can be controlled very well in soybeans by some of the new postemergence herbicides, but they can't be controlled well in corn. Conversely, some of the broadleaves can be controlled very economically in corn by 2,4-D, dicamba, etc. Rotating crops and herbicides lessens the chance of monoculture weed infestations. A negative aspect of rotating crops would occur with the carryover of herbicides. This can occur with both corn and soybeans.

Reduced Tillage

Very little tillage, in some cases none, needs to be done for corn following soybeans. With the new herbicides becoming available, very little tillage will be necessary for soybeans following corn. (Previous studies by Carter and Randall at Waseca showed soybean yields with no tillage following corn to be equal to that following moldboard plowed corn as long as weeds were controlled.) Yet on the heavy textured soils of south-central Minnesota rather vigorous tillage is needed for continuous corn (unless a ridge-plant system is used). In summary a crop rotation for corn and soybeans should save both time and fuel usage for tillage.

Erosion

Rotation of soybeans with corn can lead to serious erosion problems on most of our strongly sloping soils. Soybeans do not leave much residue on the soil surface and also leave the soil in a very friable condition for soil erosion. Continuous soybeans would be a poor choice. For these reasons, continuous corn or crop rotations including alfalfa would be preferred on our more erosive soils.

Soil Water

A crop of soybeans requires less water than corn, especially late in the growing season. This can result in a greater amount of soil water left in the profile for the next crop when including soybeans in the crop rotation. This may be of particular importance in the western portions of the state.

Time Expansion

Dividing one's acreage into both corn and soybeans (or other crops) spreads the critical planting and harvesting seasons out over a longer period. Soybeans can be planted later than corn without hampering yields. This in turn may be economical for the farmer as well as put less stress on him.

Risk Factor

Growing more than one crop spreads the risk factor (planting time weather, hail, summer drought, harvest weather, machinery breakdowns) out.

Production Costs

A careful analyses of the production costs has to be obtained for each individual farmer. However, production costs of a crop rotation are often less than for a monoculture.

Crop Price/Usage

The price that a farmer thinks that he can get for his crop will have a definite bearing on his decision whether or not to rotate, or how much to rotate. Also, how much of his crop he needs to feed his livestock will affect his decision.

SUMMARY

When answering the question "Should we rotate our corn and soybeans?" we must take into account the factors mentioned above. If we do this carefully, we can see that in almost all cases it will be profitable to rotate crops.

FUTURE DIRECTIONS IN EXTENSION

Gene Pilgram, Assistant Director
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THE SETTING

The Agricultural Extension Service is approaching seventy years as an institution serving the agricultural industry as well as the general population. As institutions tend to change slowly, we might look at recent years to predict future directions, then analyze the forces that may dictate change for Extension in the near future. Extension, by its cooperative (state, federal and county) support base, must be responsible to the people it serves. Thus, peoples needs and interests will be a strong determinant of future programs.

Extension is part of the Land Grant College System and by definition "extends" the research of that system. This suggests that future directions will be heavily influenced by agricultural related research.

Societal concerns impact on Extension program direction. Energy shortages, natural resource use, environmental quality, human safety are but a few examples of issues in the U.S. society where expectations have been developed for Extension to play an educational role.

The setting in which Extension programs are determined is thus influenced by four major factors:

1. The legal base or legislation creating Extension and administrative response to that mission
2. The expressed needs of the people being served
3. The research base and its analysis by specialists
4. The broad societal needs and concerns.

The following discussion will focus on the directions being taken in the Minnesota Agricultural Extension Service for the near future. The focus here is on programs relating to agriculture and its related industries. A similar presentation can be made for the community, home/family and youth phases of extension work.

EXTENSION MISSION FOR THE 1980's

There are five broad subject areas that will receive major attention in the Agricultural programs in Extension. These are listed here in priority order:

1. Efficiency in food/fiber production
2. Business and marketing management in agriculture
3. Conservation of natural resources
4. Environmental quality and human safety
5. Leadership and organizational skills development

THE PEOPLE SERVED BY EXTENSION

Minnesota's four million plus people are the audience for extension education-information programs. As extension programs are not for formal credit, are voluntary in nature, and research based, they must meet the needs and interests of local people.

In Minnesota, extension programs relating to Agriculture are planned to serve people in the following order of priority:

- Producers of food/fiber with farm income the major source of livelihood
- Agricultural leaders, public and private, in agribusiness who work directly with farm producers and/or provide goods, services or consultation
- Individuals or firms who handle, market or process agricultural products
- Other producers of agricultural products, not dependent on these products as a major source of livelihood
- Consumers of food and fiber and the general public seeking agricultural related information.

Innovative responses to needs of the lower priority listings are being expanded. Use of volunteers, low cost publications, user charges for program, mass media communication are but a few.

CRITERIA TO DETERMINE EXTENSION PROGRAMS IN AGRICULTURE

The authorizing legislation: federal, state and county; the mission and the clientele set the general parameters for extension work. Within these guidelines a frequent question is: What criteria influence decisions of how staff and support resources are utilized?

For Agriculture programs in Minnesota Extension the following criteria in ranked order are being used to guide future directions.

Consideration must be given to:

- How the program relates to the mission of extension
- How the program fits the clientele priority list
- The potential for extension education impact, i.e. research base and technology gap
- The economic value and potential
- Number of people affected
- Uniqueness to extension. Can someone else do it as well or better?
- Agricultural industry support and activism
- Political/societal expectations or pressures.

These criteria become guidelines for extension planning. No one item is a sole determinant of extension program direction. Those who provide the support dollars plus extension administrators, have the responsibility to weigh and decide the various criteria.

RELATED FACTORS

In addition to the mission, clientele and criteria, several forces are impacting on Extension's present and future directions.

1. The resources available to support the research base and the staffing of Extension positions. Will the Minnesota economy sustain the needed support?
2. The communications technology that is developing, computers in agriculture, cable T.V., satellite delivery systems, etc.
3. The specialized nature of agriculture related technology. Need for trained staff, and the need for agriculture related people to have in-depth technical extension education/information.
4. The need for and the ability of modern agriculture to pay, as users, for many of the traditionally public supported educational activities, i.e. publications, seminars, computer software, etc.
5. The place of the private consultant in agriculture and how Extension can best serve these people.

SUMMARY

I see Extension as a vital partner in the growth of the agricultural industry in Minnesota. Research needs interpretation and application to agriculture. Extension will do more of this in a more specialized sophisticated manner in the future. County agents will have to be generalists in part, but will have developed a strong subject matter expertise as a key leader for local agriculture. State level specialists will serve agriculture through specialized local agents and industry leaders, and through development of educational materials - written, electronic, etc., for these leaders.

Working closely with the Agricultural Experiment Station, Agricultural Extension will place renewed emphasis on increasing the productivity of agriculture and agri-business in Minnesota. Extension programs will continue to focus on research-based technology, improved management and marketing education. Research and Extension programs will provide a basis for improved development of integrated production-management systems for large family farms and smaller low-resource farms. Priority programming will be directed to commercial producers and related agribusiness clientele. There will be renewed initiatives for educational program thrusts in marketing, integrated farm business management systems, integrated pest management, livestock reproduction efficiencies, conservation of soil, soil and energy, public policy issues related to agriculture and preservation of agricultural land. Attention will be given to the value added industries. Expansion of enterprises, such as commercial vegetable production, will be an area where Extension can provide a strong input. All of this effort will contribute to an improved Minnesota economy.

ENTOMOLOGY FACT SHEET No. 9
Revised 1983
PHILLIP K. HAREIN

PREVENTING STORED-GRAIN INSECT INFESTATION

Minnesota grain is generally safe from infestation by stored-grain insects before harvest. This is not true for many of the southern states. The only exception in Minnesota may be where grain is cut and swathed adjacent to storage bins being treated with an insecticide (including fumigants) in preparation for the new crop. Stored-grain insects will migrate away from treated bins for short periods of time.

A survey of stored corn and wheat on Minnesota farms in 1977-1980 revealed the presence of many insect species that feed on moldy grain. These included the flat grain beetle, the rusty grain beetle and the foreign grain beetle. Other species noted were the sawtoothed grain beetle, the red flour beetle, the confused flour beetle and the Indianmeal moth.

Many species of stored-grain insects develop through their worm stage (eggs and pupal stage also for some species) within kernels of grain. These are usually weevils or the lesser grain borer. Other insect pests do not develop within kernels. However, they will feed into the germ and advance later into the endosperm. They prefer broken kernels, but will feed also on sound whole kernels.

Accumulations of post-harvest grain are primary targets for insect infestations especially if stored with or adjacent to old grain. The initial site where this post-harvest infestation can begin is within the harvesting machinery. Unfortunately, this equipment is not designed to remove old grain from last year's harvest. The same applies to grain augers and elevators and the sub-floors or aeration ducts in most storage bins.

Although stored-grain insects can be killed by various chemical and non-chemical methods, thorough sanitation (with the use of insecticides as a supplement rather than as a substitute for sanitation) is the most effective procedure for preventing insect infestations.

CONDITIONS THAT ENCOURAGE STORED-GRAIN INSECTS

Temperature, moisture, and grain dockage or broken kernels interact providing adequate (if not optimum) conditions for stored-grain insect reproduction and survival. The most favorable grain temperature for these insects is about 80°F. At temperatures above 90°F or below 60°F, reproduction is nil and survival time is reduced.

The most favorable moisture range for stored-grain insects is 12% to 18%. Insects that feed on mold prefer the higher moisture levels. However, as temperatures increase insects can reproduce in grain with relatively low moisture content, and when moisture increases they can reproduce at relatively low temperatures.

Insect infestations differ in clean vs. dirty grain. Dockage will directly influence the preference in subsequent insect infestation of grain. This is the primary reason insects often accumulate in spout line areas.

Unfortunately over-filling bins is a common practice in Minnesota which results in inadequate space to inspect or treat the grain. Uneven grain surfaces also contribute to nonuniform air flow during aeration. Level the grain, after binning is complete, at least 6 inches below the top of the bin wall. Or, immediately following harvest, level the grain to the proper height in an over-filled bin by removing enough grain from the bottom of the spout-line area. This grain will contain a relatively high percentage of broken kernels and foreign matter. Feed it to livestock, screen it before rebinning or sell it.

Inspect grain at 7 to 30 day intervals, depending on the potential for increased insect infestations. Check for insects by screening them from the grain, examining kernels for damage, looking for webbing, detecting off-odors or determining grain temperatures. The temperature could be as high as 110°F due to the insect activity. During the summer and fall, insect infestations are usually near the surface of the grain. During cold weather these insects will congregate to the center of the grain mass.

PREVENTING INFESTATION OF STORED-GRAIN INSECTS

Spraying Facilities

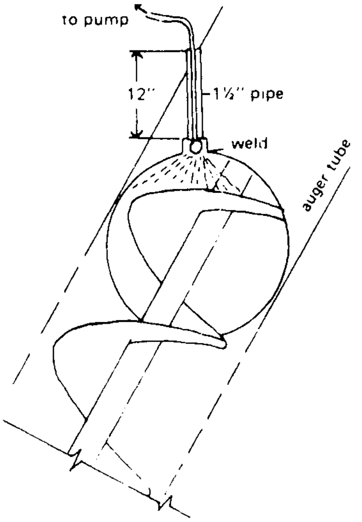
Thoroughly clean combines, trucks, wagon beds, conveyors, elevators and bins. Spray the surfaces of the equipment that will be in contact with the grain with one of the following insecticides at least 2 weeks before harvest.

Insecticides	Amount of insecticide mixed with water
methoxychlor 50% W.P.	1 lb/2.5 gallons
methoxychlor 25% E.C.	1 qt/2.5 gallons
malathion-premium grade 50 to 57% E.C.	1 pt/3 gallons

W.P.=wettable powder
E.C.=emulsifiable concentrate

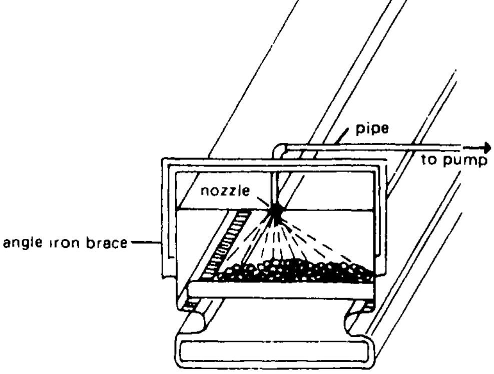
Spray to the point of run-off using 1 gallon of total formulation containing one of the insecticides listed above per 500 square feet of surface. A 2- or 3- gallon compressed air garden sprayer should be adequate for applying these insecticides. Also spray the outside walls of the bins to a height of 6 feet and the ground to a distance of 6 feet out from the foundation of each bin. Wettable powder suspensions must be agitated frequently in the sprayer during application to insure uniform dosages. Mix only one days' supply of these formulations as they lose their effectiveness in contact with water overnight.

Figure 1. Spray applicator into grain auger.



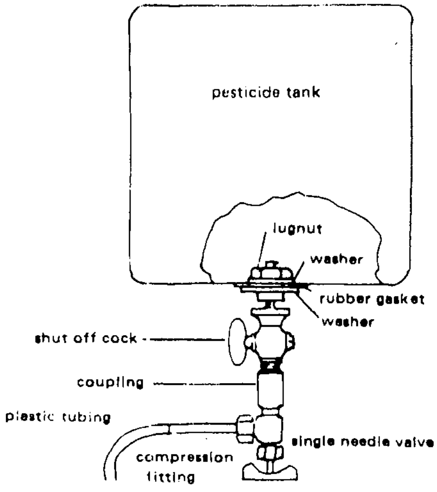
NOTE: Clamp nozzle inside approximately 12" length of 1½" pipe. Be sure pipe is large enough to observe spray pattern. Place nozzle near intake end of auger tube, but above grain level in hopper.

Figure 2. Spray applicator into grain conveyor.



NOTE: For convenience, locate spray nozzle near hopper end of conveyor. Adjust nozzle height to give coverage across entire width of conveyor.
(From University of Georgia College of Agriculture. "Protect Stored Grain From Insect Damage" by John French.)

Figure 3. Drip-on applicator.



(From Jim Quinlan, USDA, Manhattan, Kansas.)

It is not recommended to mix new grain with old grain in storage. However, if it is not possible to remove the old grain before harvest, check it carefully for stored-grain insects and, if needed, treat it with recommended residual insecticides or fumigants before adding new grain.

Grain Protectants

Insect infestation is prevented or reduced by treating small grain and shelled corn as they are moved into storage with one of the approved insecticide formulations described below:

malathion - 1 pint 50% to 57% premium-grade E.C. per 2 to 5 gallons water per 1,000 bushels.

malathion - 1% premium-grade in wheat flour dust, 60 pounds per 1,000 bushels (also available in 2, 4 and 6% dust formulations).

Malathion is registered for use directly on stored barley, corn, oats, rye, sorghum, and wheat. It cannot be applied to stored soybeans or sunflowers. Grain can be fed or sold anytime after treating. The protection provided by malathion is reduced to a few weeks if the treated grain is warm and has a high moisture level. Malathion on cool dry grain should be effective for 3 to 6 months.

Protectants are formulated as dusts or liquids. Dusts can be added to the grain stream as it is elevated or conveyed into the bin. Liquids can be applied adequately as a spray (see figures 1 and 2) or with "drip-on" applicator (see figure 3).

A simple "drip-on" applicator for metering liquid formulations is adequate. To build the applicator, fit two brass plumbing valves and polyethylene tubing in sequence to an opening in the bottom of a container to hold the insecticide formulations. This container is suspended over the top of the auger or conveyor with the end of the tubing positioned so the insecticide can drip directly into the grain. A shut-off cock on the container serves as an on-off valve, while a needle valve regulates the amount of insecticide applied. The needle valve is calibrated to the desired flow for the amount of grain being delivered into storage. Two hundred bushels can be treated at the 5 gallon per 1,000-bushel rate with 3.2 ounces of 57% malathion emulsifiable concentrate mixed with one gallon of water.

Surface Grain Treatments

Suggested rates for the surface treatment of filled grain bins are:

malathion - 1/2 pint 50% to 57% premium-grade E.C. in 2 gallons of water per 1,000 square feet of grain surface area.

malathion - 1% premium-grade in wheat flour dust, 30 pounds per 1,000 square feet.

Apply the spray evenly over the surface immediately after the grain is loaded into storage and leveled off. This "topping off" treatment helps prevent insects from infesting the grain on the surface.

If grain is to be stored for long periods, it is necessary to have adequate drying and aeration equipment to maintain grain temperature and moisture control. However, malathion should not be applied to the grain until it is dried adequately. Drying and aeration should be considered part of an integrated insect management program with the malathion treatments.

Information Source

For details on aeration equipment for grain temperature control refer to the University of Minnesota Agricultural Extension Service Publication #M-165 "Management of Stored Grain With Aeration."

A current list of approved residual insecticides for use in empty bins and directly on the grain is available from the Minnesota Department of Agriculture, 90 West Plato Blvd., St. Paul, MN 55107 or Mr. Ron Gardner, University of Minnesota, 228 Hodson Hall, St. Paul, MN 55108.

ENTOMOLOGY FACT SHEET No. 50 **FUMIGATING STORED GRAIN**

Revised 1983
PHILLIP K. HAREIN

Stored grain should not require fumigation in Minnesota, especially if adequate preparations are provided to prevent insect infestations by proper sanitation and the use of residual insecticides (see Entomology Fact Sheet No. 9, "Preventing Stored Grain Insect Infestation"). Moving or aerating grain, especially when air temperatures are low enough to reduce grain temperatures to 60^{O}F or lower, will reduce insect activity. Malathion can be applied as a residual insecticide to supplement a stored-grain insect pest prevention program. A fumigation may be justified if the insect prevention efforts fail.

Fumigants can be applied as solids, liquids, or gases but they all must be in the gaseous state to penetrate grain and kill the insects. They have no long-term effectiveness; as soon as they diffuse away from the target area, insect reinfestation can follow immediately.

It often is safer, less expensive, and more effective to have your stored grain fumigated by a licensed and certified professional fumigator than to do it yourself. This applies especially to single bins containing more than 5,000 bushels. Flat storage structures are usually more difficult to fumigate satisfactorily than upright bins because of the relatively large grain surface area in flat storages where insects congregate and fumigants dissipate quickly to ineffective concentrations.

There are several reasons to consider hiring a professional fumigator to conduct your fumigations. The most important reason is your personal risk in handling a highly toxic pesticide. A professional fumigator will; 1) have both the knowledge and experience in fumigating, 2) have the special equipment required to apply fumigants and 3) be aware of the safety devices (such as gas masks) to prevent overexposure.

The grain fumigant application method most often used on Minnesota farms is pouring liquid type fumigants onto the surface of the grain mass. Recommended dosages usually range from 2 gal. to 5 gal. per 1,000 bu. of grain. Thus, in a 20,000 bu. bin this would require a minimum application of 40 gal. of fumigant. Most Minnesota farmers would apply these liquid fumigants by inverting a sufficient number of 1 gal. or 5 gal. containers of the fumigant into the grain surface. The time required for such an application to a grain mass of over 5,000 bu. could be excessive for the applicator especially if the proper gas mask was not being worn properly. Two people should always work together when fumigating. Both need adequate safety equipment. Grain bins must also be posted with adequate warning signs during the fumigation, but then be removed when the fumigant has been released. However, grain fumigants can be used satisfactorily if proper safety measures are followed and the major factors (listed below) that alter the effectiveness of a fumigation are understood.

TEMPERATURE

Grain temperature is extremely important, as it controls the speed of fumigant vaporization and penetration of the gas through the grain. Low grain temperatures (less than 50°F) significantly slow down the movement of the gas. Insect respiration is also reduced at temperatures below 50°F, resulting in reduced kill. Extended fumigation periods may be needed. The adjustment for grain temperature is often given on the label.

MOISTURE

High moisture grain retards the movement of the fumigant and may result in increased absorption into the grain kernels resulting in reduced gas concentrations and higher residues.

BIN CONSTRUCTION

A fumigant must be held in the grain long enough and at sufficient concentrations to kill insects. Tightly sealed metal or concrete structures are required for some fumigants. Carefully caulked wooden bins can be used. Covers of polyethylene or plastic-coated nylon will be helpful to assure effective fumigation in any grain storage facility.

DEPTH OF GRAIN

The shape and depth of grain in the bin also affects the fumigant. Upright bins present a minimum of grain surface for the loss of the gas. A gas-tight cover should be used whenever possible over grain in flat storages or when a bin is only partially filled.

VENTILATION

Most fumigants are heavier than air and sink through the grain. Penetration through the entire grain mass, especially in deep bins, can be assisted by using aeration. Remember to seal off the aeration system during the actual fumigation. Aeration also can be used to remove the fumigant following the recommended exposure period.

DOCKAGE

Dockage in grain presents another variable affecting the efficiency of a fumigant. The sorptive capacity of grain will increase with increases in dockage. As grain is loaded into bins the light dockage (chaft, dust, etc.) settles around the outside of the grain mass while heavier dockage settles or is trapped near the center. This uneven distribution of dockage causes fumigants to channel through grain by flowing through areas of least resistance. Insects congregate in areas of high dockage and may escape lethal gas concentrations.

FUMIGANT AND DOSAGE

Although fumigant formulations vary in their efficiency, this variable is usually of less importance than the variables listed above. Whatever fumigant you select follow recommended dosages. Less than maximum labelled dosages may require refumigation. Excessive dosages are wasteful and can initiate unnecessary hazards.

FUMIGATION GUIDELINES

Effective fumigations result from following several recommended guidelines such as the following:

- Level the grain. Remove or break up any crust on the surface.
- Seal all cracks, making the bin as airtight as possible.
- Fumigate when the grain temperature is between 70° and 90°F.
- Keep the bin closed for at least 72 hours after applying the fumigant.
- DO NOT ENTER the bin during or after fumigation until gasses have been removed by aeration.

FUMIGANT CHARACTERISTICS

Basic characteristics of some of the most common fumigants used for stored-grain insects in Minnesota are listed below:

Type	Characteristics
Liquid grain fumigants:	
Tetrafume Tetrakill Dowfume 75 Vertifume Weevil-Cide	Liquid formulation usually containing various percentages of carbon tetrachloride, carbon disulfide, ethylene dibromide and ethylene dichloride. Pungent odors are common.
Larvacide	Liquid formulation of chloropicrin. Good penetrator. Low concentrations irritate eyes.
Solid grain fumigants:	
Phostoxin Fumitoxin Gastoxin	Solid formulations that release phosphine. Carbide-like odor. Relatively easy to apply. Excellent penetrator.

PHOSPHINE FORMULATIONS

Phosphine is applied to grain from various solid formulations. It can be applied to grain by prorating the tablets, pellets or packets of powder in the grain as it flows into storage or by injecting the tablets or pellets into binned stored grain using a special metal probe. The procedure calls for pushing the probe into the grain mass and then applying the solid formulation through the center of the tube as it is withdrawn. The phosphine formulations may also be applied to layers of grain in the bin during loading to aid in the distribution of phosphine. However, since the phosphine gas is usually released within 2 hrs. after the formulation is applied to the grain, it should be covered with plastic following each phosphine application if the bin is not going to be filled within 2 hrs.

SELECTING A FUMIGANT

The selection of fumigants for your particular need may be difficult. They vary in their chemical, physical and biological factors. As a guideline, an ideal fumigant should have most of the following properties:

1. low in cost per effective fumigation;
2. highly and acutely toxic to all developmental stages of the target insects;
3. highly volatile with good penetration power (but not be excessively sorbed by grain);
4. easily detected, with adequate warning properties;
5. noncorrosive, nonflammable, and nonexplosive under practical conditions, with good storage life;
6. nonreactive with the commodity so as not to produce adverse odors or flavors;
7. able to aerate readily, leaving no harmful residues;
8. noninjurious to seed germination and not detrimental to the commercial grain grade;
9. nondamaging to milling qualities or other processing properties of grain;

10. readily available and simple to apply.

INFORMATION SOURCE

A current list of approved residual insecticides for use in empty bins and directly on the grain is available from the Minnesota Department of Agriculture, 90 West Plato Blvd., St. Paul, MN 55107 _or_ Mr. Ron Gardner, University of Minnesota, 228 Hodson Hall, St. Paul, MN 55108.

POTATO LEAFHOPPER ECONOMIC THRESHOLD FOR ALFALFA

Recommended sampling procedure

Use a standard (15" diameter) sweep net. It should have a heavy cloth bag and be of sturdy construction.

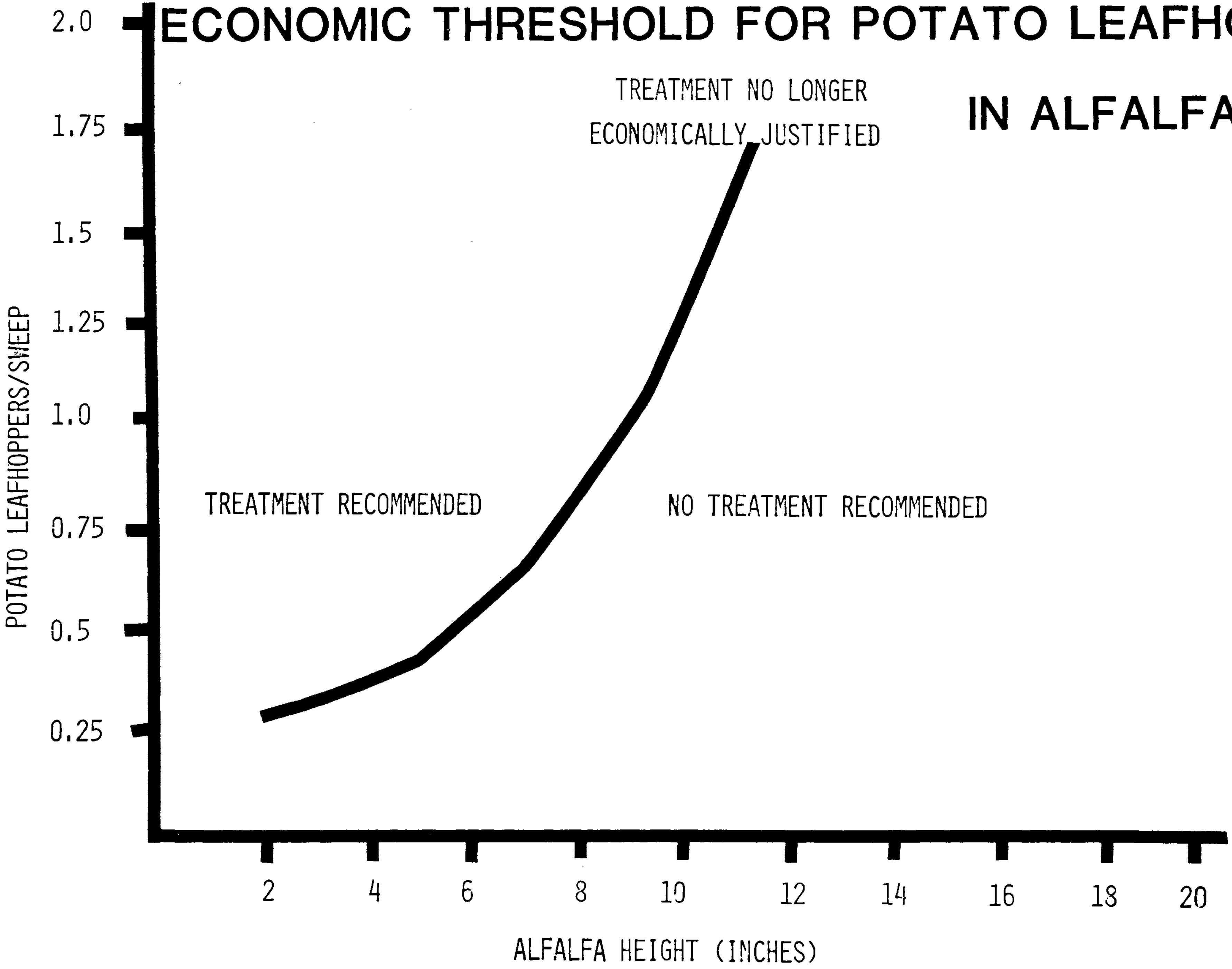
Sample in five locations of the field, avoiding field edges where leafhopper populations tend to be highest. At each location, make 20 sweeps. Carefully open the bag and count all potato leafhoppers caught. Calculate the average number of leafhoppers per sweep.

Sampling for potato leafhopper is most important in the early regrowth stage and should begin following the first cutting. Try to avoid sampling during windy conditions or when foliage is wet.

Interpreting the economic threshold

The threshold as given shows a generalized relationship between potato leafhopper populations and economic injury. Factors which can make potato leafhopper infestations more injurious (shift the treatment guideline down and to the right) include: a high price for alfalfa hay, droughty conditions, or young fields in the first year of establishment. The main factor which reduces the economic injury by potato leafhopper (shift the treatment guideline up and to the left) is a depressed price for alfalfa hay.

ECONOMIC THRESHOLD FOR POTATO LEAFHOPPER IN ALFALFA



APHIDS ON SMALL GRAIN

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Four species of aphids are found to occur in small grains in Minnesota. These include greenbug (Schizaphis graminum), corn leaf aphid (Rhopalosiphum maidis), oat-birdcherry aphid (R. padi) and English grain aphid (Macrosiphum avenae). Economic aphid infestations in Minnesota small grain are normally initiated by weather frontal aided migrants from the southern states. As a result, mixed populations of two or more species are usually observed during our aphid years. Indeed, in 1982 all four species were common in heavily infested wheat, albeit in widely differing numbers. Greenbug tends to be the least commonly appearing aphid of the above four.

Aphids on small grain are capable of producing from 1 to 3 living young (ovoviparity) per individual per day. Such young are able themselves to begin to reproduce within a week. Optimal population increase tends to occur at lower temperatures (50-60°F) during periods free of heavy weather. Lower temperatures apparently reduce predator and parasite effectiveness. Weather extremes, on the other hand, are detrimental to the aphids.

Aphid reproduction is not usually limited by the plant during the early stages of plant development until aphid numbers actually hurt the plant. And aphid numbers can decline dramatically, apparently due to plant maturity, as the plant enters the late boot and heading stages.

The fact that several good pieces of research demonstrate no yield effect from control of aphids from head emergence onward provides one clear point beyond which aphid control will not be profitable.

The question then becomes, what yield reduction can one expect from the numbers of the given aphid at the particular plant stage? Or more importantly when must one apply controls to prevent economic aphid injury to the plant?

Most research agrees that small grain injury/aphid is greatest with greenbug, next greatest with corn leaf aphid and least with oat-birdcherry aphid. English grain aphid appears not to injure the plant up to 100 or more per stem. In light of such injury differences, it is of some importance to know which aphid species are present and in what proportions. (A guide for aphid identification and a list of insecticides recommended for aphid control are discussed in Entomology Fact Sheet No. 43, Aphid Pests of Small Grain.)

Emphasis was placed on numbers of aphids per foot of row in our earlier discussions of action levels for aphids in small grain. These action levels, as you will see, were on the conservative side of more precise data generated recently by Kieckhefer et al. in South Dakota.

Kind of Aphid	Suggested Action Levels for Aphids in Small Grains in Numbers of Aphids per Stem		
	Seedling	Boot stage	Headed
Greenbug	15	25	Treatment rarely pays
Corn leaf aphid	20	30	
Oat-birdcherry aphid	20	30	
English grain aphid	30	50	

In making the decision of whether one should treat, it perhaps is most straightforward to count total aphids per stem. In no case should treatment take place at 15 aphids or less per stem irrespective of species of aphid, of plant stage, soil moisture conditions, presence of natural controls and/or crop value. Also one will rarely benefit from treating grain that is heading.

Adjustments in action level should be made, however, according to: 1) the aphid species complex as indicated, 2) soil moisture conditions, 3) abundance of predators and 4) value of the crop. In general a somewhat higher action level should be used where soil moisture is adequate, predators are abundant and the crop value is low.

SUNFLOWER DEFOLIATING AND SEED INSECT ACTION LEVELS

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SUNFLOWER DEFOLIATION

Excellent information (Table 1) is now available from hail injury tables relating defoliation to yield reduction in hybrid sunflower. Data relating insect numbers to percent defoliation and to yield reduction are much less available. However, some rules-of-thumb action levels based on defoliating insect numbers will permit control judgments before economic injury thresholds are exceeded.

Table 1. Percent yield reduction vs percent defoliation at following plant stages.

Percent defoliation	Percent yield reduction for defoliation at given plant stage: 2-14 leaf	15-32 leaf	Early to late bud	Bloom complete
25	0	0	10	0
50	5	15*	25*	12*
75	10*	22*	50*	20*

*Significantly different from untreated check.

With sunflower beetle each larva contributes about 1½% defoliation. Thus 25% defoliation of one plant would be equaled by the completed feeding of approximately 17 larvae. Certainly a grower would be justified to treat fields with 20 sunflower beetle larva/plant. A thistle caterpillar will contribute between 3 and 5% defoliation so that fields with between 5 and 7 thistle caterpillars per plant normally would require treatment.

Occasionally the normal phenology of the plant and insect pest are displaced temporally. In such cases the more correct way to make control judgments is base control on defoliation and not on insect numbers.

An abundance of sunflower beetle in 1982 permitted comparisons of several potential substitutes for toxaphene. Both yields and percent larval control were collected but yields have not been analyzed. Of the compounds compared Supracide, Toxaphene and Sevin are presently labeled. Pydrin, Ambush, Cymbush, Pay-Off and Ammo are synthetic pyrethroids, a group of insecticides with unusual biological activity.

In Table 2 all compounds at all rates performed exceedingly well. A second trial (Table 3) employing reduced rates for candidate compounds again showed excellent control by most materials. All plots were replicated four times.

Table 2. Larval sunflower beetle control - Minnesota 1982. Dave Noetzel and Lisa Behnken. (Preliminary data)

Insecticide	Rate ai/A	Percent control
Supracide	0.5	100
Ambush	0.1	100
Pydrin	0.1	100
Pydrin	0.05	100
Cymbush	0.04	100
Cymbush	0.02	100
Pay-Off	0.04	100
Pay-Off	0.02	100
Pay-Off	0.01	100
Ammo	0.02	100
Toxaphene	1.0	99
Penncap M	0.5	98
Sevin XLR	1.0	89
Penncap M	0.25	88
Check	-	0

Treated in the evening
Total material = 25 gallons/A
Counts 7 days after treatment; initial population 17 larvae per plant

Table 3. Larval sunflower beetle control - Minnesota 1982. Dave Noetzel and Ken Pazdernak. (Preliminary data)

Insecticide	Rate ai/A	Percent control
Pydrin	0.05	100
Pydrin	0.025	100
Ammo	0.01	99.6
Ambush	0.05	99.6
Ambush	0.025	98.8
Cymbush	0.01	98.4
Pay-Off	0.005	97.6
Ammo	0.005	96.4
Toxaphene	1.0	96.4
Supracide	0.25	93.2
Check	-	0

Treated in early evening
Total material = 25 gallons/A
Counts 24 hours after treatment; initial population 13 (3rd and 4th instar) larvae/plant

SUNFLOWER SEED INSECT ACTION LEVELS

Insects which infest the florets of sunflower include sunflower midge, sunflower moth, banded sunflower moth and seed weevils.

SUNFLOWER MIDGE

Following work in 1981 which clearly confirmed differential sunflower hybrid response to moderate and light midge infestations the question of insecticide control of midge appeared still to be confusing. Thus a trial (Table 4) was initiated at Morris under the direction of Dr. Dennis Warnes.

Four replicates of four planting dates with ½ of each plot treated with 0.2 lb. Ambush per acre every four days starting before midge eggs hatched and until midge activity ceased produced the following results. A total of six insecticide applications were applied to half of each plot for each of the first two dates of planting.

Table 4. Sunflower midge control. Morris 1982. Noetzel and Warnes. (Preliminary data)

Hybrid	Damage rating					
	Planted 5/21		Planted 5/27		Planted 6/4	
	Treated	Untreated	Treated	Untreated	Treated	Untreated
NK 212	2.0*	3.0	1.5	2.6	.3	.6
IS 894	.3	.5	.9	1.3	.1	.3
St 315	.1	.3	.9	.9	+	.1

Damage rating scale 0 to 4 where 4 is 75% or more damage and/or cupping.

The results confirm the hybrid difference in midge response observed in 1981. Date of planting does have a relationship to midge injury. It appears equally clear that even a spraying regime that far exceeds the practical possibilities for control is almost totally ineffective.

Special thanks are expressed to Northrup King, Interstate Seed, and Seed Tec for providing seed for this trial. We particularly appreciate the use of NK 212 which is an outstanding indicator plant for the sunflower midge.

SUNFLOWER MOTH

Adults which initiate economic infestations in this area are blown along weather frontals from southern states. Eggs and early instar larvae (dark colored with narrow white longitudinal stripes) are nearly impossible to monitor so control actions must be based on adult counts.

Canadian workers isolated a pheromone with which they were able to collect adult male moths shortly after they arrived in Canada. This pheromone is now available from Albany International, Controlled Release Division, 110 A Street, Needham Heights, MA 02194. Although we have not had an economic infestation in recent years, the traps are effective.

We have no additional data with which to question the two adult moths per five sunflower plants as an action level. However, fields which are beginning to bloom at the time the migrant adult arrives will not suffer economic injury. Likewise fields which are more than 14 days away from bloom will also escape injury.

BANDED SUNFLOWER MOTH

The Crop Pest Management program permitted us to pull pre-harvest samples from nearly 80 fields in 1980 and about 40 fields in 1981. We dried these samples, removed a random sample from each plot prior to cleaning the samples and then measured seed weevil and banded moth injury in the monitored fields. In 1980 we did not have any insecticide treated fields. In 1981 there were about 15% treated. However, these were not separated for this study.

As you can see in Tables 5 and 6 it would appear that we are probably overestimating the seed weevil problem and greatly underestimating banded sunflower moth damage.

The average percent reduction per seed agrees very well with Oseto's data from North Dakota. A difficulty, however, is the small seeded hybrids have a much greater % reduction in seed weight per seed. This amounts to nearly 100% difference in economic threshold if calculated from a percent weight loss per seed.

The two years data are quite consistent and are presented because of the threshold question for seed weevil control and because banded sunflower moth is a much greater problem than any of us thought.

It's my feeling that banded sunflower moth may have been the number one problem in sunflower in Minnesota in 1982 and certainly was no worse than second to midge.

Table 5. Effect of seed weevil and banded sunflower moth on seed weight reduction per seed and yield reduction. 77 West Central Minnesota CPM fields. 1980. (Noetzel & Sederstrom)

Insect	Percent reduction in seed weight/seed			Percent fields showing following % yield reduction			
	Lowest	Average	Highest	0	1-9	10-19	20 →
Seed weevil	12*	35	68	7	93		
Banded moth	16	54	100	15	76	9	
Combined	-	-	-	0	82	13	4

* This value represents a value for a hybrid or field and is based on a 200 seed sample from 3 commingled (75 row feet) pre-combine samples. Damage was counted before the material was cleaned.

Table 6. Effect of seed weevil and banded sunflower moth on seed weight reduction per seed and yield reduction. 38 West Central Minnesota CPM fields. 1981. (Noetzel & Sederstrom)

Insect	Percent reduction in seed weight/seed			Percent fields showing following % yield reduction			
	Lowest	Average	Highest	0	1-9	10-19	20 ->
Seed weevil	7*	34	65	4	89	7	
Banded moth	18	56	100	7	75	12	6
Combined	-	-	-	0	71	18	11

* This value represents a value for a hybrid or field and is based on a 200 seed sample from 3 commingled (75 row feet) pre-combine samples. Damage was counted before the material was cleaned.

We have several trials of banded sunflower moth control over the years and have included one from the Lamberton experiment station for this report (Table 7). We have been interested in effect of different insecticides on pollinators and pests in a high and a low autogamous hybrid. No differences in this pollination aspect are apparent, but we can compare efficacy of the insecticides used against, in this case, banded sunflower moth. All of the compounds at the rates tested appear to provide acceptable banded sunflower moth control.

Table 7. Banded sunflower moth control. Lamberton 1981. (Ford & Noetzel)

Insecticide	Rate* ai/A	Infested seeds per 200	Percent reduction
Supracide	0.5	2.4	86
Penncap M	1.0	2.6	85
Pounce	0.1	3.6	79
Pydrin	0.1	3.6	79
Ambush	0.1	4.2	75
Untreated	-	17.0	-

* Two applications at this rate 7 days apart. First application at 10-20% bloom.

At the present time there is no foolproof monitoring system for this insect. A pheromone trap is being researched but is not presently available. We have collected adults from sunflower moth pheromone traps, but we are unsure that the banded moth male is responding to that chemical. We have determined economic infestations (10% or more yield reduction) to have occurred in fields which were regularly visually monitored and in which we failed to see adults.

We almost feel that if one observes moderate banded moth activity in field margins, field treatment will benefit the grower. Growers in areas which routinely treat for seed weevil will not need to pay as much attention to banded sunflower moth as those who do not. Excellent banded moth larval control is being obtained with the insecticides and timing used for seed weevil control.

We are currently unsure that treating field borders and grassed waterways are sufficient to handle economic levels of banded moth. The two times we have attempted this control measure it has failed miserably.

SUNFLOWER SEED WEEVIL

There is general concensus that yield is reduced 0.006 (or 0.6%) per seed weevil adult based on Oseto's study which indicated 20 seeds are infested for each weevil counted. We have generated information which shows considerable difference in the % of a single kernel consumed by a larva, but final yields do not show a proportionate yield effect. The minor disagreement about adult counts used for action levels is caused by slightly different interpretation of control experiment data.

Statistical variation in yield data is usually so great in sunflower that yield differences of something around 200 lbs per acre are required to be significant at the 5% level. However, if one calculates actual yield reduction per acre with one weevil per plant, it turns out to be 12 lbs. Yield reduction for 10 weevils per plant would justify control costs if such differences were statistically significant.

We have tended downward on our action levels for sunflower seed weevil control and would tend to agree that control at about 10-15 weevils per plant in oil hybrids will pay. Confection hybrids require weevil control at perhaps 2 adults/plant. (The movement of confection production out of weevil and banded moth area was indeed wise.)

To count adult weevils it is very simple if a repellent, such as Off, or a pyrethrin aerosol is sprayed lightly over the head. Be sure the counts are made in several sections of the field.

The second "disagreement" in seed weevil control has to do with timing the insecticide application. Again there is agreement that the optimum timing for control lies between 3/10 plants in bloom (30% bloom) and 10/10 plants in bloom (100% bloom). The data we have collected would suggest that insecticide efficacy peaks at about 80% bloom (8 of 10 plants with male flowers). However, we have experiments where controls were applied at 30% bloom and percent control equaled the best control we have achieved. We have also had failures with early treatment.

To summarize then it will probably pay the grower to control seed weevil in oil hybrid sunflower at approximately 10-15 adult weevils per plant. Controls should be applied somewhere between 30% and 80% bloom (where bloom is more or less uniform). If adult weevil populations are marginal (i.e., 10-20 per plant), it will be best to wait until 80% bloom or so to treat.

STATUS OF TOXAPHENE

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On October 17 the EPA announced the proposed cancellation of all but selected uses of Toxaphene. Registrants had thirty days in which to reply to the proposed cancellation. All indications were (and are) that the cancellations will not be protested.

In the proposed cancellation it stated that products in manufacturers' hands (this appears to include distributors) would have to be re-labelled for permitted uses. Henceforth the permitted products would be Restricted Use. Permitted uses included scabies control on sheep and non-dairy animals, 24(C) use for sickle-pod control in soybean, peanuts and no-till corn, and special emergency use (Sec 18's) for cutworm, armyworm and grasshoppers in cotton, corn and small grain. These uses will continue only until 1986.

We are unable to obtain a legal opinion on whether toxaphene in growers' or applicators' hands can be used. However, the opinion was offered that since the order did not specifically speak to this disposition, the material could be used.

All suggested uses of toxaphene have been removed from the 1983 Minnesota recommendations. If the final order should alter the need for this, we will make news releases to extension agents and dealers. The cancellation will not leave very many insecticide gaps to fill in Minnesota. In fact, replacements in many cases have superior performance for the toxaphene uses previously recommended.

UPDATE ON WHEAT AND BARLEY DISEASE CONTROL

James S. Baumer, Assistant Professor, and Roy D. Wilcoxson, Professor, Department of Plant Pathology; John V. Wiersma, Assistant Professor, Northwest Experiment Station; and Dennis D. Warnes, Professor, West Central Experiment Station, University of Minnesota

Data are presented here in tabular form (Tables 1-5) summarizing the results of several years of fungicide spray trials on wheat and barley at the Rosemount, Morris, and Crookston Experiment Stations of the University of Minnesota. Plots were drill width (8') x 20-30' long and each treatment-variety combination was replicated three or four times at each location. Fungicide (Dithane M-45, mancozeb) was applied by ground at 2 lb/ac in 50 gal water/ac at 150 PSI with a Bean sprayer equipped with D213 nozzles. Triton CS-7 was routinely used as a spreader-sticker. All plots were harvested with a plot combine, with only the center 4-5' harvested.

Experiments were not regularly performed on barley prior to 1977 or on wheat prior to 1979. Also, the experiments at Crookston in 1978 and 1980 are not reported on here due to uneven stands and drought, respectively. Data on barley varieties are presented individually since there are known differences in spot blotch susceptibility for the varieties tested (Larker=susceptible, Morex=moderately resistant, and Manker=resistant) and since this was the most prevalent disease at all locations in most years. Data on wheat varieties are consolidated since there are no great differences in disease reactions to the common foliar diseases that were present in these tests. In general, the fungicide treatments provided good disease control (not shown) although the yield increases were not always significant.

Conclusions as to the economic returns of fungicide spraying are left to the reader. Great variability was encountered between years, locations, and varieties. In certain situations, yields were increased substantially by spraying, however, the overall averages were just barely economical. If the conditions that favored large yield increases could be determined, more efficient use of these fungicides could be obtained. Therefore, we are directing our future research towards detecting those conditions. We are also directing efforts towards determining the effects of aerial application of these fungicides in commercial fields.

Table 1. Yield of Larker barley at three locations from 1972 to 1981 when sprayed with Dithane M-45.

Year	Treatment	Rosemount	Morris	Crookston	Avg.
1972[a]	CK[b]	85.0[c]	24.0	38.0	-
to	1	-3.5[d]	8.3	26.3	-
1976	2	-4.7	4.2	44.7	-
1977	CK	49.0	63.0	47.0	53.0
	1	4.1	6.3	23.4	11.3
	2	0	1.6	19.1	6.9
	3	4.1	-4.8	23.4	7.6
	4	16.3	6.3	27.7	16.8
1978	CK	37.0	56.0	-	46.5
	1	-2.7	0	-	-1.4
	2	16.2	-3.6	-	6.3
	3	24.3	5.4	-	14.9
	4	21.6	8.9	-	15.3
1979	CK	63.0	54.0	77.0	64.7
	1	6.3	-13.0	5.2	-0.5
	2	3.2	-7.4	0	-1.4
	3	12.7	1.9	-7.8	2.3
	4	12.7	0	-2.7	3.3
1980	CK	93.4	82.9	-	88.2
	1	17.8	10.9	-	14.4
	2	33.5	-1.2	-	16.2
1981	CK	52.5	63.2	66.5	60.7
	1	-0.5	8.3	8.1	5.3
	2	-0.4	15.4	18.4	11.1
Avg.	CK	63.3	57.2	57.1	59.5
	1	3.6	3.5	15.8	6.6
	2	8.0	1.5	20.6	8.3

[a] Data are from Crookston in 1972, Morris in 1973, and Rosemount in 1976.

[b] CK = not treated, the number refers to the number of sprays, 7-10 days apart, with the first spray applied at boot stage.

[c] The yield of the CK treatment is expressed in bu/acre.

[d] The yield of the Dithane treatments is expressed as the percentage increase or decrease over the CK treatment.

Table 2. Yield of Manker barley at three locations from 1977 to 1981 when sprayed with Dithane M-45.

Year	Treatment	Rosemount	Morris	Crookston	Avg.
1977	CK[a]	50.0[b]	62.0	62.2	58.0
	1	6.0[c]	0	0	2.0
	2	4.0	9.7	1.6	5.1
	3	18.0	11.3	0	9.8
	4	8.0	1.6	0	3.2
1978	CK	52.0	64.0	-	58.0
	1	0	0	-	0
	2	-3.8	1.6	-	-1.1
	3	-1.9	-4.7	-	-3.3
	4	1.9	7.8	-	4.9
1979	CK	80.0	59.0	82.0	73.7
	1	0	-3.4	9.8	2.1
	2	1.3	16.9	18.3	12.2
	3	7.5	6.8	3.7	6.0
	4	1.3	11.9	-6.1	2.4
1980	CK	74.5(82.5)[d]	84.2	-	79.4(83.4)
	1	25.0(12.8)	10.3	-	17.7(11.6)
	2	37.4(24.0)	-4.4	-	16.5(9.8)
1981	CK	65.4	87.0	76.0	76.1
	1	-0.2	-7.7	4.0	-1.3
	2	-0.8	-8.7	3.7	-1.9
Avg.	CK	64.4(66.0)	71.2	73.3	69.1(69.7)
	1	6.2(3.7)	-0.2	4.6	3.4(2.4)
	2	7.6(4.9)	3.0	7.9	5.9(4.9)

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[a] CK = not treated, the number refers to the number of sprays, 7-10 days apart, with the first spray applied at boot stage.

[b] The yield of the CK treatment is expressed in bu/acre.

[c] The yield of the Dithane treatments is expressed as the percentage increase or decrease over the CK treatment.

[d] The values in parenthesis refer to the adjusted value when one plot yield is omitted from the analysis due to extremely low yield.

Table 3. Yield of Morex barley at three locations from 1979 to 1982 when sprayed with Dithane M-45.

Year	Treatment	Rosemount	Morris	Crookston	Avg.
1979	CK[a]	75.0[b]	58.0	77.0	70.0
	1	-4.1[c]	-10.3	-2.1	-5.5
	2	-1.8	6.9	12.1	5.7
	3	-4.9	-3.4	11.1	0.9
	4	-6.2	8.6	1.0	1.1
1980	CK	85.6	82.1	-	83.9
	1	25.9	-0.3	-	12.8
	2	30.6	6.0	-	18.3
1981	CK	60.7	85.9	84.5	77.0
	1	6.3	-9.8	0.5	-1.0
	2	5.4	-13.1	-3.7	-3.8
1982	CK	55.7	82.3	71.2	69.7
	2	-2.3	6.9	9.2	4.6
Avg.	CK	69.3	77.1	77.6	74.4
	2	8.0	1.7	5.9	5.1

a/ CK = not treated, the number refers to the number of sprays, 7-10 days apart, with the first spray applied at boot stage.
b/ The yield of the CK treatment is expressed in bu/acre.
c/ The yield of the Dithane treatments is expressed as the percentage increase or decrease over the CK treatment.

Table 4. Yield of Era, Olaf, and Kitt wheats combined at three locations from 1979 to 1981 when sprayed with Dithane M-45.

Year	Treatment	Rosemount	Morris	Crookston	Avg.
1979	CK[a/]	36.3[b/]	41.2	46.0	41.2
	1	6.0[c/]	3.1	12.1	7.1
	2	8.5	0.5	8.6	5.9
	3	4.6	1.4	17.1	7.7
	4	4.4	5.7	14.4	8.2
1980	CK	40.4	52.8	-	46.6
	1	6.8	6.6	-	6.7
	2	11.2	19.0	-	15.1
1981	CK	36.8	56.9	61.1	51.6
	1	-5.2	8.0	2.8	1.9
	2	4.6	9.3	5.8	6.6
Avg.	CK	37.8	50.3	53.6	46.4
	1	2.5	5.9	7.5	5.0
	2	8.1	9.6	7.2	8.4

[a/] CK = not treated, the number refers to the number of sprays, 7-10 days apart, with the first spray applied at boot stage.

[b/] The yield of the CK treatment is expressed in bu/acre.

[c/] The yield of the Dithane treatments is expressed as the percentage increase or decrease over the CK treatment.

Table 5. Yield of Era wheat at three locations from 1979 to 1982 when sprayed with Dithane M-45.

Year	Treatment	Rosemount	Morris	Crookston	Avg.
1979	CK[a]	36.0[b]	38.9	53.3	42.7
	1	4.2[c]	6.5	5.1	5.3
	2	11.4	6.5	12.1	10.0
	3	-0.8	0.1	5.6	1.7
	4	5.4	17.4	11.3	11.4
1981[d]	CK	30.2	58.9	59.9	49.7
	1	-0.3	2.8	9.5	4.0
	2	15.0	2.6	10.6	9.4
1982	CK	38.7	54.6	56.5	49.9
	2	2.5	11.2	2.3	5.3
Avg.	CK	35.0	50.8	56.6	47.4
	2	9.6	6.6	8.3	8.2

[a] CK = not treated, the number refers to the number of sprays, 7-10 days apart, with the first spray applied at boot stage.

[b] The yield of the CK treatment is expressed in bu/acre.

[c] The yield of the Dithane treatments is expressed as the percentage increase or decrease over the CK treatment.

[d] The individual variety yields for 1980 were unavailable.

RUST PROBLEMS AND CONTROL IN DRY BEANS

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Rust on pinto beans was again prevalent during the last growing season. Specific fields which were not sprayed, or sprayed too late did not yield near their potential. Losses due to this disease can be devastating.

Rust first appears as small chlorotic pale spots, (lesions), usually slightly yellow with a small dark center. As the disease progresses, the spots enlarge and are covered with a brick red rust (summer) spores, which spread the disease. With cooler weather, these lesions will develop black, (overwintering) spores.

Bean rust is caused by the fungus (Uromyces phaseoli var. typica) and symptoms appear 5-10 days after infection. The earlier these symptoms appear, the greater the potential for crop yield reproduction.

Cultural practices are important in slowing initial infection by this fungus. Three to four years rotations are recommended to help control this disease. Following bean harvest, all refuse should be plowed under as completely as possible as soon as convenient, because refuse is a primary source of inoculum for the next year's growing season. Chemical control of early rust infection can be accomplished when the disease is identified in the early stages. Fungicides, such as Coppers, Manebs, Zineb and Bravo will control the disease. The chemicals used to prevent rust infection on pinto beans are protectants. They will not cure the disease already present, but will help prevent spread and subsequent infection.

Results of spray trials at Staples, Minnesota show that early applications of Bravo followed by 3-4 sprays, will control rust effectively and prevent yield losses (Table 1). The July 28th spray was made as soon as small chlorotic spots (flecks) were discovered. Spray programs started at this time were just as effective as the healthy checks which were sprayed before any rust pustules were visible (Preventative Treatment) (Table 1). Bravo has been labelled for use on dry beans for rust control but can only be applied up to 6 weeks before harvest.

The spray trials at Staples, Minnesota this year included Tilt, a systemic fungicide. Tilt is not labelled for use on dry beans for rust control but trial results show that it will prevent yield losses due to this disease, (Table 2). Early applications (started at the fleck stage of rust development) followed by 1-2 applications were very effective in controlling the disease and preventing yield loss (Table 2). Although Tilt shows promise not only for rust control but for white mold control it cannot be recommended for general use until it is labelled. Plants treated with Tilt have puckered leaves and short internodes. This does not seem to affect yield as all the plants in the high yielding plots had these symptoms. More testing on this compound is scheduled for 1983.

Rust has been discovered on Fleetwood navy beans and Olathe pinto beans this year. In the past, they have shown a great deal of resistance to the races present in this area, however, new races may have developed. Dr. Jim Groth, Department of Plant Pathology is now examining these collections to determine if indeed these are new races. This discovery suggests that we should start monitoring the Olathe and Fleetwood fields for rust and initiate spray programsm when the disease is found.

Work is now in progress to collect data to be incorporated into a computerized model to predict losses due to rust and to estimate a return/acre of a spray program. A model for loss due to bean rust has been developed from 1 years data and as more data is added to the program it will become more reliable. The following steps are used in determining potential loss in rusted pinto beans; without any chemical control.

1) Determine the stage of growth of the plant (Table 3 & 4).
2) Determine the disease index on the plant canopy in several areas of the field.

<u>Severity Scale</u>

0: no rust
1/2: 1-2 spots/leaf
1: 10 spots/leaf
2: 40 spots/leaf
3: 200 spots/leaf
4: 400 spots/leaf
5: most leaves dead from rust

Rating X % of leaves with each rating = index I

Example: If 40% of the leaves have a #1 rating on the above severity scale and 60% have a #2 rating, then:

$$\begin{array}{r} 40 \times 1 = 40 \\ 60 \times 2 = \underline{120} \\ \\ I = 160 \end{array}$$

3) Select one graph that represents the growth stage of the field (figure 7-9).
4) Determine the percentage loss from that graph.
5) Potential loss in dollars can be determined by using this equation:

$$\text{Potential loss} = P\left(\frac{PY \times \%\ L}{100}\right)$$

P = Price
PY = Potential Yield
L = Loss

More data are needed to determine the returns from a spray program. Data from 1981 (a severe rust year) suggest that at growth stage R_6 17-22 percent of the loss can be recovered, and at growth stage R_7 3-10 percent of the loss can be recovered.

Using this model will only predict yield loss when rust is discovered. Until adequate data can be gathered to more accurately estimate returns of a spray program, the following guide can be used for spraying:

1) Look for rust every week. (The earlier rust is discovered, the greater is the potential for loss without a spray program.)

2) The most critical period for protection against rust is from early bloom to 4 weeks before harvest.

3) A 7-day spray schedule should be initiated any time rust is discovered.

4) The spray program should be stopped 4 weeks before harvest, (6 weeks before harvest if Bravo is used).

5) Dithane M-22 or Bravo should be applied at 2 pounds per with 5 gallons water aerial or 40-60 gallons per acre at 150 pounds pressure using ground application equipment. (Bravo may not be applied within 6 weeks before harvest.)

Fig. 7 - Growth Stage R_6

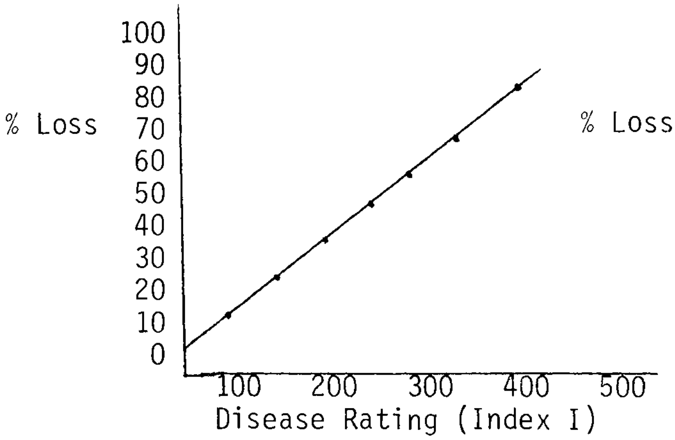

Fig. 8 - Growth Stage R_7

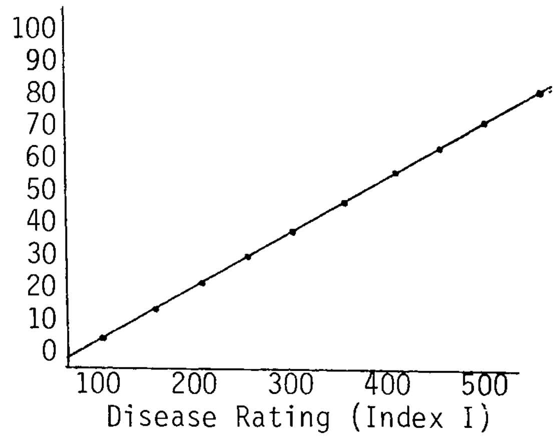

Fig. 9 - Growth Stage R_8

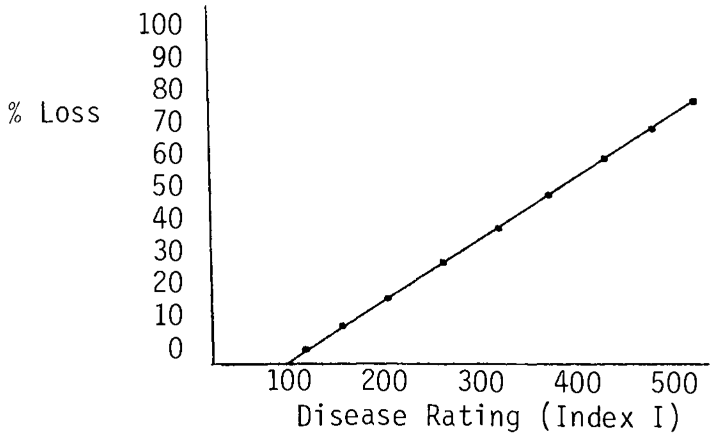

Table 1.

THE EFFECT OF BRAVO SPRAY PROGRAMS

Treatment Dates[1]							Average Yield[2] at 13% Moisture					
7/8	7/14	7/28	8/6	8/11	8/18	8/25						
2	I	2	2	2	2	2	2743	│				
4	I	4	4	4	4	4	2693	│				
	I	4	4	4	4	-	2655	│				
	I	2	2	2	-	-	2582	│				
	I	4	4	4	-	-	2516	│	│			
	I	4	4	-	-	-	2380	│	│	│		
	I	2	2	2	2	-	1991		│	│		
	I	-	4	4	-	-	1899		│	│	│	
	I	2	2	-	-	-	1788			│	│	
	I	2	-	-	-	-	1735			│	│	
	I	-	2	2	-	-	1566			│	│	
	I	4	-	-	-	-	1521			│	│	│
	I	-	-	2	-	-	1254				│	│
	I	-	-	4	-	-	1232				│	│
	Unsprayed Ck.						985					│

[1] The number 2 or 4 indicates 2 or 4 pints/acre respectively.

[2] Values connected with a vertical line are not significantly different.

Table 2.

THE EFFECT OF TILT SPRAY PROGRAMS ON THE YIELD OF PINTO BEANS

	Treatment Dates							Average Yield							
Rate g ai/A	7/14	7/20	7/22	7/29	8/8	8/12	8/18	at 13% Moisture	[2]						
100	-	I[1]	-	↓	↓	-	-	2919	|	|					
70	-	I	-	↓	↓	↓	-	2849	|	|					
100	-	I	-	↓	↓	↓	-	2761	|	|	|				
70	↓	I	↓	↓	↓	↓	↓	2690	|	|	|				
70	-	I	-	↓	↓	-	-	2545	|	|	|	|			
70	-	I	-	↓	-	-	-	2441		|	|	|			
100	-	I	-	↓	-	-	-	2402			|	|			
100	↓	I	↓	↓	↓	↓	↓	2359			|	|	|		
70	-	I	-	-	↓	↓	-	2043				|	|	|	
100	-	I	-	-	↓	↓	-	1875					|	|	|
70	-	I	-	-	-	↓	-	1597						|	|
100	-	I	-	-	-	↓	-	1571						|	|
0	-	I	-	-	-	-	-	1448							|
100	-	I	-	-	-	-	↓	1355							|

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[1] I = Date of Inoculation.

[2] Values connected with a vertical line are not significantly different.

Table 3.

DESCRIPTION OF VEGETATIVE DEVELOPMENT OF DRY BEANS[1]

Stage	Vegetative Description	Approximate number of days from planting
VE	Hypocotyl emerging from soil	5
VC	Cotyledons above ground; epicotyl small and developing	6-7
V1	Fully developed unifoliolate leaves at primary node	10
V2	Trifoliolate leaves unfolded; one node above primary	19
V3	Trifoliolate leaves unfolded at second node above primary	29
V(n)	Nodes with unfolded trifoliolate leaves, no blossoms open	New node each 3 days
V5	Bush type beans may blossoms and become R1	50
V8	Vine type beans may blossom and become R1	40

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[1] Adapted from A Description: Developmental Stages of the Common Bean Plant, Current Information Series No. 228, Cooperative Extension Service, Agricultural Experiment Station, University of Idaho, 1974.

Table 4.

DESCRIPTION OF REPRODUCTIVE DEVELOPMENT OF VINE TYPE DRY BEANS[1]

Stage	Reproductive Description	Approximate number of days from planting
R1	One open blossom, any node; tendril begins to show	40
R2	First pods 1/2 inch long	43
R3	First pods 1 inch long, pods visible at upper nodes; 50 percent bloom	46
R4	First pods 2 inches long (node 1)	50
R5	Pods over 3 inches long; seeds visible in pods	56
R6	Pods 4-6 inches (maximum length); seeds at least 1/4 inch	60
R7	First pods have fully developed seeds; pods full length elsewhere; blossoms on tendril (10-13 nodes present)	70
R8	Leaves yellowing on half of plants (maximum production point)	82
R9	80 percent of pods yellow or ripe; 40 percent of leaves still green	94

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[1] Adapted from A Description: Developmental Stages of the Common Bean Plant, Current Information Series No. 228, Coop. Ext. Ser. Ag. Expt. Sta., University of Idaho, 1974.

"SOYBEAN PHYTOPHTHORA ROOT ROT AND CONTROL"

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Phytophthora root rot (PRR) of soybeans, caused by Phytophthora megasperma (Pm) is a significant soybean disease in south eastern and south central Minnesota. Phytophthora rot may be found in soybeans at any stage of development. Susceptible young plants die quickly. Seed rot and preemergence damping-off reduce stands. Postemergence root and stem rots cause wilting and death of seedlings, further reducing the number of plants. At the primary leaf stage, affected stems appear water-soaked, leaves turn yellow and wilt, and affected seedlings die.

Older plants are killed more gradually, or vigor is reduced throughout the season. The first symptom on late-infected plants is the yellowing of the lower leaves between the veins and along the margins. The upper leaves soon become chlorotic, followed by complete wilting of the plant. The withered leaves commonly remain attached for a week or more after the plant dies. Affected plants usually occur in groups in a row rather than singly.

Infected lateral and branch roots are nearly destroyed, and infected taproots turn dark brown. The discoloration often progresses 10-20 cm or more up the stem and lower branches, occasionally to the forth or fifth node. Internally, the cortex and vascular tissues are discolored. The stem, small lateral branches, and main root (except the root tip) usually remain firm, and no definite external lesions are formed. Some tolerant lines and cultivars are not easily killed by the fungus but show yellowing of the foliage and poor vigor similar to that produced by wet soil and nitrogen deficiency.

Primary inoculum comes from crop residue in the soil where Pm survives with or without soybeans mainly as oospores. Many more oospores are formed in susceptible and tolerant cultivars than in resistant ones. While resistant cultivars do have oospore formation little or no death or discoloration of the root occurs. PRR is most common in heavy, tightly compacted, fine-textured (clay) soils subjected to shallow tillage. High soil moisture and rainfall are most favorable for disease development. A dry period before or after planting drastically reduces the disease. The "root pruning" effect of the pathogen if seen is an overall decrease of plant growth, i.e. reduced leaf size, plant height and weight without wilting. New roots are produced when the soil is dry. The probability of PRR is high once the fungus is established in a field. Infection will occur when flooded conditions, i.e. saturated soil occur soon after planting.

This condition is reported to occur 30% of the time in northern Ohio. Disease pressure is considerably less in Minnesota, however, reports of PRR continue to occur. The disease gradually lessened and nearly disappeared nationally in the mid-60's with the widespread use of resistant varieties. A second disease cycle began with the release and use of high yielding but non- resistant lines. The release of high yielding resistant lines has also now failed to control PRR as new races become widespread in Ohio. Race 1 resistance was effective in Ohio until 1972, and resistance to races 1-3 and 6-9 is available in several lines but already additional races are present in Ohio which can attack this kind of resistance. In Ohio the first cycle of race build-up occurred from 1965 to 1973, 8 years making race 1 resistance useless. Similar build-up of additional races is expected in Ohio and alternatives to Pm resistance are needed. While the picture in Minnesota is not as bad, less disease pressure, i.e. fewer plants lost each year and fewer reports of new races, a similar build-up can be expected. Race 1 resistance has in general performed very well, yet some fields were seen where Corsoy 79 had some PRR and a near by field with a private line (resistant to race 1 & 2) was lost to PRR.

Research has demonstrated that cultural practices can lessen Pm damage. This includes tilling to remove excess water, deep plowing to break down and disperse inoculum, rotation with corn to reduce inoculum and avoid nitrate nitrogen prior to planting. However, even under these conditions Pm is not completely controlled when disease pressure is high, as was observed in 1982. In some states growers have planted lines that are highly tolerant of PRR which has worked well when disease pressure is low to moderate. Tolerance is the relative ability of susceptible varieties to survive and yield well even when infected. This type of plant tolerance is best expressed after the seedling stage, indeed the weakest point is damping off at seed germination or seedling stages. Results from Ohio again, suggest this tolerance is not adequate when disease pressure is high and may result in poor stands and thus poor yields. Seed treatments with Captan & Vitavax are not effective against seedling problems caused by Pm. In Minnesota several fields may have benefited from traditional seed treatments in 1982 since we still find most seedling problems are associated with Pythium, Rhizoctonia and Fusarium. Two fungicides have shown considerable more promise for the control of PRR of soybeans. 1) Apron (Gustafson Co.) or Ridomil (Ciba-Geigy) and 2) Grandstand (Dow) are effective as seed treatments. While season long control was not demonstrated, a significant improvement in early season stand was reported when growing slightly tolerant lines and increased yield and stand was reported for highly tolerant lines. In Minnesota, Apron 2 Fl oz/100# seeds improved final stand counts, no yields were taken (Table 1).

Since PRR control by cultural factors, race specific resistance and tolerant lines all have potential weaknesses, i.e. there is no simple solution integrated control including chemical seed treatment may be the best alternative. While severe PRR in Minnesota is not common, it is present at some level every year and often the losses are hidden. PRR, once established remains in the field and when conditions are favorable Pm can cause serious PRR. The addition of these seed treatment materials to the PRR control methods may be significant even in Minnesota. Further testing and observations are needed.

TABLE 1.

Stand Counts in Paired Rows Untreated-Treated on
Sept. 23, 1982 Susceptible Line II-54-254

	Untreated	Treated
	15	23
	12	20
	23	30
	20	23
	11	21
	10	25
	28	30
	27	33
	26	27
Mean	19.1	25.7

NEW HERBICIDE APPLICATION TECHNIQUES AND EQUIPMENT

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INTRODUCTION

Several new developments in equipment and techniques can be identified that allow more efficient and precise application of herbicides. None will completely revolutionize and replace present practices, but each has potential in special applications. After extensive evaluation, these techniques and equipment either will fade into oblivion or, if proved effective, will take their place in our arsenal of devices.

CONTROLLED DROPLET ATOMIZERS

Much of the research on improving application efficiency has concentrated on controlling the droplet spectrum. Spray nozzle manufacturers have been active in designing nozzles that reduce the number of unwanted small drops. Delavan Corporation is marketing two designs of Raindrop® nozzles that rely on a secondary swirl chamber to absorb some of the energy in the liquid after it emits from the primary chamber. Spraying Systems Company has wide-angle full-cone nozzles that can be used with a premetering orifice to decrease nozzle exit pressure and increase spray droplet size. Spraying Systems also has developed the LP (low-pressure) flat-fan nozzle.

Methods to completely control the droplet size spectrum with uniform-sized spray drops are being studied. The premise for herbicides is that eliminating droplets smaller than 150 um will reduce off-target drift and eliminating droplets larger than 300 um will allow good coverage with low application volumes. Many different ways have been found to generate uniform spray drops. One method uses a magnetostrictive device, piezoelectric crystal, air horn, or wave generator to apply a controlled frequency pulse to the liquid either at or above the orifice. Although development work has been considerable, no commercially successful field application has resulted. Problems include producing accurate multiple-orifice plates, adequate filtering spray liquids to prevent clogging, and preventing formed drops from coalescing. A multicapillary jet unit, the Micro-Foil, relies on the natural frequency of the liquid jet to form fairly uniform large drops and is used primarily on helicopters.

One of the most widely used application units for producing a narrower droplet spectrum is a spinning disc. Studies on the formation of droplets from spinning discs, cups, and perforated screens have been carried out since 1949. In 1970, Mr. Ed Bals designed a toothed disc to provide issuing points for ligaments and drops to leave the disc. Subsequent designs added grooves to feed the teeth and improved the unit so larger volumes could be applied without sheet formation. These discs are usually powered by small D.C. electric motors. Speed is controlled by voltage control or other variable speed drives.

The most widely used controlled droplet application (CDA) sprayers are produced by Micron Sprayers in England and are hand held units for use in developing countries. Several models are available including the ULVA, the ULVAFAN, and the Herbi. The Herbi is commonly used for herbicide application and operates by direct droplet formation. The maximum flow rate that allows the formation of "controlled droplets" is 0.24 gallons per minute. With higher flow rates, and more ligament formation, the droplet size range widens. The application capacity of the Herbi is therefore lower than is probably desirable for a field sprayer.

The most recent CDA model, the Micromax, is tool-bar mounted for broadcast applications and has been marketed in the USA since 1980. These units can give a good droplet spectrum if properly operated. Changing disc speed or flow rate will change the droplet sizes obtained. Tests at the University of Illinois have shown the spray pattern uniformity to be reduced to 4% with 40 inch spacing between units. Drift was also found to be similar to that of hydraulic nozzles at wind speeds up to 3 miles per hour but drift deposits from the Micromax units increased dramatically compared to the hydraulic nozzles at higher wind speeds. The 1983 model utilizes a direct-drive three-speed motor that should eliminate many of the mechanical problems that have occurred in the past.

The "Beecomist" rotary atomizer is being developed by Beeco Products Company. It is a spinning cage unit with variable speed hydraulic or electric motor drive. Droplet size range is changed by varying drive speed and changing the spinning cages to ones with larger or smaller openings. The unit is made in several sizes ranging from hand carrier units to large ground sprayers and aircraft units. It appears to give a narrow range of droplet sizes. Worldwide interest in low volume CDA application is considerable. Controlling droplet size of sprays may well result in much lower spray volumes with significantly less drift.

ELECTROSTATIC SPRAYERS

Electrostatic spraying has great potential as a means to obtain more efficient applications of herbicides. Electrostatic charging of herbicide particles by a high voltage is an effective means of transporting small particles and impacting them on the target.

Prototypes of electrostatic sprayers based on Dr. Edward Law's patent were field tested in 1978-80 by the FMC Corporation. Evaluations of prototype units have shown excellent pest control when one-half the recommended pesticide rate is applied at low spray volumes. This design typically uses an air atomizing nozzle where the air blast drives the spray particles through an electrostatic induction charging ring that operates at about 1,500 volts D.C. Force of the air drives the charged spray particles down into the plant canopy where the particle movement is controlled by the charge on the particles. Concentrated low volume water based pesticide mixes are typically used with this unit. These nozzles require about 1.3 horsepower to supply air to each nozzle.

Imperial Chemical in the United Kingdom is developing its "Electrodyn" electrostatic atomizer head which has no moving parts. The charging voltage atomizes the spray in addition to charging the drops. Spray materials are supplied in sealed containers that are inserted in the charging unit for application. Hand held units are now being sold overseas and tractor mounted units are being extensively tested in the U.S. preparatory to the proposed 1984 marketing goal. These units use only oil based sprays supplied in sealed premixed containers by the manufacturer.

Researchers at Rothamsted (United Kingdom) have developed a spinning disc electrostatic atomizer unit using corona charging (the APE 80). This unit permits the use of some oil based liquids which do not charge well in other electrostatic units.

VEGETABLE OIL CARRIERS

The use of CDA and electrostatics has generated a renewed interest in low volume application of pesticides. Low volume and ultra-low volume applications allow both aerial and ground applicators to spray many more acres per tankful, spend less time filling tanks, and spray more acres per day. The use of vegetable oils as carriers in place of water have potential for improving the efficiency of low volume applications because the spray droplets are relatively non-evaporative and should drift less than water droplets of the same size. Oil droplets should also deposit better than partially evaporated water droplets. Development of equipment and techniques to apply pesticides in vegetable oil carriers at 2 gallons/acre or less is difficult due to the changing physical properties of the pesticide-vegetable oil mixtures. Research to evaluate the properties of vegetable oil as carriers is just beginning but there is already tremendous interest in this concept from the entire industry.

ELECTRONIC SENSORS AND MONITORS

Advances in electronics are having an impact on pesticide application techniques. Several companies make spray rate monitors. Each system has a meter to sense total flow to the spray boom, a transducer to sense travel speed, a control to dial in the effective width sprayed, and a panel that continuously displays the spray rate during operation. Some units have such additional features as displays of nozzle flow, travel speed, area covered, total volume sprayed, and amount of solution remaining in the tank. Initial problems with flowmeters have been solved by the manufacturers, and most monitors are maintaining good reliability in the field. Spray rate monitors have the potential of eliminating many of the current errors in application accuracy.

Some manufacturers add a controller system to their spray rate monitors. A microprocessor-controlled servovalve assembly automatically regulates the flow in proportion to travel speed to maintain a constant spray rate. Several control systems have such features as alarm systems, manual overrides, and individual boom controls.

Studies are also being conducted to develop sensors that continuously monitor soil organic matter content during field application of pesticides. In the research studies, reflected light passes through optical interference filters into phototransistors, which transform the reflected light into an electrical signal proportional to soil organic matter content. An on-board microprocessor delivers the properly amplified signal to a stepping motor for automatic control of application rate. The concepts needs a great deal more development before becoming commercially available.

Marking swaths is a major problem when applying pesticides, especially with high-speed sprayers that have wide booms. Overlaps and skips could be reduced with accurate swath-marking systems. Current research activities are aimed at utilizing such electronic advances as light sensing, rotating lasers, and radio-controlled guidance systems. One commercially available system, the Ag-Nav, uses radio signals that an on-board processor converts to a series of relative locations to track and guide the operator by means of a continuous display on the dashboard.

Sonar is now being used to measure travel speed, to monitor the spray boom for clogged or partially clogged nozzles and to sense the height above the soil surface for maintaining the proper boom height.

Work is again being conducted on developing a spraying system that injects undiluted herbicide directly into a conventional sprayer applying only carrier solution. Herbicides are metered at rates directly proportional to travel speed using adjustable displacement metering pumps. Errors in application can result if the herbicide is injected into the carrier at the pump, then is delayed in reaching the nozzle; improper mixing may occur if the herbicide is injected directly into the nozzle. Handling of wettable powders is also a problem. No units are commercially available, but several state universities and commercial firms have systems in development. If the major problems can be overcome, induction sprayers have the potential for eliminating some of the environmental and human hazards of using herbicides. Operators do not have to handle the concentrated herbicides during mixing and loading, there are no surplus mixtures requiring disposal, and the supply tank does not have to be cleaned to prevent contamination.

SELECTIVE PLACEMENT

Efficiency of application can be improved by spraying only the target pest. Tests have shown that shutting off the spray between each plant reduces the pesticide amount by 25-80%, with no loss of pest control. Some intermittent sprayers use mechanical feelers to trigger the spray. Others have photoelectric sensors for activating the system; when the light beam is interrupted by a plant, a solenoid valve opens and pesticide flows to the spray nozzles. Timers allow for various lengths of spray. Easy Hoe, Inc., has a commercial unit designed for herbicide application that activates when weeds trigger a mechanical switch.

Many devices for selective application of pesticides have become available during the past few years, including directed nozzles, shielded nozzles, wax bars, burlap-wrapped booms, foam-rubber wipers, and recirculating sprayers. Acceptance of the selective application concept was limited somewhat by the scarcity of suitable pesticides, but interest has been revived and expanded by development of the herbicide glyphosate.

The newest development for selective application that has gained wide acceptance is the ropewick applicator. Much of the method's popularity lies in the fact that functional models can be easily constructed from inexpensive materials; several companies also manufacture the applicator. Work is continuing on devising new wick materials and configurations to improve contact with weeds.

Shielded air-blast and air-cushion sprayers are being studied as a way to obtain good plant coverage with spray mists while protecting the environment from drift damage.

CONCLUSION

Despite the many new approaches and concepts, development of equipment has not kept pace with development and knowledge of the new era of modern pesticides. In terms of the total pesticide industry, only a relatively small amount of research is being conducted on improving the efficiency of application equipment.

Spraying systems of the future will have to be more precise, placing more of the material on the desired target with less drift. The use of electronics will continue to increase, with the operator able to easily monitor and control more of the parameters. The potential for improving application efficiency is good and with proper research support technical breakthroughs are possible that can completely "revolutionize" the application industry.

LEB/dld
11/12/82

POSTEMERGENCE GRASS HERBICIDES IN SOYBEANS

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Diclofop (Hoelon) was the first postemergence grass herbicide marketed for use in soybeans. It is used at rates of about 1 lb per acre for controlling small annual grass weeds and volunteer corn in soybeans.

Since the introduction of diclofop, numerous new postemergence grass herbicides have been introduced by chemical companies and evaluated by weed scientists. These herbicides have all been effective in controlling annual grass weeds in soybeans in postemergence treatments at much lower rates than required for diclofop. Three of these new postemergence grass herbicides have been dropped from further development after considerable research. But, at least six (and probably more) new postemergence grass herbicides are currently in various stages of development. Two of these have been developed to the point of having trade names. PP 009 has the trade name of "Fusilade" and BAS 9052 OH has the trade name of "Poast". Many Minnesota soybean growers used the latter herbicide during the 1982 growing season.

The large number of these new herbicides that potentially may become available to soybean growers makes the task of adequate evaluation difficult. Thus far, it appears that soybeans have excellent tolerance to these postemergence grass herbicides. It appears that most of these new herbicides benefit from the addition of crop oil concentrate to the spray mixture. It appears that these new herbicides will be effective on larger grass plants than was the case with diclofop (Hoelon).

Because these new grass herbicides do not control any broadleaf weeds, it would be desirable to mix broadleaf herbicides, such as bentazon (Basagran) or acifluorfen (Blazer or Tackle) with them. Such mixtures have sometimes resulted in antagonism -- the activity of one or both of the herbicides in the mixture being reduced.

Last year I used four of these postemergence grass herbicides -- Dowco 453, CGA 82725, PP 009 (Fusilade), and BAS 9052 OH (Poast) -- in various experiments involving the control of giant foxtail, tame proso millet (to simulate wild proso millet), and volunteer corn. Results may be summarized as follows: All four herbicides at 0.2 lb/A plus oil concentrate were highly effective in controlling all three grass species. Dowco 453 was the most active in controlling all three grass species, giving excellent control at the low rate of 0.05 lb/A with oil concentrate. At low rates of application, CGA 82725 and PP 009 (Fusilade) decreased in effectiveness as the size of the grasses increased, whereas BAS 9052 OH (Poast) increased in effectiveness as size of the grasses increased. Additives were helpful in increasing the activity of all four herbicides. Oil concentrate (AtPlus 411F) at a concentration of 0.5% was generally more effective than surfactant (X-77) at the same concentration. There was little or no advantage in increasing the concentration of the oil concentrate above 0.5%. A spray volume of 20 gal/A gave slightly better results than did 10 gal/A with all herbicides except BAS 9052 OH (Poast). With the latter there was no advantage in increasing the spray volume from 10 to 20 gal/A. All four herbicides should be highly effective in controlling annual grasses; low rates were required to bring out differences among them.

For the immediate future, these new postemergence grass herbicides will not replace herbicides currently used as preemergence or preplanting treatments. All the preemergence or preplanting treatments currently used for grass control in soybeans also give some broadleaf weed control, whereas the new postemergence grass herbicides do not. The new herbicides will be useful on soils where preemergence or preplanting treatments are not effective. They will be useful to control grass where preemergence or preplanting treatments have not been used or where they have been used but failed to give satisfactory grass control. The new postemergence grass herbicides will be particularly useful for controlling volunteer corn in soybean. Some will be useful in controlling quackgrass (this aspect will be discussed in the following presentation).

If methods can be devised to obtain satisfactory postemergence broadleaf weed control in conjunction with grass control from these new postemergence herbicides, postemergence weed control may become the primary method in soybeans of the future. Postemergence treatments have several advantages, an important one being that they can be adapted to most any tillage system a grower chooses to use.

CONTROLLING QUACKGRASS

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Infestations of quackgrass continue to plague Minnesota soybean producers, because none of the selective herbicides used in soybean production give adequate quackgrass control. Vernolate has been the only herbicide available for selective quackgrass control in soybeans and when applied preplant incorporated provides only marginal short-term quackgrass suppression.

During the last few years there have been some excitng new developments for improving quackgrass control in soybeans. Several experimental herbicides have been evaluated for selective postemergence quackgrass control in soybeans; two of these herbicides may be available for use in the 1983 growing season.

The data I will present today is a summary of five years of research that evaluated the influence of several cultural practices on the control of quackgrass with selective postemergence herbicides.

SUMMARY

A. Herbicide application rate.

The herbicides had different unit activities.

B. Use of oil concentrate.

The phytotoxicity of all herbicides was increased when oil concentrate was added to the spray mixture.

C. Stage of application.

Herbicide phytotoxicity was reduced greatly when applied to quackgrass in the five- to six-leaf stage.

D. Cultivation.

Cultivation following herbicide treatment increased quackgrass control. Cultivation was equal to or better than a split treatment of each herbicide.

E. Row spacing.

Soybean row spacing did not influence the efficacy of the herbicides tested.

CORN WEED CONTROL - 1983

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Minnesota farmers are now using herbicides on over 90% of their corn. The use of herbicide mixtures and multiple applications is widespread because a single herbicide is rarely adequate to control all weed species that are present. There are eight herbicides which are now used on more than one-half million acres of corn in Minnesota. A copy of Extension Folder 641 "Weed Control in Corn" follows this article. It provides much information on the effectiveness of herbicides on weeds in corn, timing of treatments, effectiveness of herbicide mixtures, and precautions in herbicide use. Further information on specific herbicides is given on the labels found on the containers.

Herbicides now available, if carefully selected and properly used, give satisfactory control of nearly all weed infestations in corn. However, occasional weed control failures are possible due to adverse climatic conditions or improper application. In the case of broadleaf weeds, effective follow-up herbicide treatments are available if control from the initial treatment is poor. However, the control of larger grassy weeds, 3 to 10 inches tall, is more difficult. Research is currently under way to improve postemergence grass control in corn and some progress has been made. The effectiveness of postemergence applications of atrazine and cyanazine on annual grasses up to 2 inches tall is improved when these herbicides are combined with a new herbicide, Dowco 356 (Tandem). This treatment has not been cleared but will be available under an experimental use permit in 1983. This will allow use by Minnesota farmers on a limited acreage to determine its reliability under Minnesota conditions. Larger annual grasses, 8 to 10 inches tall, have been controlled by two applications of atrazine plus Dowco 356 spaced one week apart. For the second application drop nozzles were used to reduce corn injury. These sequential treatments require further study before their use is recommended.

Wild proso millet is a serious weed in corn that is spreading rapidly in Minnesota. It has been found from the Iowa border to as far north as corn is grown. Initially EPTC (Eradicane) gives good control of wild proso millet. However, with repeated annual use of EPTC, this treatment becomes less effective because of more rapid destruction of EPTC in the soil. Recently an additive has been discovered which reduces the rate of EPTC breakdown in the soil and improves the effectiveness of EPTC on wild proso millet. Studies are now under way to determine whether the extender retains its effectiveness with repeated annual use.

Suggested control practices for wild proso millet are based on sequential herbicide applications. Preplant incorporation of EPTC (Eradicane) or EPTC plus extender (Eradicane Extra) followed by delayed preemergence or spike stage treatments with cyanazine (Bladex) plus alachlor (Lasso), metolachlor (Dual), or pendimethalin (Prowl) usually result in satisfactory season-long control of wild proso millet in corn. If corn is beyond the spike stage, corn injury may result from the cyanazine combinations. See Fact Sheet No. 35 following this paper for more information on wild proso millet and its control.

EXTENSION FOLDER 641—1982

Weed Control in Corn

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

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[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. The 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, once in each direction, 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) 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. A new formulation of EPTC also has an added chemical that extends the effectiveness of EPTC. This new formulation has improved performance of EPTC on some fields where the chemical has been used previously and on wild proso millet.

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- to medium-textured soils with less than 2 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 1.2 to 4 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, Bexton) 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), chemically related to propachlor, controls annual grasses in corn. In addition, alachlor has given fair to good control of redroot pigweed and common lambsquarters, but control of other broadleafs has been erratic. Corn has good tolerance to alachlor. Suggested rates are 2½ 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 (Dual), chemically related to alachlor and propachlor, controls annual grasses and redroot pigweed. Corn has good tolerance to the chemical. Preemergence applications have controlled nutsedge on coarser soils that are low in organic matter, but on finer-textured, dark soils, preplanting applications have controlled nutsedge better than preemergence treatments.

Metolachlor is labeled for preemergence application at 1.5 to 3 pounds per acre. Corn, soybeans, sorghum, root crops, or small grains may be grown the year after using metolachlor. Other crops should not be planted for 18 months after application of metolachlor.

Pendimethalin (Prowl) may be used alone at 1 to 2 pounds per acre or in mixtures at 1 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. It does not give adequate weed control on peat or muck soils. 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

(Text continued Page 94)

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 seed stock.
(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 + protectant (Eradicane)	3 to 6	None	
Metolachlor (Dual)	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	1 to 1½ + 3 to 4	Do not graze or feed forage for 21 days after treatment.	
Atrazine + EPTC (Eradicane)	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 (Eradicane)	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. Do not use preemergence applications of cyanazine, propachlor, 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 2.5% organic matter.
(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, Bexton)	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	1 to 2 + 1¼ to 2	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.
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	1/8 + 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.	

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[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 braodcast. See Agricultural Chemcials Fact Sheet No. 5, *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.

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 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

Such 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 formulation 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.

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	9 + 6% G, 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
Butylate and protectant	Sutan+	6.7 lb/gal L, 10% G
Butylate + atrazine	Sudan +/ atrazine	18% + 6% G
Cyanazine	Bladex	80% WP, 15% G, 4 lb/gal F
Dicamba	Banvel	4 lb/gal L
Dicamba and 2,4-D	Banvel-K	1.25 lb/gal dicamba + 2.50 lb/gal 2,4-D L
EPTC and protectant	Eradicane	6.7 lb/gal L
Linuron	Lorox	50% WP, 4 lb/gal F
Metolachlor	Dual	8 lb/gal L
Pendimethalin	Prowl	4 lb/gal L
Propachlor	Bexton, Ramrod	65% WP, 20% G, 4 lb/gal L
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.

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 (Bexton, Ramrod) alone or mixed with atrazine may be applied after corn has emerged to control grasses up to the two-leaf stage.

Pendimethalin (Prowl) in mixtures with atrazine or cyanazine wettable powder may be applied after corn emergence, but no 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.

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 no 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 can 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. 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.

A mixture of dicamba and atrazine is cleared for use on corn as an early postemergence treatment. The mixture has given good broadleaf control, but grass control has been erratic. Oils and other additives should not be used with the mixture.

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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AGRICULTURAL EXTENSION SERVICE
UNIVERSITY OF MINNESOTA

AGRONOMY
FACT SHEET No. 35—Revised 1982
O.E. STRAND and R. BEHRENS

Identification and Control of Wild Proso Millet

Wild proso millet (*Panicum miliaceum L.*) was first identified as a serious weed problem in Minnesota in 1970. Since then it has been found in 41 Minnesota counties ranging from Dakota and Chisago in the east to Lincoln, Lac Qui Parle, and Wilkin in the west. Found mainly in corn and soybean fields, wild proso millet is a prolific seed producer and a vigorous competitor in row crops.

Cultivated proso millet (*Panicum miliaceum L.*), also called "Hog Millet," is grown as a feed grain and bird seed crop in Minnesota and in several other states. Since it is similar to oats or barley in feed value, in some countries of the world proso millet is used as human food.

The exact origin of wild proso millet is unknown. Some evidence exists that it may have come from Asia or central Europe, or it may have developed a weedy growth habit over time from one of the many cultivated varieties. Wild proso millet resembles the seed and panicle type of an old proso millet variety, "Crown," which was grown widely in Minnesota in the 1940s and 1950s. One farmer in Stevens County, Minnesota, reported that he had observed wild proso millet in several patches on his farm since the 1930s when he purchased seed and grew a mixed millet emergency hay crop on his farm.

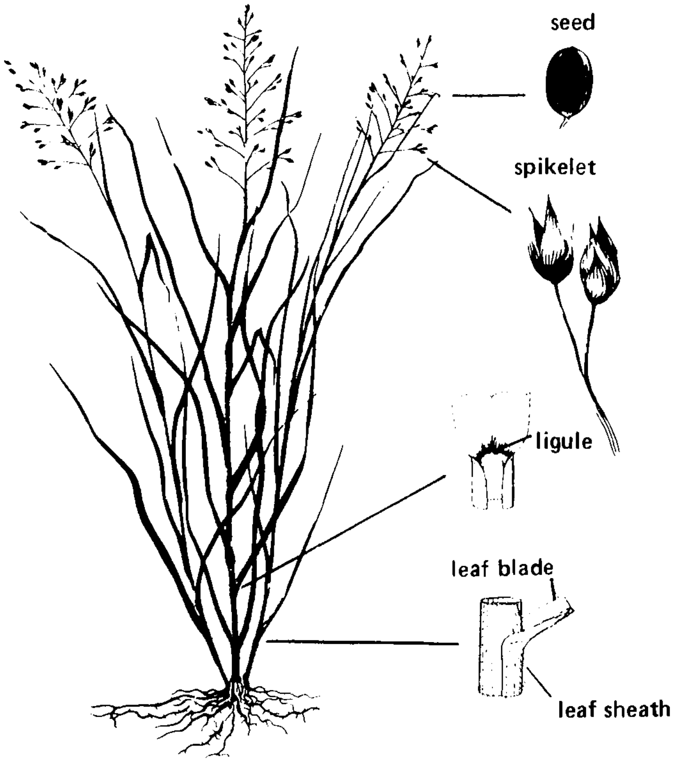
DESCRIPTION AND TAXONOMY OF WILD PROSO MILLET

Wild proso millet is a very competitive branching annual that grows from seed each year. It is erect in growth habit, growing from 2 to 6 feet tall, but some culms (stems) may be decumbent (prostrate) at the base. It has leaf blades that range from smooth to somewhat hairy on both surfaces and from ½ to 3/4 inch wide. The leaf sheaths (which encircle the stems) are round, split, and have long, spreading hairs. The ligule (projection at base of leaf blade) is a dense fringe of hairs fused at the base and approximately 2 mm. long. Each culm is topped by a spreading panicle 6 to 12 inches wide, which often is not fully extended from the leaf sheath. The spikelets, composed of the seed and surrounding glumes, are 4 to 5 mm. long, ovate, pointed at the tip, and strongly nerved with 7 to 9 nerves. There is one fertile floret (seed) per spikelet with a hardened lemma and palea (hulls) and the caryopsis, or grain, within. The seed is smooth and shiny, olive-brown to brownish-black in color at maturity, and approximately 2½ to 3 mm. long by 1½ to 2mm. wide with definite nerves or veins visible on the surface.

Wild proso millet is in the *Paniceae* (millet) tribe of the grass family, closely related to the corn and sorghum tribes. These three tribes make up one subfamily of the grasses as classified by A.S. Hitchcock, a noted authority on grasses, in *Manual of the Grasses of the United States.* Like corn, the first internode of wild proso millet elongates during emergence, permitting this weedy grass to germinate from depths of 2 or more inches in the soil. The readily identifiable seed of wild proso millet usually does not deteriorate after germination. If the plant is carefully removed from the soil, the seed often can be found among the roots to aid in identification of the plant. Also like corn, wild proso millet is tolerant of atrazine and has been increasing rapidly in areas where atrazine has been used widely as the principal corn herbicide.

Unlike cultivated proso millet, the wild strain has definite weedy characteristics. Several panicles are produced on each plant, some from the axils of the upper leaves that ripen later than the terminal inflorescence over a several-week period. Seed production usually continues until a killing frost stops plant growth in the fall. The seed is easily shed from the plant when mature and normally does not germinate in the fall but remains dormant over winter to germinate the following spring. Wild proso millet produces a large quantity of seed per plant. It is common to find 500 or more seeds per square foot in infested areas. The seed is spread easily by harvesting equipment, especially in sweet corn production fields (where it has been spreading rapidly).

Wild proso millet (*Panicum miliaceum L.*).



CONTROL OF WILD PROSO MILLET IN FIELD CROPS

Wild proso millet is a warm season grass that germinates most readily when soil temperatures are at least 50° F. For that reason wild proso millet is less competitive if corn is planted early in narrow rows (30 inches wide or less) than if it is planted later in wide rows, as is usually the case with sweet corn.

Most field crops can be planted in wild proso millet infested areas if good weed control practices are followed and a good choice of herbicides is made.

Corn

Wild proso millet germinates readily from deep in the soil (2 to 3 inches or more). For this reason herbicides such as EPTC with protectant (Eradicane), butylate with protectant (Sutan Plus), alachlor (Lasso), or metolachlor (Dual), when applied at the full label rate for the soil type and incorporated into the soil before planting, have given the best control of wild proso millet in Minnesota trials.

Of these four herbicides, EPTC has given the most consistent control. However, repeated annual usage of EPTC has resulted in reduced effectiveness on wild proso millet due to rapid breakdown of EPTC. In recent research, the addition of (Dyfonate) or related compounds (called extenders) have prevented this rapid inactivation of EPTC. Use of extenders has not yet been cleared in Minnesota, however. With rainfall soon after application, alachlor and metolachlor applied preemergence have given good, early season control of wild proso millet. However, a single application of any of these four herbicides usually fails to give full-season control of wild proso millet. Combinations of EPTC plus protectant (Eradicane) applied preplant incorporated followed by a delayed preemergence application of cyanazine (Bladex) plus alachlor or metolachlor, or an early postemergence application of cyanazine plus pendimethalin (Prowl) have given satisfactory season-long control of wild proso millet in corn.

Soybeans

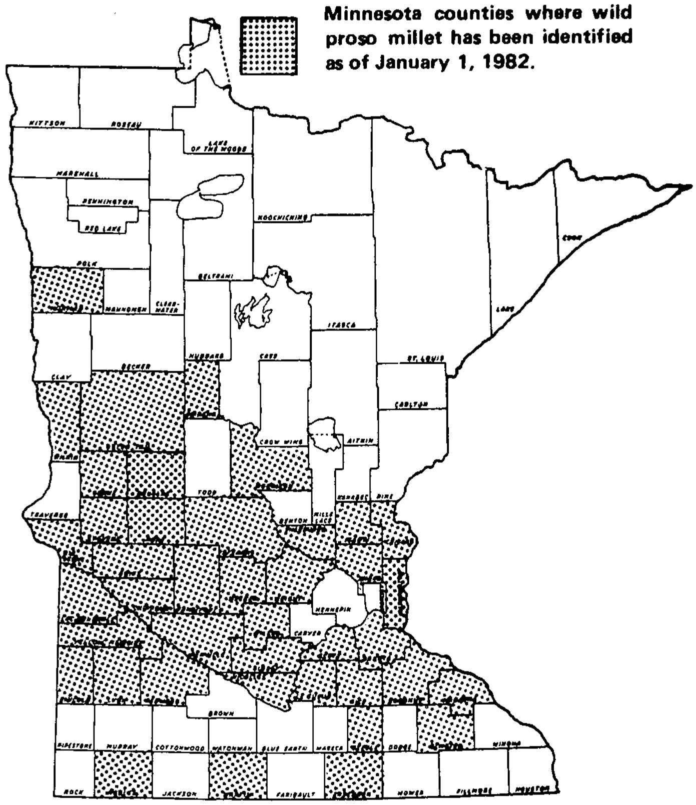
The herbicides trifluralin (Treflan), profluralin (Tolban), fluchloralin (Basalin), pendimethalin (Prowl), or vernolate (Vernam) applied preplanting and incorporated have given only fair control of wild proso millet when used alone. However, if one of these herbicides is used preplanting, incorporated, followed by preemergence use of alachlor (Lasso), metolachlor (Dual), or chloramben (Amiben), good control of wild proso millet usually has resulted.

These preemergence herbicides may be banded and one or two cultivations used to control weeds in the row. Chloramben (Amiben) may be tank-mixed with trifluralin (Treflan) and the mixture incorporated. Alachlor or metolachlor, applied preplant and incorporated at the full label rate for the soil condition, also has given acceptable control in some trials when applied alone or in combination with chloramben as an overlay or tank-mix treatment.

For effective control of wild proso millet in soybeans, the full label rate of each herbicide – for the soil condition – must be used.

Small Grains

If small grains are planted in April in Minnesota, with adequate fertility and soil moisture, wild proso millet normally does not compete seriously with the crop. Small grains should not be planted late in areas known to be infested with wild proso millet because there is currently no effective herbicide for control.



Minnesota counties where wild proso millet has been identified as of January 1, 1982.

Sunflowers

EPTC (Eptam) or pendimethalin (Prowl) applied preplanting and incorporated at the full label rate has given fair to good control of wild proso millet in sunflowers if soil moisture conditions are favorable. Chloramben (Amiben) can be applied preemergence, banded, or broadcast together with row cultivation to give additional control.

Dry Edible Beans

Preplanting applications of EPTC (Eptam), trifluralin (Treflan), profluralin (Tolban), or mixtures of EPTC with these herbicides, should give fair to good control of wild proso millet in dry edible beans. However, do not use EPTC on Adzuki beans. Alachlor (Lasso) may be applied alone or in a tank mixture combination with trifluralin (Treflan) as a preplanting, incorporated treatment. The combination, when used at maximum label rates for the soil type, may give better wild proso millet control than any herbicide used alone. Row cultivation also may be needed to give additional control. Alachlor should not be used on Adzuki beans.

Flax

Flax does not compete well with weeds such as wild proso millet. EPTC (Eptam) or dalapon will suppress wild proso millet in flax but cannot be depended upon for adequate control. Therefore, flax should not be planted in fields where wild proso millet is a problem.

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NEW WEED PROBLEMS IN MINNESOTA

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Weed populations tend to shift over time. These shifts involve two basic types or groups of weeds. The first group of weeds are those that have been around all the time, but have not been serious problems under a traditional farming system. The second group of weeds are new weeds that come in from other areas, become established, and persist as problems. Shifts are often caused by new breakthroughs in weed control or simply by extra efforts for control of problem weeds. Before the discovery and use of 2,4-D, field bindweed was considered a major weed problem in small grains. Today, field bindweed is still with us, but it is not considered a major weed problem in most field crops. Also, several years ago, field dodder was considered a major problem in red clover and other legume seed fields. Because of efforts to clean up seed lots and fields, field dodder is now encountered only very rarely as a significant problem.

In the past ten years, many weed problems have increased in severity in Minnesota. Many of these troublesome or potentially troublesome weeds have increased in numbers because certain crops and herbicides have been used repeatedly on the same fields for several years. For example, atrazine, which farmers found to be a very reliable and safe herbicide for the control of many common weeds in corn, killed most weeds but allowed atrazine tolerant weed species such as wild proso millet, fall panicum, and woolly cupgrass to increase in numbers until they became a problem in many fields. Another example is the increase in wild buckwheat and smartweed in small grain fields where 2,4-D or MCPA have been used repeatedly as the only herbicide. Also, a change in tillage practices prompted by the need to conserve soil, water, energy, and time has helped to change the weed spectrum in many fields. A reduction in moldboard plowing and deeper tillage and a trend toward more minimum-tillage and shallow or no-till methods have increased populations of several perennial weeds such as common milkweed and Canada thistle and several small-seeded annual grass weeds such as foxtails, barnyardgrass, and panicum species. Certain weed species may be given an advantage and increase in numbers if farmers in depressed economic times cut back too drastically on fertilizer or if excessively wet or dry weather conditions persist for a year or two.

Many of these troublesome weed problems can be solved simply by the correct identification of the weed and by selection of an effective herbicide or herbicide combination. For example, many of the annual grasses that are not controlled by atrazine may be controlled in corn by grass herbicides such as alachlor (Lasso), metolachlor (Dual), EPTC plus protectant (Eradicane), etc., or mixtures of these herbicides with atrazine or cyanazine (Bladex). Many of the new weed problems, however, are not controlled by the most commonly used herbicides available for use in field crops at safe usage rates and must be controlled prior to planting the crop or after crop harvest by non-selective herbicides such as glyphosate (Roundup).

One weed problem that has recently been identified in corn in Fillmore County, Minnesota, is a type or strain of atrazine resistant lambsquarters. Atrazine has been very effective over the years for controlling common lambsquarters in corn with repeated atrazine use on continuous corn. However, an atrazine resistant biotype has apparently evolved which will require the use of another herbicide or weed control method for control. This may present an argument for the rotational use of herbicides and/or rotation of crops to reduce the potential for the development of herbicide resistant weeds.

A list of new weed problems in Minnesota that have increased in importance in over the past ten years together with the area of the state and the principle crops they infest is given in Table 1.

Table. Principle "new" weed problems. (O. E. Strand)

Weed species	Life Span[1]	Crops infested	Area of the state where most prevalent
Wild proso millet	A	Corn, soybeans	Southern half of state
Wooly cupgrass	A	Corn, soybeans, small grain	Southeastern Minnesota
Almum grass	A	Corn, soybeans	Southern Minnesota
Robust green foxtail	A	Corn, soybeans	Southwestern Minnesota
Large crabgrass [2]	A	Corn, soybeans	Northcentral Minnesota
Field sandbur [2]	A	Corn	Northcentral Minnesota
Eastern black nightshade	A	Soybeans, dry beans	Southwestern Minnesota
Hairy nightshade	A	Soybeans, dry beans	Northcentral Minnesota
American germander	P	Corn, soybeans	Southcentral Minnesota
Venice mallow	A	Soybeans, corn	Southwestern Minnesota
Buffalobur	A	Soybeans, corn	Southwestern Minnesota
Jimsonweed	A	Soybeans, corn	Southern Minnesota
Carolina horsenettle	P	Small grain, corn	Southeastern Minnesota
Hemp dogbone	P	Alfalfa, corn, soybeans	Southern Minnesota
Smooth groundcherry	P	Soybeans, corn	Southern Minnesota
Narrowleaf hawksbeard	B	Alfalfa	Southeastern Minnesota
Musk thistle [2]	B	Pasture, alfalfa	Southern Minnesota
Plumeless thistle [2]	B	Pasture, alfalfa	West central Minnesota
Wild cucumber	A	Soybeans, corn	Southern Minnesota
Burcucumber	A	Soybeans, corn	Southern Minnesota
Hemp nettle	A	Small grains, grass seed fields	Northern Minnesota
Leafy spurge [2]	P	Pasture, non-cropland	Statewide

[1] A = annuals; B = biennials; P = perennials

[2] These weeds have been around longer but have become more serious in recent years.

HERBICIDE USE IN CONSERVATION TILLAGE SYSTEMS

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INTRODUCTION

Reduced or "conservation" tillage systems are very effective in reducing soil erosion from cropland. Tests at the University of Illinois on a 5% slope resulted in 5 to 6 tons/acre of soil loss with 3 inches of rainfall on moldboard plowed soil but well under 1 ton/acre of soil loss from chiseled soil. In addition to reducing soil erosion, conservation tillage systems allow crops to use water more efficiently by making the soil surface rough and by leaving a mulch of crop residues. Fuel, machinery, and labor cost are also lower when tillage is reduced. Conservation tillage systems commonly used include substitution of chisel plowing for moldboard plowing; use of a disk, field cultivator, or other secondary tillage implement with no primary tillage; and no-tillage or slot-planting. Many farmers are also using less secondary tillage than is currently suggested for herbicide incorporation in an effort to reduce production cost and insure timely planting.

Although there are several advantages to reducing the amount of tillage for crop production, these advantages are often offset by inadequate weed control. Reasons cited for poorer weed control with reduced tillage systems include difficulty in incorporating some herbicides, inadequate herbicide rates, and interference of crop residue with herbicide placement.

TILLAGE EFFECTS ON WEED CONTROL

Siemens and Oschwald (1976) in a study of several tillage systems, found that with the same herbicide application rates weed control decreased and the amount of crop residue on the soil surface increased as the amount of tillage was reduced. They noted that although preplant incorporated herbicide treatments could have been used with most tillage systems, the additional secondary tillage required to provide uniform incorporation would have resulted in smooth seedbeds with much less crop residue left on the soil surface for soil erosion control.

Erbach and Lovely (1975) found that good weed control could be obtained with preemergence herbicides even when large quantities of corn residues (5000 lb/A) were present on the soil surface. They noted in greenhouse studies, however, that higher herbicide rates were required to provide good weed control as the amount of crop residue increased and that rainfall after herbicide application improved weed control. Moomaw and Burnside (1979) reported that good weed control could be obtained in soybeans with several preemergence and preplant incorporated herbicide treatments where a significant portion of the soil was covered with corn residues. However, they also noted reduced weed control, especially with preemergence treatments, when herbicide application was followed by a lack of rainfall for ten or more days.

Results of our studies at the University of Illinois have shown that weed pressure increases as tillage is reduced. Results from one experiment is summarized in Table 1 and shows an inverse relationship between weed populations and tillage. Conventional moldboard plowing with three spring tillage operations had only 6.8 weeds per square foot where no herbicide was used. The highest weed population, 177 weeds per square foot, occurred in zero-tillage plots that received only a contact herbicide at time of planting. Studies have also shown that weed control generally decreases slightly as tillage is reduced (Table 2). Soil roughness, residue level, and degree of cloddiness all determine the effectiveness of herbicides applied to the soil surface. Our studies indicate that herbicide rates must be increased for reduced tillage in order to give weed control comparable to that obtained at normal rates with conventional tillage systems. The rate increase is not large, however, and we have been able to obtain satisfactory weed control from applications within the maximum labeled rates.

More research is needed to determine the effect of each variable on weed control. We have been unable to separate the effect of residue, roughness and cloddiness on weed control. Some data is available that indicates that although crop residue will absorb soil applied herbicides, most of the herbicide is removed from the residue by rainfall of one-half inch or more. Amount absorbed and removed by rainfall vary depending on formulation and type of herbicide used.

SOIL INCORPORATION

A considerable amount of research has been conducted in past years to determine the efficiency of mixing preplant herbicides in the soil. The commonly accepted incorporation practice has been to apply the herbicide to a well-tilled seed bed and mix the chemical into the soil with two perpendicular passes with a tandem disk or field cultivator. With conservation tillage practices, farmers need methods of applying herbicides to the soil that provide consistent weed control.

Many farmers are now incorporating herbicides in the soil using only one tillage operation. Adequate weed control is obtained many times, but increasing complaints of weed streaking and decreased performance are being received. To answer questions about soil incorporation in reduced tillage systems, we are conducting laboratory and field studies to evaluate the effect that interactions between tillage and herbicides have on weed control.

Disk and Field Cultivator

Our studies verify that two passes with a tandem disk or field cultivator are required to give uniform mixing for consistent weed control. With rough chiseled ground it has been generally recommended that you level the soil before applying a herbicide. Because this approach requires three tillage passes primarily to apply the herbicide, it is not compatible with conservation tillage. Farmers who are interested in limiting the number of secondary tillage operations to one or a maximum of two are asking if they should apply the herbicide on the rough surface and incorporate twice or if they should level the soil, and then apply and incorporate the herbicide with only one pass.

We have conducted field studies for the three years on both corn and soybean residues to determine the effect of applying herbicides on rough soil surfaces versus applying them after tilling the soil. Incorporation treatments have included (1) applying the herbicide on undisturbed soil and incorporating them twice with a disk or field cultivator or incorporating them once with a PTO tiller or a combination tool, (2) tilling the soil, applying the herbicides, and incorporating once with a disk or field cultivator, (3) applying the herbicides between the disk gangs or field cultivator shanks and incorporating with one additional pass, or (4) applying the herbicide during the tillage operation with a PTO tiller or combination tool. The percentage of grass controlled in 1981 with each of these methods is summarized in Tables 3 and 4. Note that less than the recommended herbicide rates were used to accentuate the differences between incorporation techniques.

Results for the three years indicate that the most consistent weed control was achieved with spraying the herbicide on the rough chiseled surface and incorporating twice with a disk or a field cultivator. Leveling the soil surface, applying the herbicide, and then incorporating with only one pass resulted in weed streaking in some cases. Our research results over the past three years show that most herbicides can be applied directly on corn or soybean ground chiseled in the fall, or on undisturbed soybean ground. If the chiseled ridges have been reduced to no more than 3 to 4 inches tall during the winter months and your secondary operations till the soil 4 to 5 inches deep to fully move and level the soil seedbed, you can achieve adequate weed control by applying the herbicide directly on the untilled soil surface. However, the results of this technique are not as consistent as those of conventional techniques (such as one tillage to level the soil, then two tillages to incorporate); therefore, you must accept some risk in exchange for the advantages of reducing tillage.

A one-and-one-half pass incorporation can be successfully performed by mounting the spray nozzles between the front and rear gangs of a tandem disk or between the first and second rows of shanks on a field cultivator. This pass is then followed with a second incorporation pass. We obtained about the same results with the one and one-half pass incorporation system that we did when the herbicide was applied directly to the rough chiseled surface and incorporated with two passes. When mounting a boom between disk gangs or field cultivator shanks they should be positioned to allow spraying on leveled nonmoving soil. The brackets for mounting the nozzles must allow several degrees of freedom in order to obtain a uniform spray pattern that is not affected by physical obstructions such as the tires and frame. Flooding nozzles are the most flexible. They allow you to obtain uniform spray distribution in spite of restricted mounting heights and nozzle orientations. In extremely rough fields with a lot of residue, the equivalent one-and-one-half pass incorporation may not mix the herbicide into the soil and prepare the seedbed adequately. We have found that application in front of both gangs or shanks followed by two incorporations is the best way to insure consistently good weed control.

Combination Tools

Several new tools are available that combine disk gangs, field cultivator shanks, and leveling devices. These combination tools seem to have good potential for providing adequate incorporation of many soil-applied herbicides while leaving sufficient residue on the surface for soil erosion control. Our experience with the combination tools indicates that most of them handle large amounts of surface residue without clogging, and that they leave considerable residue on the surface for soil conservation. With the combination tools, soil mixing has frequently been inadequate at the center between the two disk gangs where the soil is not disturbed by the disk blades. As a result, weed streaking has occurred in our plots. The elimination of these streaks would result in an incorporation more uniform than with one pass using a disk or field cultivator, but not as uniform as with two passes using the same tools.

Mounting the boom between the disk and first row shanks gave unsatisfactory weed control because we were unable to apply the spray uniformly in the moving soil coming off the disk blades. Installing a batter board to stop the soil and level it before applying the chemical may be a feasible means of applying the spray material behind the disk sections.

In weed-infested plots, one pass with the combination tool did not result in sufficient tillage to control all the existing weeds. Consequently, a severe weed problem resulted shortly after planting. Under these conditions, additional tillage or the use of contact herbicides is required to control the germinated weed seedlings.

One-Pass Incorporation Tools

There is considerable interest in the amount of soil incorporation from tillage tools such as the Do-All, Roterra, Niemeyer, Vicon, and others. Generally, we have found that although most of these tools have potential for one-pass incorporation, they do not incorporate chemicals as deeply as tandem disks and may not give adequate control of deep-seeded weed seeds such as nutsedge, quackgrass, and johnsongrass.

The power-driven tools must be operated within a range of ground speeds, rotor speeds, and operating depths to obtain proper mixing. If depths are maintained at 3 to 4 inches and the manufacturer's recommended speeds are used, adequate mixing will be achieved. Most of the interest in power-driven tools centers upon their potential for use in one-pass tillage operations. In some cases the PTO-driven tool is mounted directly ahead of the planter to level the soil, apply and incorporate the herbicide,and prepare a smooth seedbed for planting, all in a single pass. On the Roterra the spray boom is generally mounted in back and sprays forward into the rotating tines. In our fall chiseled corn or undisturbed soybean ground plots, we have not measured any differences in weed control between applying herbicides in front of and applying them into the rotating tines of the Roterra.

To be effective the ground-driven multipurpose tools must be operated at high ground speeds in soil that have good tilth. Operating at low speeds or in wet soil will not provide adequate mixing for weed control. Tools such as the Do-All that have ground-driven blades can be used only on soils that are essentially free of residue. These tools are not used in conservation tillage programs.

SUMMARY

Weed control is a major consideration in making reduced tillage systems work. If preplant incorporation herbicides are used, they must be mixed properly in the soil for effective control. There is no single incorporation technique that is best for all conditions. The method used must be a part of the total tillage and planting system. Many types of equipment are available that if used properly will provide adequate soil incorporation of herbicides in a variety of soil types and conditions. In general, a farmer must weigh the benefits of reduced tillage against the increased risk of less effective weed control as he reduces soil mixing from two, to one and one-half, to one pass.

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Table 1. Effect of Tillage for Corn on Weed Control with No Herbicides

Tillage		Weeds (sq. ft.)		
Fall	Spring	Grass	Broadleaf	Total
P	D,D,F,PL	2.6	4.2	6.8
P	D,PL	4.6	5.5	10.1
C	D,D,F,PL	57.9	24.7	82.6
C	D,PL	4.9	14.7	19.6
-	D,D,D,PL	85.6	14.2	99.8
-	D,PL	95.9	44.9	140.8
-	PL,H	140.9	36.3	177.2

Tillage treatments: P = moldboard plow; C = chisel plow; D = disk; F = field cultivate; PL = plant; H = contact herbicide at planting.

Table 2. Effect of Tillage on Weed Control with a Herbicide

		Primary tillage		
Herbicide	Rate	Plow	Chisel	Disk
Metribuzin	3/8	95	71	65
Metribuzin	1/2	99	82	83
Metribuzin	5/8	100	97	84
Average		98	83	80

Table 3. Grass Control Obtained from Various Herbicide Applications on 1981 Corn Plots Following Soybeans

	Sutan+, @ 1 qt./A		Dual, @ 1/2 qt./A		Average	
Order of treatments	Percent control	Rank (1 = best control)	Percent control	Rank (1 = best control)	Percent control	Rank (1 = best control)
Spray, Disk, Disk	96.7	1	98.3	1	97.5	1
Disk, Spray, Disk	85.0	8	90.0	4	87.5	6
Disk-Spray[a], Disk	95.0	3	96.7	2	95.9	3
Spray, FC[b], FC	96.7	1	96.7	2	96.7	2
FC, Spray, FC	88.3	5	88.3	5	88.3	5
FC-Spray[a], FC	91.7	4	85.0	7	88.4	4
Spray, Soil Finisher	80.0	9	85.0	7	82.5	9
Soil Finisher-Spray[c]	75.0	10	83.3	9	79.2	10
Spray, Roterra	86.7	6	81.7	10	84.2	8
Roterra-Spray[d]	86.7	7	86.7	6	86.7	7
AVERAGE	88.2	-	89.2	-	88.7	-

[a] Herbicides applied between disk gangs or rows of field cultivator shanks.

[b] FC = Field cultivator

[c] Herbicides applied behind disk gang.

[d] Herbicides sprayed into rotating tines.

Table 4. Grass Control Obtained from Various Herbicide Applications on 1981 Soybean Plotw Following Corn

Order of treatments	Treflan, @ 1/2 qt./A		Lasso, @ 1-1/2 qt./A		Average	
	Percent control	Rank (1 = best control)	Percent control	Rank (1 = best control)	Percent control	Rank (1 = best control)
Spray, Disk, Disk	78.3	5	75.0	6	76.6	5
Disk, Spray, Disk	85.0	2	80.0	3	82.5	2
Disk-Spray[a], Disk	81.7	3	83.3	2	82.5	2
Spray, FC[b], FC	88.3	1	93.3	1	90.8	1
FC, Spray, FC	73.3	8	75.0	6	74.2	8
FC-Spray[a], FC	81.7	3	75.0	6	78.3	4
Spray, Soil Finisher	75.0	6	78.3	4	76.7	5
Soil Finisher-Spray[c]	75.0	6	76.7	5	75.8	7
Spray, Roterra	71.7	9	75.0	6	73.3	9
Roterra-Spray[d]	68.3	10	75.0	6	71.7	10
AVERAGE	77.8	-	78.7	-	78.3	-

[a] Herbicides applied between disk gangs or rows of field cultivator shanks.

[b] FC = Field cultivator .

[c] Herbicides applied behing disk gangs.

[d] Herbicides rpayed into rotating tines.

SMALL GRAIN WEED CONTROL - 1983

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Herbicides are a major means used by Minnesota farmers to control weeds in small grains. Over 75 percent of the Minnesota small grain acreage is treated annually. Though current weed control practices greatly suppress weed infestations, substantial numbers survive as indicated by state-wide survey conducted in 1979. The ten most prevalent weeds found in grain fields are listed in Table 1 along with the percent of grain fields infested and weed densities. These weed populations are sufficient to cause a loss of 10% in grain yields. Yield reductions of this magnitude result in total annual losses exceeding $50 million in spite of herbicide costs approximating $20 million. Weed control research and educational programs conducted by the University of Minnesota are aimed at reducing these yield losses. Extension Folder 493 "Weed control in small grains," included with this paper, describes the herbicide treatments that are now suggested for use in small grains. Timely applications of the appropriate herbicides could substantially reduce current small grain yield losses from weeds.

A problem area in small grain weed control is the control of weeds in small grains undersown with forages. The forage legumes, alfalfa and red clover, are seriously injured by herbicides such as 2,4-D and MCPA which are cleared for the control of broadleaf weeds in small grains. Efforts are now under way to clear a compound safer to legumes, bentazon (Basagran), for the control of broadleaf weeds in small grains undersown with legumes. Caution: At this time, December 1982, this use has not been cleared by the Environmental Protection Agency.

After four years of research in Minnesota a new herbicide, chlorsulfuron (Glean) was used by Minnesota farmers on a limited basis in 1982. Chlorsulfuron has now received a label clearance for use in wheat or barley and should be available to all Minnesota farmers in 1983. This herbicide is very active so application rates are extremely low, ranging from 1/100 to 3/100 lb/A (1/6 oz. to 1/2 oz./A). Chlorsulfuron controls most of the broadleaf weeds and several common grassy weeds. Exceptions are wild oat and several nightshade species which are not controlled by this herbicide. Application in wheat (including durum) can be made preemergence, or postemergence. In barley only postemergence applications are suggested. Chlorsulfuron is formulated as a 75% dry flowable granule which readily disperses in water for sprayer application. It is very low in toxicity to humans and animals. Under certain conditions (high soil pH, low soil moisture, and cool temperature) chlorsulfuron may persist in the soil for several growing seasons. Since crops other than wheat and barley are sensitive to chlorsulfuron, they should not be planted until a test strip of the crop, planted in the treated field, has grown normally over a full season. See the chlorsulfuron label for further information.

Table 1. Weed species and densities present in Minnesota grain fields under current weed control practices.*

Weed species	Minnesota small grain fields infested	Density in infested fields
	(%)	(plants/sq M)
Green foxtail	60	35
Lambsquarters	56	9
Smartweeds	55	7
Wild buckwheat	53	7
Yellow foxtail	47	42
Pigweeds	44	6
Canada thistle	39	2
Wild oat	30	6
Wild mustard	28	3
Ragweed	27	10

* Results from field surveys of grain field made in 1979

AGRICULTURAL EXTENSION SERVICE
UNIVERSITY OF MINNESOTA

EXTENSION FOLDER 493—Revised 1982

Weed Control in Small Grains

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This folder summarizes herbicide treatments for controlling weeds in small grains. For additional information refer to herbicide labels.

Spring Wheat, Durum Wheat, Oats, and Barley

If small grain is not underseeded with a legume, more herbicides and higher rates may be used (see tables 1 and 3).

Winter Wheat and Rye

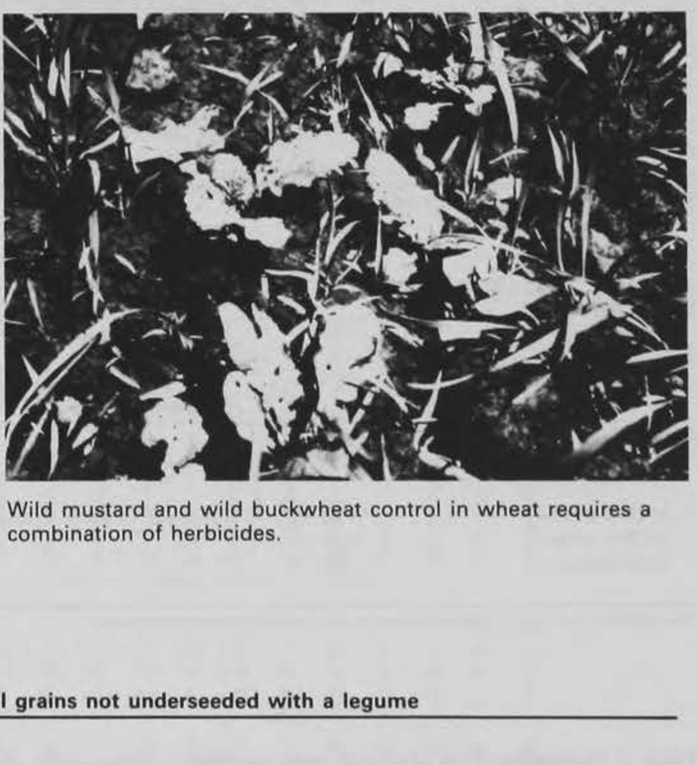
For winter wheat and rye apply all weed control chemicals except triallate in the spring only. Apply triallate in either fall or spring (see table 3).

Consider Effectiveness and Tolerance

Accurately identify the weed problem and then select the most effective herbicide (see table 4). Consider crop tolerance as well as effectiveness, however (see table 5). See table 6 for common names and trade names of herbicides and their formulations.

Caution

Avoid repeated and prolonged contact with all herbicides, especially direct contact with skin and eyes. Check label directions and restrictions. Avoid wind drift of herbicides to susceptible crops and ornamentals.



Wild mustard and wild buckwheat control in wheat requires a combination of herbicides.

Table 1. Suggestions for chemical weed control in spring-sown small grains not underseeded with a legume

Chemicals[1]	Pounds per acre of acid equivalent or active ingredient broadcast	Time of application	Remarks	Environmental Protection Agency limitations on use
Spring or durum wheat or barley				
2, 4-D amine	¼ to ⅔	After tillering to early boot.	For broadleafs. Amine less injurious to crop.	Do not graze for 2 weeks after treatment.
2, 4-D ester	⅙ to ½			
MCPA amine	¼ to ⅔	Two-leaf to early boot.		None
MCPA ester	⅙ to ½			
bromoxynil	¼ to ½	Two-leaf to early boot.	For broadleafs. Best control when weeds are small. Bromoxynil is effective on smartweeds and wild buckwheat, and may be tank-mixed with diclofop.	Do not graze for 30 days after treatment.
bromoxynil and MPCA esters	¼ + ¼	Three-leaf to early boot.		

Table 1. (cont.) Suggestions for chemical weed control in spring-sown small grains not underseeded with a legume

Chemicals[1]	Pounds per acre of acid equivalent or active ingredient broadcast	Time of application	Remarks	Environmental Protection Agency limitations on use
picloram and 2, 4-D amine	1/64 to 3/128 + ¼ to ⅜	Four-leaf to early boot.	Picloram may persist in the soil to harm most broadleaf crops the following year. See label.	None
triallate	1 to 1¼ (wheat) 1¼ to 1½ (barley)	Preemergence, spring (wheat). Preplanting or preemergence, fall or spring (barley).	For wild oat control. Must be incorporated into soil. Use higher rates for granules, lower rates for liquid. Liquid may be tank-mixed with trifluralin on spring wheat or barley.	Do not graze livestock on treated areas.
barban	¼ to ⅜	When wild oat is in two-leaf stage. Two sequential applications at ¼ lb/A each or one "late" application of up to ½ lb/A permitted. See label.	For wild oat control. Do not spray after crop is in the four-leaf stage. Use high rate on wild oat populations over 50 plants/sq. ft. and on semi-dwarf wheats.	Do not graze treated fields until after harvest.
difenzoquat	⅝ to 1	When wild oat is in three- to five-leaf stage.	For wild oat control. Use higher rates for higher density stands of wild oat. May be tank-mixed with MCPA and/or bromoxynil and with 2, 4-D.	Do not graze treated fields or cut for silage. Grain and straw can be fed. Use only on barley, and on durum wheat and spring wheat varieties listed on the label.
diclofop	¾ to 1¼ (wheat) ¾ to 1 (barley)	One- to four-leaf stage of grass weeds (wheat). One- to three-leaf stage of grass weeds (barley).	For annual grass weeds including wild oat. Use high rate for larger weeds. Only tank mix with bromoxynil. Do not apply other broadleaf herbicides within one week of diclofop application.	Do not graze treated areas or harvest forage from treated fields prior to grain harvest.
trifluralin	½ to ¾	Postplanting incorporation.	Improper application may result in crop injury. See label. Liquid formulation may be tank mixed with triallate.	None
Spring or durum wheat or oats				
dicamba and MCPA	⅛ + ¼	Two- to five-leaf stage.	Dicamba is effective on wild buckwheat or smartweeds.	Do not graze or feed forage to dairy animals prior to crop maturity.
Spring wheat				
propanil	1½	Three- to five-leaf stage of wheat.	For annual grasses and certain broadleafs. May cause temporary leaf injury or a slight delay in maturity.	Do not graze treated crop or cut for green chop feed.
propanil + MCPA isooctyl ester	1⅛ + ¼	Two- to four-leaf stage of grass weeds.		
Oats				
2, 4-D amine	¼ to ½	Six-leaf to early boot.	MCPA less injurious to crop.	Do not graze for 2 weeks after treatment.
MCPA amine	¼ to ⅔	Two-leaf to early boot.	Bromoxynil for smartweeds and wild buckwheat.	None
MCPA ester	⅙ to ½			None
bromoxynil	¼ to ⅜			Do not graze for 30 days after treatment.

[1] See table 6 for trade names of herbicides and their formulations.

Table 2. Suggestions for chemical weed control in spring-sown small grains underseeded with a legume

Chemicals	Pounds per acre of acid equivalent broadcast	Time of application	Remarks	Environmental Protection Agency limitations on use
Spring-sown wheat, oats, and barley				
2, 4-D or MCPA amine	⅛ to ¼	Six-leaf to early boot stage of small grain. Not before clover is 2 inches tall.	Legumes injured, canopy of crop or weeds reduces injury. Do not use on sweet clover.	Do not graze dairy animals on treated areas for 14 days after application of 2, 4-D.
diallate	1¼	Incorporate into the soil after planting but before emergence.	For wild oat control in barley underseeded to a legume.	None

Table 3. Suggestions for weed control in winter wheat and rye

Chemicals	Pounds per acre of acid equivalent broadcast	Time of application	Remarks	Environmental Protection Agency limitations on use
Winter wheat or rye				
2, 4-D amine	¼ to ¾	In spring, after grain is fully tillered, but before boot stage.	For broadleafs	Do not graze for 2 weeks after treatment with 2, 4-D. None for MCPA.
2, 4-D ester	¼ to ½			
MCPA amine or ester	¼ to ¾			
bromoxynil	¼ to ½	After wheat is fully tillered to boot stage.	For broadleafs	Do not forage or graze for 30 days after treatment with bromoxynil.
bromoxynil + MCPA ester	¼ + ¼			
Winter wheat only				
dicamba + 2, 4-D amine	⅛ + ¼ to ⅜	After winter dormancy until wheat begins to joint.	For broadleafs	Do not graze dicamba treated fields or harvest for dairy feed prior to crop maturity.
dicamba + MCPA amine	⅛ + ¼ to ⅜			
diclofop	¾ to 1¼	When grass weeds are in the one- to four-leaf stage.	For annual grass control. May be tank-mixed with bromoxynil.	Do not graze treated fields or harvest treated forage prior to grain harvest.
difenzoquat	⅝ to 1	When wild oat is in three- to five-leaf stage.	For wild oat control.	Do not graze treated fields or cut for silage. Grain and straw can be fed.
triallate	1¼ (liquid) 1¼ to 1½ (granules)	Must be incorporated into soil after application. See label.	For wild oat control.	Do not graze livestock on treated areas.
barban	¼ to ⅜	When wild oat is in two-leaf stage.	For wild oat control. Use high rate for wild oat populations over 50 plants/sq. ft. Sequential applications may be made if necessary. See label.	Do not graze treated fields until after harvest.
picloram + 2, 4-D amine	1/64 to 3/128 + ¼ to ⅜	Four-leaf to early boot.	For broadleaf weeds. May persist in the soil. Use only where a grass or grain crop will be planted the following year; one application per year.	None

Table 4. Effectiveness of herbicides on major weeds in small grains

	Small grains											
	trifluralin (Treflan)	triallate (Far-go)	diallate (Avadex)	2, 4-D amine or ester	MCPA amine or ester	bromoxynil (Brominal/ Buctril)	dicamba (Banvel)	picloram (Tordon 22K)	barban (Carbyne)	difenzoquat (Avenge)	diclofop (Hoelon)	propanil (Stampede)
Grasses												
Green foxtail	G	N	N	N	N	N	N	N	N	N	G	G
Yellow foxtail	G	N	N	N	N	N	N	N	N	N	F	G
Barnyard grass	G	N	N	N	N	N	N	N	N	N	G	G
Wild oat	P	G	G	N	N	N	N	N	G	G	G	P
Broadleafs												
Wild mustard	N	N	N	G	G	F	P	P	N	N	N	F
Wild buckwheat	P	N	N	F	F	G	G	G	N	N	N	G
Lambsquarters	G	N	N	G	G	G	G	F	N	N	N	G
Pigweed	G	N	N	G	G	G	G	F	N	N	N	G
Smartweed (annuals)	P	N	N	F	F	G	G	P	N	N	N	P
Common ragweed	N	N	N	G	G	G	G	F	N	N	N	P
Giant ragweed	N	N	N	G	G	G	G	F	N	N	N	P
Kochia	P	N	N	G	G	G	G	F	N	N	N	F
Marshelder	P	N	N	G	G	G	G	F	N	N	N	P
Canada thistle	N	N	N	F	F	N	G	P	N	N	N	N
Perennial sowthistle	N	N	N	F	F	N	G	P	N	N	N	N

G = good; F = fair; P = poor; N = no control

Effectiveness ratings apply if herbicide is used according to label recommendations as to rate, time of application, etc., and if favorable temperature and moisture conditions prevail.

Table 5. Crop tolerance and herbicide clearance[1]

Herbicides	Oats	Wheat	Barley	Rye
2, 4-D amine	F	G	G	G
2, 4-D ester	P	F	G	F
MCPA amine	G	G	G	G
MCPA ester	G	G	G	G
bromoxynil	G	G	G	G
dicamba	G	F	P	—
triallate	—	G	G	—
diallate	—	F	F	—
barban	—	F	F	—
difenzoquat	—	*	G	—
trifluralin	—	F	F	—
picloram	—	G	G	—
propanil	—	F	—	—
diclofop	—	G	G	—

[1] P = poor, F = fair, G = good, — = not cleared for use

*Good tolerance on winter wheat, and on spring wheat and durum wheat varieties listed on the label Not cleared for use on other spring wheat varieties See label

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Table 6. Herbicide names and formulations used in small grains

Common name	Trade name	Concentration and commercial formulation[1]
barban	Carbyne, Carbyne 2EC	1 lb/gal L, 2 lb/gal L
bromoxynil	Buctril, Brominal	2 lb/gal L
bromoxynil and MCPA	Bronate, Brominal Plus	2 lb/gal MCPA + 2 lb/gal bromoxynil L
diallate	Avadex	4 lb/gal L 10% G
dicamba and MCPA	MonDak Banvel M	1.25 lb/gal dicamba + 2.50 lb/gal MCPA L
difenzoquat	Avenge	2 lb/gal L
MCPA	Several, mixtures	See product label.
triallate	Far-go, Avadex-BW	4 lb/gal L 10% G
2, 4-D	Several	See product label.
trifluralin	Treflan	4 lb/gal L
picloram	Tordon 22K	20 lb/gal L
propanil	Stampede	3 lb/gal L
diclofop	Hoelon	3 lb/gal L

[1] G = granular, L = liquid