Soils, Fertilizer and Agricultural Pesticides Short Course

December 10-11, 1985
Minneapolis
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Service

PROCEEDINGS

SOILS, FERTILIZER AND AGRICULTURAL PESTICIDES

SHORT COURSE

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ACID-TYPE FERTILIZERS - WHAT ARE THEY AND WHERE DO THEY FIT IN THE CROP PRODUCTION PICTURE?

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Acid-type fertilizers generally are considered those which have a relatively high degree of acidity, as measured by a pH value between 0.5 and 3.0. These products also are called "acid-based" fertilizers. Acid-type fertilizers were first patented in 1922 but only recently have they been produced commercially. About 15 years ago, the National Fertilizer Development Center (NFDC) of TVA began studying the potential of producing solid urea phosphate from urea and merchant-grade wet-process phosphoric acid. Processes were developed to produce granular 16-41-0 and a highly purified crystalline form with a grade of 17-44-0 (1). However, these fertilizers are not produced commercially.

In recent years, several companies have been producing and marketing a wide range of fertilizer grades of "acid-type" fluid fertilizers made by mixing urea solutions with phosphoric acid and/or sulfuric acid. Some attributes claimed for these acid-type fertilizers are: (a) an effective source of nitrogen (N), phosphorus (P) and/or sulfur (S); (b) less N loss due to ammonia (NH_3) volatilization after surface applications; (c) enhanced micronutrient availability; (d) less clogging of drip irrigation emitters; and (e) an effective soil amendment for some saline-sodic soils.

Urea forms adducts with phosphoric and sulfuric acids when they are mixed in varying proportions, according to the equations:

$$CO(NH_2)_2 + H_3PO_4 \rightleftharpoons CO(NH_2)_2 \cdot H_3)O_4$$
$$CO(NH_2)_2 + H_2SO_4 \rightleftharpoons CO(NH_2)_2 \cdot H_2SO_4$$

Adducts are a type of "addition chemical compound," which has somewhat different properties than those of the individual components. For example, the adduct, urea-sulfuric acid, is not nearly so corrosive as sulfuric acid alone. A typical formulation for 10-30-0 would be: water - 452 lbs, urea - 436 lbs, and wet process phosphoric acid (54% P_2O_5) - 1,112 lbs, while that for 10-30-0-7S would be: water - 8 lbs, urea - 436 lbs, phosphoric acid - 1,112 lbs, and sulfuric acid - 444 lbs.

Little agronomic research information on this type of fertilizer is available because of limited use. This report summarizes results of several papers as well as some recent unpublished information from NFDC greenhouse and laboratory studies.

Effects on ammonia volatilization losses

Surface application of solid urea or urea-ammonium nitrate (UAN) solution to some soils may result in loss of N due to NH_3 volatilization. Urea hydrolyzes to ammonium carbonate which may lead to NH_3 losses with favorable conditions of high soil pH, high temperatures, drying conditions, and crop residues on the soil surface. The acidic nature of urea phosphate (UP) appears to delay or reduce NH_3 loss after surface application to acid and neutral soils (2). However, more recent results showed that surface application of UP to a highly calcareous soil did not significantly reduce NH_3 loss when compared with surface-applied urea (6). Field results generally have shown that there is little N loss from urea or UAN topdressed to winter wheat in the early spring. Further research is needed to determine if N losses are significantly affected by late spring or summer topdressings to wheat or other crops of acid-type fertilizers instead of urea or UAN.

Soil reactions in fertilizer injection zones

In a laboratory study, several fluid fertilizers were injected into a moderately acid (pH 6.6) and a calcareous (pH 7.8) soil, both from Colorado (7). The fertilizers were 10-34-0 (ammonium polyphosphate), 10-34-0 plus ammonium hydroxide, and 14-14-0-4S. The latter product was an acid urea phosphate made from combining urea with phosphoric acid and sulfuric acid. Inclusion of ammonium hydroxide (NH_4OH) with the 10-34-0 was to simulate the dual application of anhydrous NH_3 with 10-34-0.

The fertilizers were injected two inches below the surface of soil placed in quart-size cartons to simulate band application, assuming a 1-inch diameter fertilizer band on 15-inch centers at a rate of 40 lbs of P_2O_5/acre. Soil from the injection zone was sampled at periods from 1 to 75 days after application. Soil pH, $NaHCO_3$-extractable P, and DTPA-extractable zinc (Zn) and iron (Fe) were determined.

Results in Table 1 show that soil pH in the injection zone of the acid-type fertilizer (14-14-0-4S) applied to the acid soil was 3.6 after 1 day but increased to 6.2 after 10 days, which was similar to that with 10-34-0. The pH of injection zones in the calcareous soil was not affected by either fertilizer, probably because the free lime (5.2% $CaCO_3$ equivalent) served as a pH buffer. Including NH_4OH with 10-34-0 increased soil pH of the injection zone in both soils until about 25 days.

Available P was increased by dual NH_4OH with 10-34-0 and by 14-14-0-4S up to 10 days in both soils (Table 1). After 25 days only the dual N-P treatment produced higher available P levels. The level of available P in the injection zone of the acid-type fertilizer applied to the calcareous soil decreased rapidly with time after 10 days and was about 30% lower than that with 10-34-0 alone. These results help explain why dual application of anhydrous NH_3 with 10-34-0 results in improved P uptake by crops over that from 10-34-0 banded alone (3).

TABLE 1. Soil pH and extractable P and Zn in fertilizer injection zones of two soils (7).

Fertilizer	Days after application							
	1	10	25	50	1	10	25	50
	acid soil, pH 6.6				calcareous soil, pH 7.8			
	Soil pH							
10-34-0	6.3	6.3	6.0	5.8	7.5	7.6	7.5	7.6
10-34-0+NH_4OH	7.6	7.2	6.9	6.5	7.9	7.7	7.7	7.7
14-14-0-4S	3.6	6.2	6.1	5.9	7.6	7.8	7.7	7.8
--	6.2	6.4	6.2	6.3	7.6	7.6	7.6	7.8
	$NaHCO_3$-extractable P, ppm							
10-34-0	128	92	84	60	119	85	92	76
10-34-0+NH_4OH	186	99	80	72	175	130	103	110
14-14-0-4S	180	100	83	52	258	128	63	53
--	9	10	10	9	11	12	12	12
	DTPA-extractable Zn, ppm							
10-34-0	1.6	1.9	1.2	1.2	0.5	0.8	0.6	0.5
10-34-0+NH_4OH	1.9	2.1	1.2	1.6	0.6	0.7	0.5	0.5
14-14-0-4S	2.0	1.9	2.8	2.7	0.4	0.7	0.7	0.5
--	1.4	1.6	1.1	1.2	0.5	0.9	0.5	0.4

Application of 14-14-0-4S resulted in increased levels of available Zn only in the acid soil (Table 1). Similar results (not shown) were obtained with Fe. Since moderately acid soils usually are not deficient in available Fe and may not be deficient in available Zn, whether there is any agronomic advantage for using of the acid-type fertilizer is unknown. Applying 10-34-0 alone resulted in increased levels of DTPA-extractable Fe in the calcareous soil, but field results have shown that Fe uptake by crops is not affected by band application of 10-34-0. A possible reason is that the banded fertilizer only contacts a very small portion of the root zone in the field, so banded fertilizers may not react with enough of the soil micronutrients to significantly affect crop response.

Soil reactions near fertilizer bands

Two acid-type fertilizers and 10-34-0 each were band-applied to an acid Mountview silt loam soil from Tennessee which was limed to pH 7.6 and placed in plexiglass cells in a NFDC laboratory study. The application rate was equivalent to 40 lbs of P_2O_5/acre applied on 36-inch centers. Soil was sampled in radial increments of 0.5 cm horizontally along the fertilizer band after 7, 21, and 35 days.

Soil pH in the fertilizer band (0-0.5 cm) after 7 days was 7.1 with 10-34-0, increasing with distance to pH 7.4 at 2.5 cm (1 inch) from the fertilizer band (Table 2). Soil pH levels remained relatively constant until 35 days (not shown). With the acid-type 10-30-0, soil pH was 5.7 in the fertilizer band, increasing to pH 7.5 at 1.0 - 1.5 cm from the band after 7 days. Including sulfuric acid in the 10-30-0-7S product resulted in lower soil pH levels only to 1 cm from the fertilizer band. Soil pH levels near these fertilizer bands generally decreased with time.

TABLE 2. Effect of banded acid-type fertilizers and 10-34-0 on soil pH and extractable nutrients in soil around the fertilizer band (7 days after application).

Banded fertilizer	Distance from band, cm	Soil pH	Extractable nutrient, ppm			
			P	Fe	Mn	Zn
10-34-0	0-0.5	7.1	1310	75	91	17
	0.5-1.0	7.1	1140	22	23	14
	1.0-1.5	7.1	320	5	9	12
10-30-0	0-0.5	5.7	1220	59	24	6
	0.5-1.0	6.3	1680	20	56	9
	1.0-1.5	7.5	670	4	12	5
10-30-0-7S	0-0.5	4.6	770	51	9	4
	0.5-1.0	5.3	1320	28	51	18
	1.0-1.5	6.7	470	5	39	11
--	--	7.5	4	3	3	3

Available P (extracted by the double-acid procedure, Mehlich I, used for acid soils) was 1310 and 1220 ppm in fertilizer bands of 10-34-0 and 10-30-0, respectively, but levels of available P were much lower with 10-30-0-7S (Table 2). Levels of available P were higher at the 0.5 - 1.0 cm distance with the acid fertilizers and then they decreased with distance, approaching those of the untreated soil at 1.5 - 2.0 cm after 7 days. This indicates that the applied P moved about 1.5 cm (0.6 inches) away from each fertilizer band in this soil. Levels of extractable P in soil beyond 1 cm increased with time, which indicates diffusion of applied P from the fertilizer bands in soil. Levels of DTPA-extractable Mn and Zn were higher at the 0.5 - 1.0 cm distance than in the acid fertilizer bands, but decreased with distance beyond 1 cm. Concentrations generally decreased with time and were related to soil pH levels. In contrast, concentrations of DTPA-extractable Fe were higher in all fertilizer bands and decreased with distance.

Higher levels of extractable micronutrients suggest that native micronutrients in the soil were solubilized by all three fertilizers. However, some of the increased levels may have been due to impurities contained in the fertilizers. Whether higher Fe, Mn and Zn levels in soil are related to improved micronutrient nutrition of plants isn't known. Results generally have shown that band application of 10-34-0 alone to soil has not resulted in increased micronutrient concentrations in plant tissue. Therefore, the same results would be expected for the acid-type fertilizers. Clearly, more research is needed.

Acid-type fertilizers as carriers of $FeSO_4$

In a NFDC greenhouse study, three acidic urea phosphates cogranulated with $FeSO_4$ to contain 4% Fe were banded to a calcareous Fe-deficient soil (pH 7.5) from Nebraska (4). Grain sorghum response to the UP-Fe products varied with method of incorporating of $FeSO_4$. Chemical reactions between the $FeSO_4$ and UP during granulation and storage resulted in decreased levels of water-soluble Fe and oxidation of Fe to unavailable forms. Plant availability of the applied Fe decreased with level of water-soluble Fe in these products. These results suggest that granular UP is not an effective carrier of $FeSO_4$ for calcareous soils. Field results generally have shown that other P fertilizers also are not effective carriers of $FeSO_4$ for calcareous soils.

In another greenhouse study on the same soil, urea-sulfuric acid (28-0-0-9S), acidic urea ammonium nitrate phosphate (27-9-0), urea and a cogranulated urea-urea phosphate (38-12-0), were banded alone or with $FeSO_4$ (5). Grain sorghum forage yields were similar with $FeSO_4$ banded alone or with each fertilizer except for higher yields with banded urea-sulfuric acid at the high Fe rate (Table 3). Crop response with the acid-type fertilizers banded alone was similar to that of the control treatment. This suggests that these fertilizers did not solubilize soil Fe to increase its availability to plants.

TABLE 3. Forage yields and Fe uptake by grain sorghum, as affected by band application of acid-type fertilizers alone or with $FeSO_4$ to a calcareous, Fe-deficient soil (5).

Fertilizer	$FeSO_4$ applied, mg of Fe/pot					
	0	12	36	0	12	36
	Forage yield, g/pot			Fe uptake, mg/pot		
--	15.5	19.8	27.8	0.58	0.72	1.15
Urea	12.5	21.2	20.8	0.49	0.71	0.86
28-0-0-9S [1/]	14.7	21.6	32.6	0.57	0.78	1.18
27-9-0 [2/]	15.1	22.1	25.0	0.65	0.73	0.94
38-12-0 [3/]	10.7	22.0	21.7	0.47	0.78	0.65

[1/] Urea-sulfuric acid
[2/] Urea ammonium nitrate phosphate
[3/] Cogranulated urea-urea phosphate

Where do acid-type fertilizers fit?

A wide range of fertilizer grades, from 3:1 to 1:3 $N:P_2O_5$ ratios, can be conveniently produced from relatively less expensive urea, phosphoric acid, and sulfuric acid. The resulting acid-type fertilizers can be used just like other fluid fertilizers, if they are applied properly, but care must be taken in handling the acids during formulation and application of acid-type fertilizers. Although there is little agronomic data comparing these products, acid-type fertilizers and conventional fluid fertilizers should be similar in effectiveness with broadcast applications. While band applications of acid-type fertilizers result in increased levels of extractable P, Zn, Mn, and Fe in some soils, results discussed in this paper do not confirm that plant uptake of these nutrients was affected. Free lime in highly calcareous soils neutralizes the acids contained in acid-type fertilizers, so no changes in availability of native nutrients in soil should be expected after band application to these soils.

In general, acid-type fertilizers should provide the plant nutrients, N, P, and S at prices competitive with conventional fluid fertilizers. Crop response to acid-type fertilizers should be comparable to that with conventional products. Further research on these relatively new fertilizers is needed.

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CONSERVATION TILLAGE IN SOUTHEASTERN MINNESOTA - 1985

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Conservation tillage (as an opportunity to check erosion and reduce production inputs) continues to be adopted by innovation farmers. According to the 1984 survey by the SCS there is about 20% of the corn, soybeans, and small grain grown with conservation tillage (CTIC, 1984). Most farmers are aware of conservation tillage. What is needed are site specific recommendations which offer a relatively low risk approach under local conditions. In an effort to help disseminate research findings and fine tune them to local conditions a series of statewide tillage demonstrations are being established. This program is being funded to a large degree by the Soil Conservation Service. In 1985 this effort was focused in southeastern Minnesota (primarily due to the lack of Experiment Station data for these soils and the erosive nature of the soil in this area). Following is a summary of some of the findings for the 1985 season.

STAND

Although there are several notable exceptions, for the most part corn planted "no till" after corn resulted is substantial stand reductions. It appears that the following three causal factors were responsible: 1) poor seed to soil contact due to residue pushed into the seed furrow during planting, followed by dry conditions; 2) possible germination inhibition due to crop residue exudates (alleopathy) and; 3) cutworm activity at some sites. The stand reduction associated with the "no till" approach (the only in row tillage was done by a fluted coulter) is rare on these well drained silt loam soils in this part of the state. Two of the four sites with corn grown after corn (for grain) had substantial stand reduction with this treatment. More favorable soil and residue conditions (drier at planting) coupled with timely rains eliminated this problem at the other two sites. To eliminate this risk, however, it is advisable to use clearing discs or sweeps to keep the row area clean when planting corn into heavy corn residue.

ROW FERTILIZER

There is much data showing the importance of row fertilizer when using conservation tillage. Often there will be response to row fertilizer even at high background soil levels (Randall, 1982). Most fields will have variable soil test P and K levels due to previous fertilization, cropping, and manure history. Row applied P and K at planting will ensure that these nutrients are non yield limiting.

In 1985 there were reports of many cases where visual K deficiency symtoms were observed on soils with marginal K levels and the absence of row K at planting. The University of Wisconsin soil testing laboratory experienced unusually low corn ear leaf tissue levels of K in farmer samples (Schulte, personal communication). The benefits of row K are shown in figure 1. In this study conducted in Goodhue County, Minnesota on a Timula, silt loam soil all rows received 14 lbs N/A + 42 lbs. P_2O_5/A at planting. In addition, every other row received 10.5 lbs. K_2O/A. A range in background K levels were established with broadcast 0-0-60 applications. The difference in the row K response due to tillage is most likely due to differences in the depth of the starter band and soil moisture levels at these depths. These plots were planted with a conservation tillage planter equipped with double disc fertilizer openers. A compromise setting was used to plant both tillage treatments which resulted in a starter fertilizer band 2 inches beside and 1 and 3 inches below the seed for the no till and chisel treatments respectively. The advantages of a relatively modest rate of row K is apparent below a soil test K of 275 lbs./A with both tillage treatments.

PRIMARY TILLAGE AND CULTIVATION

At the Fillmore County site half the plots were cultivated (16 rows, 100 feet long). Researchers in Ohio and Indiana have shown an advantage to cultivation on silt loam soils. The soil at this site is a Tama, silt loam. Benefits from cultivation on these soils are due to: 1) weed control; 2) improved infiltration and retarded runoff from roughness and; 3) improved aeration (after crusting conditions are present followed by wet period). The effect of cultivation and tillage on corn yields and weed pressure are shown in tables 1 and 2 respectively.

There were significant main effects and an interaction of tillage and cultivation on grain yields at this site. The moldboard and no till treatments resulted in a significant cultivation response. There was no effect of cultivation on yields with chisel plowing or discing. Weed pressure generally decreased with less tillage and cultivation although the interaction was not significant with this variable. The dominant weed at this site was velvet leaf followed by giant foxtail. The response to cultivation was likely due to a combination of weed control and improved water infiltration under no till and moldboard conditions with the latter factor being the dominant influence (lack of response with the chisel treatment although weed pressure differences due cultivation were similar).

The effect of tillage on corn grain yields for Steele, Wabasha, and Dodge Counties is shown in table 2. Soils at these sites were a Le Sueur, clay loam, Fayette, silt loam, and Skyberg, silt loam respectively. The Dodge and Wabasha sites were by far the driest sites in this area of the state. Tillage had no effect at Wabasha and Steele counties and a large effect at the Dodge County site. Corn was grown after corn at this site and after soybeans at the other two. It's important to realize that during the establishment year the ridge till and no till treatments are the same. The ridge till treatment would be expected to yield similar to moldboard plowing after establishment. Corn emergence and early growth was variable with the conservation tillage options at this stie although final stand was not affected.

SOYBEANS

The effects of tillage and weed control strategy on soybean yields at the Wabasha county site is shown in table 4. The major weed at this site was lambsquarter. A burndown of 2,4-D ester (.5 lbs/A) plus Poast (.19 lbs/A) was used on the post emergence treatment. The preemergence treatment was preceeded by an application of Roundup (1 lbs/A).

There is signficant main effects and a tillage by herbicide interaction. Herbicide option is of little consequence with a ridge till system due to the weed control provided by cultivation with this treatment. There is a sizeable advantage with the narrow rows (7 inches) over the 38 inch rows with the ridge till treatment, however. The lower yields with the post emerge treatment under the subsoil and no till treatment is due to giant foxtail pressure. Lambsquarter excerted the most pressure with the chisel plow treatment. This is the reason for the lower yield with the preemerge treatment with this tillage strategy. Its obvious that under 1985 conditions if weeds are controlled there is a sizeable advantage to 7 inch rows over 38.

SUMMARY

1. It is advisable to keep the row area clean when planting corn after corn no till.

2. The importance of row P and K is emphasized.

3. Tillage had no effect on yield when corn was grown after soybeans at two of three sites. No till corn after corn, resulted in lower yields than chisel or moldboard plowing in two of two sites.

4. Cultivation improved corn yield with no till and moldboard plowing.

5. Increased tillage resulted in more weed pressure at two sites (velvet leaf and lambsquarter).

6. There was a large response to narrow row soybeans. No Till and Paraplow treatments with preemerge herbicide resulted in th highest yield. Post emergence herbicide strategy in other yields has proved to be as effective. In 1985, only broadleaf control was used resulting in foxtail pressure.

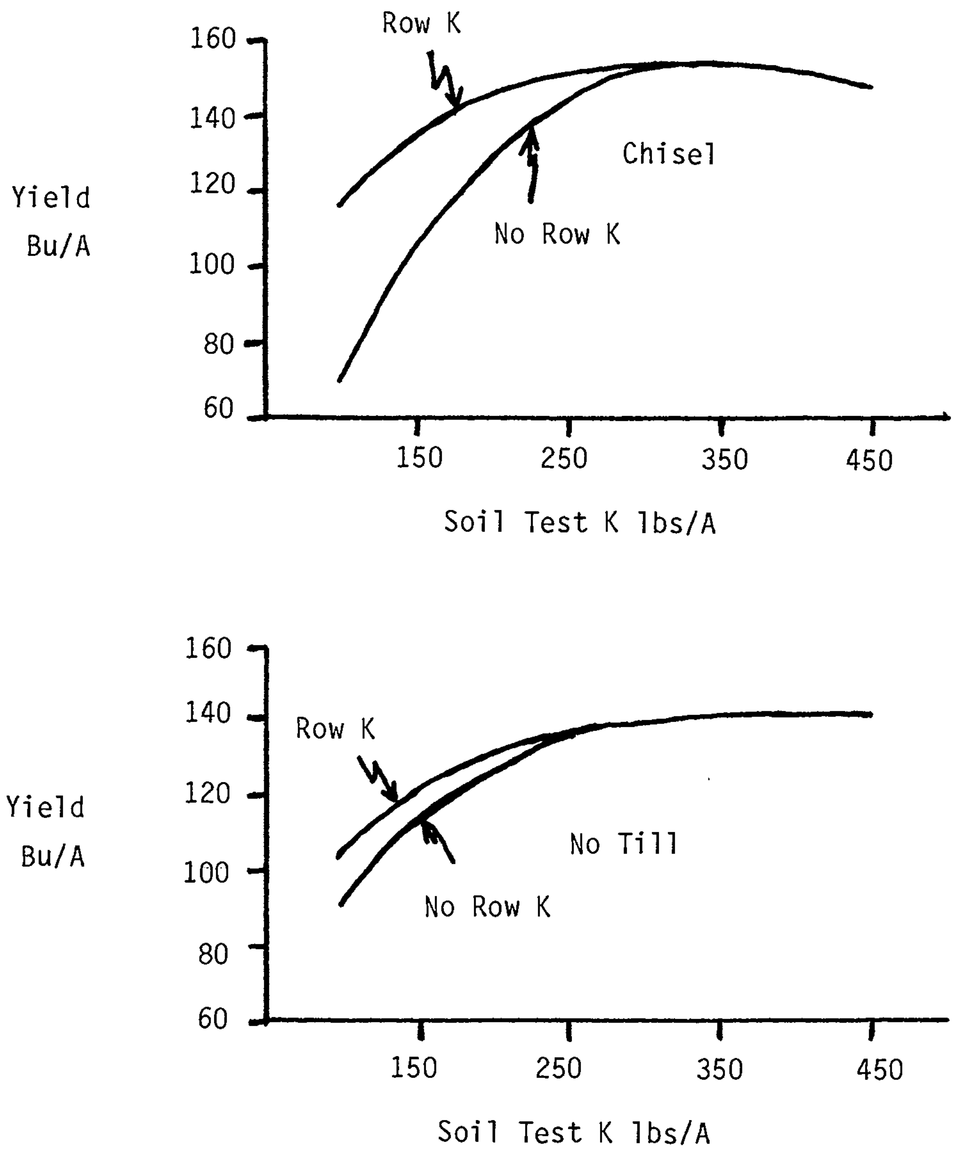

Figure 1. The effect of tillage, row potassium, and soil test K on corn grain yields at Goodhue County, 1985, (Moncrief, Swan, and Burford, unpublished).

Table 1. The effect of tillage and cultivation on corn grain yields following soybeans at Fillmore County, Minnesota, 1985 (Wagar and Moncrief)[1].

Tillage[2]	Cultivation Yes	Cultivation No
	----------Bu/A----------	
No Till	168	158
Disc	175	171
Chisel	171	174
Moldboard	177	170

[1] Tillage, cultivation, and tillage x cultivation are statistically significant at $\alpha = .10$.

[2] All tillage was accomplished in the Spring.

Table 2. The effect of tillage and cultivation on weed pressure at Fillmore County, Minnesota, July 23, 1985 (Wagar and Moncrief)[1].

Tillage	Cultivation Yes	Cultivation No
No Till	1.0	2.7
Disc	1.0	1.7
Chisel	1.7	3.3
Moldboard	1.7	3.3

[1] A scale of 1 to 5 was used to estimate weed pressure with 1 being relatively weed free (scattered) and 5 severe.

Table 3. The effect of tillage on grain yields at Steele, Wabasha, and Dodge Counties - 1985 (Wagar and Moncrief)[1].

	Steele Co.[2,3]	Wabasha Co.[2]	Dodge Co.[3]
	Bu/A		
No Till	162	108	118
Ridge Till	167	102	123
Chisel Plow	167	109	---
Moldboard Plow	169	---	150
Subsoil	171	106	---
Significance	NS	NS	α =.000

1. Corn followed soybeans at Steele and Wabasha Counties and corn for grain at Dodge County.

2. The subsoil treatment at Steele was established with an Eagle moldboard conversion unit (Minimum Till Plow Bottom). The subsoil treatment at Wabasha County was established with a Paraplow.

3. This is the establishment year at these sites (no till and ridge till are similar at this time. All plots were cultivated at these two sites.

Table 4. The effect of tillage and weed control strategy on soybean yields following corn at Wabasha County, Minnesota, 1985 (Moncrief and Wagar).

	Tillage			
Weed Control[3]	No Till[1]	Ridge Till[2]	Chisel[1]	Subsoil[1]
	Bu/A			
Preemerge	43.2	28.1	26.5	43.4
Postemerge	34.7	25.7	33.9	34.0

1. The no till, chisel plow and subsoil (paraplow) treatments had beans planted in 7 inch rows.

2. Ridge till soybeans were planted in 38 inch rows.

3. The preemerge treatment consisted of Dual, Amiben, and sencor at 2 + 2 + .25 lbs./A respectively. A post emerge treatment of Basagran and Blazer at .75 + .25 lbs./A was applied for the post emerge treatment.

RESPONSE OF SPRING GRAINS TO CHLORIDE FERTILIZATION

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Until recently you've likely never heard anyone mention chlorine (Cl) in soil fertility discussions. Even the most adamant believer in shotgun fertilization of micro and secondary nutrients hasn't included chlorine in crop recipes, and for good reason. Historically agronomists and soil scientists have ignored this element except in special cases where toxicity or salinity problems are a concern or where high Cl levels decrease the quality of the produce such as in tobacco production. Even though Cl was proven essential for plants around 1954, it has traditionally been considered present in ample quantities for crop production. Recently, however, yield responses to Cl additions have been docummented on cereal crops in several Great Plains states and in the Pacific Northwest.

Chlorine is one of the seven plant essential micronutrients and occurs almost exclusively as the chloride anion, Cl^-, in both soils and plants. It moves like nitrate in soils but does not interact to a significant extent with organic matter. Therefore, Cl^- in the soil solution is the major source for crop uptake.

EVIDENCE OF CHLORIDE RESPONSE

A growing body of experiments exist that shows response to chloride fertilization in the field. Studies in Oregon showed 12 to 30 bu/A yield advantages for ammonium chloride over ammonium sulfate when applied to winter wheat (Christensen, 1981). North Dakota experiments on barley showed a significant yield advantage of potassium chloride over potassium sulfate on one-out-of-five sites (Timm et al, 1986). South Dakota experiments, where potassium chloride (KCl) and calcium chloride ($CaCl_2$) have been compared, are summarized in Table 1.

Table 1. Spring wheat yield response to KCl and $CaCl_2$ in Eastern South Dakota at responsive sites, 1983-1985.

Treatment[1/]	Site 83A	83L	84N	84S	85S	Average
	bu/A					
Check	29	34	73	45	65	49
KCl	36	39	80	51	69	55
$CaCl_2$	36	39	78	51	68	54

[1/] 167 lbs KCl/A in 1983 and 120 lbs KCl/A in 1984-1985; $CaCl_2$ at equivalent Cl rate.
Fixen et al., 1986a.

Across these five sites where significant response to KCl occurred, $CaCl_2$ consistently gave yields similar to KCl indicating the responses measured were primarily due to Cl, not K. All these sites tested very high in exchangeable K except 84N which tested 290 lbs/A and did show a significant K response. Many other experiments have been conducted since 1982 where KCl (0-0-60) was applied but no other Cl containing material was included to determine whether response was due to K or due to Cl. Plant analysis data is useful in predicting what caused responses in these situations. Plant K and Cl levels are shown in Table 2 (1985 analysis are not completed; therefore, data from 1982-1984 only are shown).

Table 2. Influence of KCl fertilization on wheat plant K and Cl concentrations.

Treatment	Plant Concentration[1/] K	Cl
	%	
Check	3.2	0.35
+ KCl[2/]	3.2	0.74
Change	0.0	0.39

[1/] Whole plant at heading: average of 13 sites, 1982-1984.

[2/] Varying rates of KCl.

Fixen et al., 1986a.

Addition of KCl had no effect on plant K content; however, Cl content was more than doubled when averages of 13 sites are compared. It is quite apparent that the responses to KCl were largely due to Cl and not due to K.

The question of why response to Cl is being found in these areas when plant Cl concentrations are well above published critical levels needs to be answered. First, Junge (1963) showed that annual Cl input from precipitation was very low in the Midwest and plains states, amounting to 0.5 to 1.0 lbs/Ac./yr. Inputs increase as the oceans are approached and in more heavily industrialized areas where large quantities of coal are burned. Furthermore, in much of this region soils are well supplied with plant available K so potash (KCl) fertilization has been minimal. Also, in this region, occasional wet cycles cause leaching events that have the potential for flushing soil Cl^- from the root zone.

The second factor that may be involved with these surprising Cl responses relates to the definition of the critical Cl concentration. Considerable evidence exists that suggests the agronomic critical level (the level required to produce near maximum crop yield and quality) may be quite environmentally defined. The 100 ppm concentration currently in the literature was determined under greenhouse conditions where water relationships and disease pressures are quite different than under field conditions (Johnson et al., 1957). The concentration required in the field could be much higher when one considers the role of Cl in the regulation of turgor and plant water content. Under field conditions water deficits and root or foliar diseases that affect plant water status could alter considerably the optimum Cl concentration. South Dakota data suggests that approximately 0.25% is a critical Cl concentration for whole spring wheat plants at heading, which is 25 times the level reported in the literature (Fixen et al., 1986b).

RATE OF KCL REQUIRED AND ECONOMICS

The rate of KCl required to reach maximum yield at each site that has responded to KCl in South Dakota and where a rate variable has been included is shown in Table 3.

Table 3. Rate of KCl required at responsive sites for maximum spring wheat yield in Eastern South Dakota, 1982-1985.

Site	KCl Response1/	Rate Required	Return per $ invested2/
	bu/A	lbs/A	$
82H	5	86	2.91
82A	5	84	2.98
83A	7	92	3.80
83L	4	33	6.06
84S	6	121	2.48
85S	7	90	3.89
85B	8	120	3.33
85D	5	135	1.85
Avg.	6	95	3.41

1/ Variety = Butte. 2/ Calc. at $3.50/bu wheat and $0.07/lb KCl. Fixen et al., 1986a and unpublished data.

Most sites required around 100 lbs KCl except one that required only 33 lbs. This site contained over twice as much Cl in the top 2 feet of soil than the other responsive sites in 82-84.

Also included in Table 3 are the responses measured at each site. These ranged from 4 to 8 bu/A and averaged 6 bu/A. The return per $ invested on KCl at $3.50/bu and $0.07/lb of KCl averaged $3.41 indicating the responses were quite profitable. These calculations do not acocunt for the residual value of the Cl which on non-sandy soils could be quite substantial.

KCL PLACEMENT

Broadcast-incorporated versus with-seed placements have been compared at several sites since 1982 in Eastern South Dakota. These studies have consistently showed very little difference in effectiveness between the two methods on a per pound of KCl basis. Figure 1 shows that treatments containing drill KCl plotted near the same line as treatments where all KCl was broadcast. Other sites have shown similar effects. Site 84S shows a nonsignificant trend towards higher yields when all KCl was broadcast. The similarity between placements is not surprising considering that Cl is responsible for the yield increases. Chloride is a soil mobile element and should act, like NO_3^-. Therefore, localized placement should not be extremely critical.

Even though effectiveness of broadcast and drill applied KCl was similar across sites, a problem with seed placement exists. The average rate required for maximum yield discussed earlier was around 95 lbs of KCl or 57 lbs K_2O/A. This is more than can be safely applied in seed contact especially if some N is also applied with the seed.

FACTORS INFLUENCING RESPONSE

Soil Chloride Level

It seems logical that the quantity of Cl in the soil will influence the amount in the plant and the response to applied Cl. Figure 2 shows the relationship between soil Cl to a 2-foot depth and chloride concentration in the whole plant at heading of spring wheat in Eastern South Dakota. With one exception a reasonably good correlation existed, indicating that plant Cl level increased as soil Cl level increased. Figure 3 shows that 0.27% Cl was required in the wheat plant to reach near maximum yield.

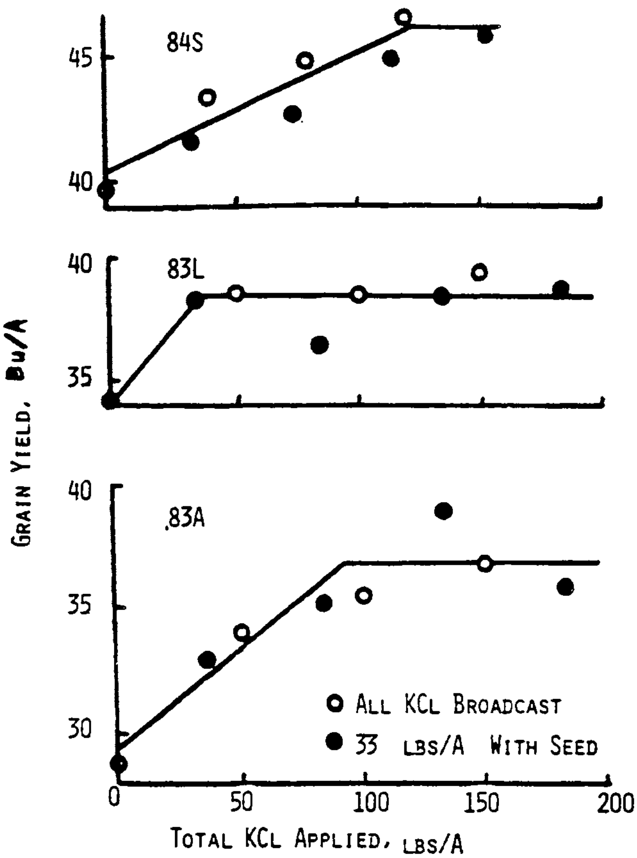

Fig. 1. Wheat grain yield response to KCl rate and placement, 1983-1984. (Fixen et al, 1986a).

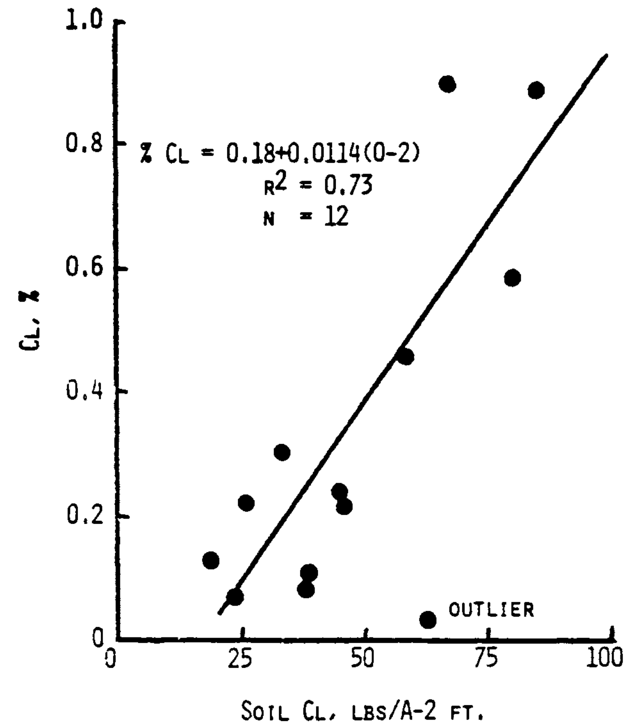

Fig. 2. Influence of soil chloride to a 2 foot depth on plant chloride concentration, 1982-1984. (Fixen et al, 1986b).

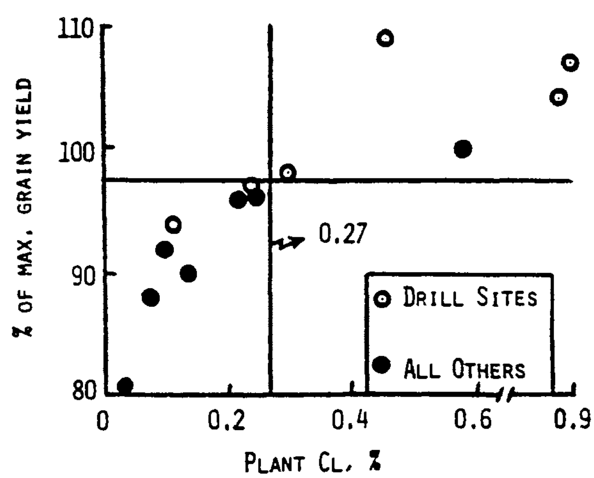

Fig. 3. Cate-Nelson analysis of plant Cl concentrations. (Fixen et al, 1986b).

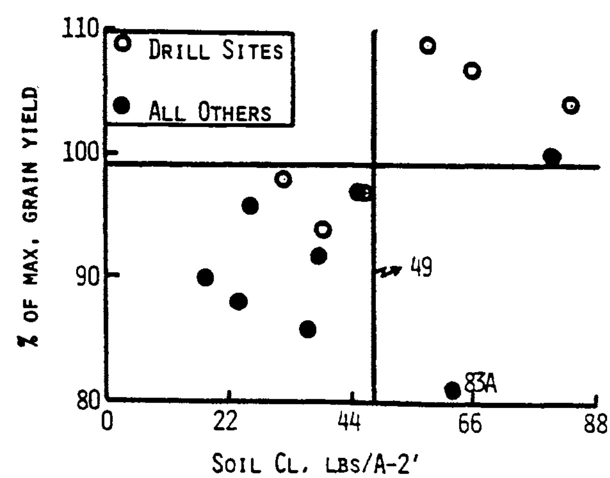

Fig. 4. Cate-Nelson analysis of soil Cl content, 0-2 feet.

A more direct measure of whether soil Cl content is a good predictor of response is its ability to divide sites or fields into responsive and nonresponsive groups. Figure 4 shows that water soluble soil Cl did successfully separate experimental sites into these two groups with one exception. Generally, if sites tested less than 49 lbs Cl/A-2' they were responsive to Cl fertilization. This indicates that testing soils for Cl may in the future be a good tool for predicting Cl responsive fields and, perhaps, the rate of Cl required, similar to current procedures for nitrate soil testing.

Since routine testing of soils for Cl is not a common practice and sufficient soil Cl calibration data is not yet available, other means of predicting Cl contents of soils are worth mentioning. Conditions that likely result in low soil Cl levels are:

1. Lack of KCl (0-0-60) fertilization in the past.
2. No recent manure application.
3. History of forage production (much greater Cl quantities are removed in forage crops than when only grain is removed).
4. If irrigated, low Cl levels in the water.
5. Significant leaching potential.

Disease Presure

Many of the studies conducted have demonstrated suppression of various diseases when Cl containing materials were applied. In Great Britain, both sodium chloride and KCl decreased the severity of yellow rust on several winter wheat varieties (Russell, 1978). Research in Oregon has shown suppression of take-all root rot, stripe rust (Christensen et al, 1981) and septoria (Christensen et al, 1982). North Dakota studies have shown that KCl application reduced common root rot of barley in experiments where potassium sulfate either increased root rot or had no effect.

Spring wheat studies in South Dakota have shown reduced incidence of leaf rust and leaf spot (complex of diseases including tanspot and septoria). Data from one site is summarized in Figure 5. A plot of grain yield versus % severity shows that severity was decreased and yields increased as KCl rate went up. Also, a treatment that did not include KCl but that received two applications of the fungicide "Tilt" plotted on the same line, suggesting that at this site the cause of the yield increase to KCl was disease suppression. These data also show that Cl was not eliminating the diseases and was not as effective as fungicide treatment. However, some suppression did occur and KCl, at these rates, is less expensive than fungicide treatment.

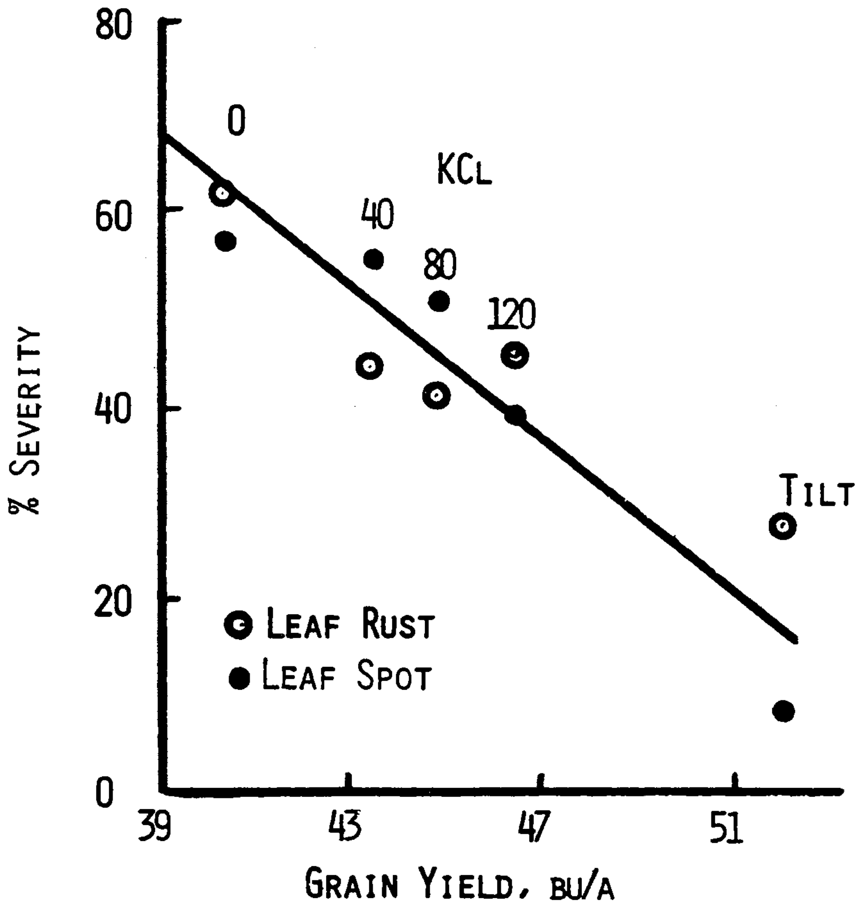

FIG. 5. RELATIONSHIP BETWEEN FOLIAR DISEASE, WHEAT YIELD, AND KCL FERTILIZATION AT SOUTH SITE, 1984. (SDSU). (FIXEN ET AL, 1986B).

Considering the number of incidences where Cl applications have decreased disease severity, situations where disease pressures are high will likely lead to more Cl response. Therefore, it the environment you grow small grain in is frequently infested with foliar or root diseases and low soil Cl levels exist, Cl application may be beneficial. Tillage systems where considerable crop residue is left on the surface or where continuous cereals are grown may be more responsive. Remember, however, that response to Cl fertilization has been found where no disease suppression was detected. Also, the good relationship between plant Cl concentration of unfertilized plots and response to Cl addition suggests that mechanisms otherthan disease suppression have been involved. Disease pressure would have to be similar across all sites for such a relationship to hold and this clearly has not been the case.

Plant water relationships have been altered by Cl addition in situations where little or no disease was apparent and where yield response occurred. Therefore, Cl effects on water relationships may be more important than the indirect disease effects.

Variety and Cereal

It is common to see small grain varieties respond differently to fertilizer addition at a given site or field. Normally, the varietal differences change when you look at other sites or years; in other words, they are not predictable. This does not appear to be the case with Cl when three South Dakota experiments are considered. The KCl response of four hard red spring wheat varieties at three sites is shown in Table 4.

Table 4. Influence of spring wheat variety on yield response to KCl fertilization in South Dakota.

Variety	Site 84N	Site 84S	Site 85S	Average Response
	bu/A[1]			
Marshall	4.2	7.7	9.2	7.0
Butte	0.0	5.3	6.2	3.8
Oslo	3.0	4.9	-1.7	2.1
Guard	0.4	-0.9	-0.4	-0.3

1/ Difference between 120 lbs KCl/A and 0 lbs/A.
Fixen et al.

Marshall was consistently the most responsive variety while Guard never responded at all. Butte and Oslo seemed intermediate with each responding at 2-out-of-3 sites. The three-site average response varied from 7 bu/A to zero. It is also interesting to note that the lowest yielding variety without KCl was the highest yielding variety with KCl (Table 5).

Table 5. Average grain yield of four spring wheat varieties, with and without KCl.

Variety	KCl, lbs/A 0	120	Response
	----------bu/A----------		
Marshall	58.3	65.3	7.0
Butte	60.5	64.3	3.8
Oslo	61.0	63.1	2.1
Guard	60.3	60.0	-0.3

Average of 3 site-years in Eastern South Dakota, 1984-1985. Fixen et al.

Spring wheat, barley, and oats have also been compared in South Dakota studies (Butte wheat, Morex barley, and Lancer or Moore oats). Table 6 summarizes the responses obtained across 6 site-years.

Table 6. Crop species influence on grain yield response to KCl.

Crop	Broadcast KCl	Grain Yield 82A	82L	82H	83A	83L	83D	Mean
	lbs/A	--------------------bu/A--------------------						
Wheat	0	36	43	36	29	36	56	39
	166	40	46	41	36	39	56	43
	Sign.	**	NS†	**	**	**	NS	
Barley	0	52	65	68	51	53	78	61
	166	46	67	70	56	57	82	63
	Sign.	NS	NS	NS	**	*	NS	
Oats	0	--	110	110	78	76	96	94
	166	--	105	113	76	81	94	94
	Sign.	--	NS	NS	NS	NS	NS	

*, ** Difference significant at 0.05 and 0.01 probability levels, respectively. † Not significant at 0.05 probability level.
Fixen et al.

Wheat responded at 4 out of 6 sites, barley at 2 out of 6 sites, while oats showed no response. Wheat and barley appeared similar in response while oats was nonresponsive. Caution must be used in interpretation of these results since the outcome could be related to the varieties selected rather than crop species. General screening of oat varieties for KCl response is underway.

Nitrogen Level

Considerable evidence exists in the literature that shows NO_3^- and Cl^- will compete with each other for uptake. Due to this previously reported competition, studies have been conducted evaluating the effect of rate of applied N on response to KCl in 1984 and 1985 in Eastern South Dakota. Two sites in 1984 did not show a significant interaction between applied N and KCl response, although trends existed at both sites for greater KCl response at lower N levels.

No KCl response occurred at one of the 1985 sites so no evaluation of N interaction is possible. At the second 1985 site, KCl response did occur and the results are shown in Table 7.

Table 7. Influence of N level on spring wheat yield response to KCl, south site, 1985.

Applied N	KCl, lbs/A 0	KCl, lbs/A 120	Response
lbs/A	---------bu/A----------		
0	59	69	10
120	70	76	6
240	70	72	2

Soil nitrate N at planting = 53 lbs/A-2 ft.
Fixen et al.

Rate of applied N had a marked influence on KCl response and decreased from 10 bu/A for the 0 level to 2 bu/A for the 240 lbs/A rate. The recommended N rate at this yield level and soil nitrate test would have been near the 120 lbs/A rate. At this rate, 4 bu/A of KCl response had already been lost. It is possible that soils with excessive nitrate accumulation may be less responsive to KCl or may require higher KCl rates for maximum yield. Also, since lower soil nitrate levels are frequently found in no till systems, they may be more responsive to KCl addition.

SUMMARY STATEMENTS

1. Economical yield increases to Cl fertilization have occurred in various states for spring wheat, barley, and winter wheat.
2. Generally a rate of 80-120 lbs of KCl (50-70 lbs K_2O) has been required to maximize spring wheat yield in responsive situations.
3. Chloride placement is not likely critical provided a sufficient rate is applied and no seed injury occurs.

4. Conditions where Cl responses are most likely include:
    a. Low soil Cl^- content (Measure?)
        - History of limited 0-0-60 fertilization
        - No recent manure application
        - History of forage production
        - Significant leaching potential
    b. High foliar and/or root disease pressure
    c. Responsive variety (?)
    d. Non-excessive N levels
5. Chloride is one additional growth factor that should be considered when striving for maximum economic yields.

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THE EFFECT OF SULFUR FERTILIZATION ON YIELD AND QUALITY OF CORN AND ALFALFA.

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The importance of sulfur (S) fertilizers for crop production in Minnesota has been recognized for several years. In past research, the use of S had increased crop production only on the sandy soils. Since the soil organic matter is a major reservior of S for plant use, there is always some question about the need for S in a fertilizer program where soils are not sandy but have a low organic matter content.

It is well known that S is an important component of some amino acids in plants and thus is important in the formation of plant proteins. The percentage of protein in plant material is one measure of the quality of that material for use as an animal feed. In Minnesota, both alfalfa and corn silage are important feed sources for the livestock industry. If the quality of this forage can be improved, this enhances the value of the forage and may result in improved profit from the livestock enterprise.

Although the effect of fertilizer S on the yield of corn and alfalfa has been studied in detail, very little attention has been devoted to the measure of the effect of fertilizer S on the quality of forage crops (alfalfa and corn silage). This report summarizes the initial results of a study designed to measure the effect of fertilizer S on both the yield and quality of corn and alfalfa.

SULFUR AND ALFALFA YIELD:

For this portion of the study, fertilizer S at rates of 0, 25, 50, 75, and 100 lb. S/acre is topdressed to established stands of alfalfa grown on sandy soils (Staples) as well as the fine textured soils in southeastern Minnesota (Winona and Goodhue Counties). Gypsum is used as the S source. For the fine textured soils, fertilizer S is applied to alfalfa which has received heavy application of manure as well as alfalfa that has not been manured. No manure was used at the sandy site at the Staples experimental field. Every attempt is made to harvest the first cutting of 1/10 bloom. Subsequent cuttings are taken at about 35 day intervals.

Soil properties for the alfalfa sites are listed in Table 1. The soil test values for phosphorus (P) and potassium (K) reflect the use of manure. The manure use had little, if any, effect on the S content of the surface soil. The S at all sites values are considered to be in the low to medium range.

The effect of fertilizer S on total alfalfa yield in 1984 and 1985 is summarized in Table 2. The alfalfa in Goodhue County was cut 4 times in 1985. In 1984, 3 cuttings were taken from the Staples and Winona County nonmanured site. The manured site in Winona County was harvested 4 times in 1984.

Except for the Staples site in 1984, the use of fertilizer S had no measurable effect on alfalfa yield, and the use of 25 lb.S/acre was adequate for highest yield at this location in 1984. Considering the S content of the soil at Staples (5 ppm) and the sandy texture, a response to fertilizer S would be expected. Although the S content of the surface soil at the other locations was marginal there was no increase in yield when fertilizer S was applied. This would indicate that the soil test for S is not suitable for predicting the need for fertilizer S for alfalfa production on fine textured soils in Minnesota.

Table 1. Soil Properties (0-6 in.) for experimental sites where fertilizer S was applied to alfalfa.

		Site and Year			
Soil Property	Staples (84)	Winona (84) no manure	Winona (84) manure	Goodhue (85) no manure	Goodhue (85) manure
pH	7.0	6.7	6.6	6.7	6.5
(Bray & Kurtz, #1), lb./acre	77	26	83	40	71
K (ammonium acetate), lb./acre	152	139	316	312	310
organic matter	medium	low	low	3.1	3.4
sulfate-sulfur, ppm	5	7.5	8	7.5	8.5

Table 2. Effect of fertilizer S on the total yield of alfalfa.

		Site and Year			
S Applied	Staples (84)	Winona (84) no manure	Winona (84) manure	Goodhue (85) no manure	Goodhue (85) manure
lb./acre		---------------ton dry matter/acre--------------			
0	3.0	4.2	3.7	5.2	4.9
25	3.7	4.0	3.9	5.4	5.1
50	3.5	4.1	3.8	5.0	5.0
75	3.6	4.2	3.8	5.5	5.0
100	3.5	4.0	3.9	5.3	5.1

SULFUR AND QUALITY OF ALFALFA:

The measurement of crude protein (CP) has always been used as an indicator of forage quality. Other measurements of quality are used in this study to provide a more complete evaluation of forage quality. These measurements are: 1) acid detergent fiber (ADF), and 2) neutral detergent fiber (NDF). The percentage of ADF is used as an indicator of the digestibility of the forage. The percentage of NDF is used as an indicator of forage intake by the animal.

For alfalfa hay, the CP, ADF, and NDF values are used to calculate the relative feed value (RFV) of the hay. A RFV in excess of 130 indicates prime quality alfalfa hay. Values in the range of 120-130 an used to designate a category of #1 alfalfa hay.

In 1984, the use of fertilizer S had no significant effect on any of the measures of forage quality that were used (Table 3). Samples taken from all cuttings were analyzed for forage quality. The results of the analysis of samples taken from the 1st cutting are typical of data collected from all cuttings and are included in this report. The values for the various components measured remained relatively constant for all cuttings taken.

SULFUR AND CORN YIELD:

For corn, various rates of S (0, 10, 20,40 lb. S/acre) were combined with rates of N (0, 75, 150, 225 lbs. N/acre to determine if the effect of S on yield and quality was affected by the rate of N applied. This portion of the study was also conducted on a sandy soil (Staples) as well as on fine textured soils (Goodhue County). Soil properties for all sites are listed in Table 4.

For the fine textured soils, the N and S used were broadcast and incorporated before planting. All S was broadcast and incorporated before planting on the sandy soils. The N rates, however, were split for these soils to reduce potential loss due to leaching. Corrective applications of phosphate and potash were used where needed. Management practices conducive to high yields were used at all sites.

Table 3. The influence of fertilizer S on the crude protein (CP) and relative feed value (RFV) of 1st cutting alfalfa in 1984.

S Applied	CP	RFV
lb./acre	%	
Winona Co. (manure)		
0	24.9	134
25	25.7	135
50	25.2	134
75	25.7	134
100	25.8	134
Winona Co. (no manure)		
0	24.4	130
25	24.2	131
50	24.0	131
75	24.1	132
100	24.2	133
Staples		
0	20.9	120
25	21.9	122
50	21.6	123
75	21.9	124
100	21.9	121

As would be expected, grain yields were increased by the use of fertilizer N at all sites in both years. The effect of fertilizer S on grain yield, however, was not as consistent.

Grain yields from the Staples location in 1984 are summarized in Table 5. The N rate of 150 lb./acre produced maximum yield. The broadcast application of 20 lb.S/acre was satisfactory produce optimum yields. When averaged over all N rates, additional S did not produce additional significant increases in yield. It's also important to point out that the rate of 20 lb.S/acre was satisfactory for optimum yield regardless of the rate of N applied. The rate of S necessary to achieve the highest yield was not affected by the rate of N used.

In 1984, grain yields at the Goodhue County location increased as the rate of applied N increased (Table 6). Highest yields were produced by the application of 225 lb. N/acre When averaged over all N rates, the broadcast application of 10 lb.S/acre also produced a significant increase in yield. As was the case at Staples, the rate of S needed for optimum yield did not change as the N rate changed.

The response to S at Staples is to be expected because of the sandy soil and the low amount of S in the soil. The response of corn to applied S at the Goodhue County location was unique. Factors contributing to this response are: 1) low organic matter content of the surface soil, 2) high grain yields and 3) above average growing season rainfall in 1984.

Table 4. Soil properties (0-6 in.) for experimental sites where fertilizer S was applied to corn.

Soil Property	Site and Year			
	Staples (84)	Goodhue (84)	Staples (84)	Goodhue (85)
pH	7.1	6.6	6.5	7.0
P (Bray & Kurtz #1), lb./acre	91	56	52	147
K (ammonium acetate), lb./acre	178	231	139	402
organic matter	medium	1.6	medium	3.6
sulfate-sulfur, ppm	4	9	2	6

Table 5. The effect of rate of applied N and S on corn yield at Staples 1984.

S Applied	N Applied (lb./acre)				
	0	75	150	225	Ave.
lb./acre	----------	----------	bu./acre	----------	----------
0	63.3	128.0	145.3	152.8	122.4
10	78.6	143.0	152.7	155.1	132.4
20	92.0	145.5	154.8	158.7	137.8
40	81.5	129.1	149.1	154.6	128.6
Ave.	78.9	136.4	150.5	155.2	

BLSD (.05) for N = 9.9 BLSD (.05) for S = 12.7

Table 6. The effect of rate of applied N and S on corn yield at Goodhue Co. 1984.

S Applied	N Applied (lb./acre) 0	75	150	225	Ave.
lb./acre			bu./acre		
0	102.7	162.1	163.8	190.0	154.7
10	122.8	171.4	185.1	187.4	168.9
20	120.8	181.2	174.8	184.3	165.3
40	126.7	174.2	186.2	188.4	168.9
Ave.	118.2	172.2	177.5	187.5	

BLSD (.05) for N = 6.7 BLSD (.05) for S = 7.5

Table 7. The effect of rate of applied N and S on corn yield at Staples 1985.

S Applied	N Applied (lb./acre) 0	75	150	225	Ave.
lb./acre			bu./acre		
0	30.7	85.4	126.6	116.7	89.9
10	44.1	88.4	114.7	111.9	89.8
20	50.2	84.8	112.9	118.8	91.6
40	56.7	92.6	130.8	128.2	102.0
Ave.	45.4	87.8	121.2	118.9	

BLSD (.05) for N = 10.4 BLSD (.05) for S = 13.2

In 1985, grain yields at Staples were restricted by cool temperatures during the growing season (Table 7). Highest yields were produced by the use of 150 lb.N/acre. Yields were also improved by the application of fertilizer S but a rate of 40 lb.S per acre was needed to achieve the highest yield. This is in contrast to the 20 lb. per acre rate needed in 1984.

There is no readily apparent reason for the higher rate of S needed in 1985, but the time of application may provide one possible explanation. The total amount of S used was broadcast and incorporated before planting. Rainfall was excessive in late spring and early summer and could have moved substantial amounts of sulfate-sulfur (SO_4-S) below the root zone. Thus the highest rate of applied S was needed to achieve the highest yield. As was the case in 1984, the rate of S needed to produce the highest yield was not related to the rate of N applied.

Yields at the Goodhue County site selected in 1985 were restricted by dry weather during the early part of the growing season and were not as high as anticipated. The use of 75 lb.N per acre was enough to produce highest yield. The use of fertilizer S had no significant effect on grain yield at this site (Table 8). There was apparently enough S released from the soil organic matter at this site to supply the S needs of the corn crop.

NITROGEN, SULFUR AND QUALITY OF CORN SILAGE

Three measurements were taken to monitor the effect of the use of fertilizer N and S on the quality of corn silage. The results from the Staples location in 1984 are typical of results collected from other locations. In contrast to alfalfa hay, there are no established procedures for calculating the relative feed value (RFV) of corn silage.

As would be expected, the crude protein (CP) of the silage incrased as rate of applied N was increased (Table 9). The percentage of both acid detergent fiber (ADF) and neutral detergent fiber (NDF) decreased with the application of fertilizer N. The values for these measurements were decrased by all rates of applied N when compared to the control. This reduction, however, did not increase as rate of applied N was increased.

The percentage of acid detergent fiber is an indicator of the digestibility of the forage. The data from this site indicate that the digestibility is reduced by the use of N fertilizer. The percentage of neutral detergent fiber is an indicator of forage intake. As with ADF, the percentage of NDF decreased with the application of fertilizer N. Explanations for these reductions are not apparent at this time.

In contrast to N, the use of fertilizer S had no effect on the quality measurements taken for the corn silage (Table 10). These data would indicate that the quality of the corn silage produced should not be a major concern when assessing the benefits of fertilizer S for corn production.

SUMMARY

The effect of fertilizer S on the yield of crops in Minnesota has been studied for several years. The results of these early studies show that fertilizer S has a positive effect where soils are sandy. This is especially true where the sandy soils have a low organic matter content. Since sulfur is an important component of some amino acids and protein, it would seem logical that fertilizer S might affect the quality of forage crops. So, a study was started in 1984 to measure the effect of fertilizer S on the yield and quality of alfalfa and corn silage.

It is not possible to make broad and sweeping conclusions from data collected for only 2 years. The results that have been recorded to date may be summarized as follows

-Applications of fertilizer S increased the yield of both corn and alfalfa when these crops were grown on a sandy soil. Relatively low rates were required to achieve maximum yield.

-Except for a site where the organic matter content was low, fertilizer S had no effect on the yield of alfalfa and corn grown on fine textured soils.

-Initial results show that the use of fertilizer S has had no significant effect on the quality components of both alfalfa and corn silage. It is emphasized that these are preliminary results and more trials will be conducted before definite conclusions are made.

Table 8. The effect of rate of applied N and S on corn yield at Goodhue County 1985.

S Applied	N applied (lb./acre) 0	75	150	225	Ave.
lb./acre	bu./acre				
0	100.3	125.4	131.6	122.2	119.9
10	111.2	123.5	119.0	128.9	120.6
20	111.3	133.6	129.0	132.4	126.6
40	112.8	119.4	131.8	129.2	123.3
Ave.	108.9	125.5	127.8	128.2	

BLSD (.05) for N = 6.7

Table 9. Quality components of corn silage as influenced by rate of applied N Staples, 1984.

N Applied	Component CP	ADF	NDF
lb./acre	%		
0	5.6	31.2	48.9
75	6.9	28.3	45.6
150	7.9	27.9	45.3
225	8.1	26.7	44.1

Table 10. Quality components of corn silage as influenced by rate of applied S. Staples, 1984.

S Applied	Component CP	ADF	NDF
lb./acre	%		
0	7.1	27.4	44.5
10	7.1	28.8	46.3
20	7.2	28.3	46.2
40	7.0	29.5	47.1

NITROGEN FERTILIZATION AND THE ENVIRONMENT

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Nitrogen (N) fertilizer management for corn production has been and will continue to play a major economic and environmental role for crop producers. Unless growing conditions are very poor or substantial N exists in the soil, large and profitable yield increases are usually obtained with N fertilizer additions. Frequently though, N fertilizers have been linked to the occurrence of nitrates in ground and surface waters. This contamination of drinking waters is gaining public conern. Consequently, steps are being taken to establish the relationship between N fertilizer management, fate of N in the soil, and the occurrence of nitrates in groundwater.

Through a process called nitrification, fertilizer N is converted to nitrate (NO_3^-), which is extremely mobile in the soil system. Under wet conditions NO_3^- in the soil can either be leached downward with the percolating water or can be lost to the atmosphere through another process called denitrification. For the purposes of this short course this paper will address the downward movement of NO_3^-, commonly called leaching.

FACTORS AFFECTING NO_3^- LEACHING

The amount of NO_3^- that leaches from a soil depends on the amount of water that moves through the soil and the amount of NO_3^- in the soil when the water drains through and out of the soil profile (Pratt, 1984). Other factors such as the soil, climate, irrigation, crop grown, and fertilizer N management either directly or indirectly affect NO_3^- leaching from the rooting zone.

Drainage water that leaves the upper root zone percolates through an unsaturated zone to a saturated zone at some depth below. In some cases, tile lines are installed to transport the excess water from the perched water table of a soil profile. This creates an unsaturated zone above the tile line but does transport mobile nutrients from the soil profile to surface water. The rate of percolation can change tremendously from high values in areas of high drainage volumes and sandy soil materials to low values in areas of low drainage volumes and clayey soil materials. Consequently, the travel time for NO_3^- to reach an aquifer (water bearing rock formation) depends not only on the depth to the aquifer but also on the properties of the soil.

SANDY SOILS

Some of the earliest Midwest work on the movement of N through a sandy soil was reported by Olsen et al. (1970) and is shown in Fig. 1. They applied N as ammonium nitrate to a Plainfield sand in Wisconsin on 1 August 1968 and followed the N movement over an 8-month period. The 12 inches of rain or irrigation received by the plots between August 1 and September 9 caused most of the NO_3^- to move down to the 2.5 to 5-foot depth. An additional 5.5 inches of rain from September 9 to October 28 reduced NO_3^- recovery in the 10-foot profile to 26 to 46% of the N applied (depending on N application rate) and to about 25% at the end of 8 months with an additional 6 inches of precipitation. The low recovery values for the second and third sampling dates were apparently due to leaching of the NO_3^- beyond the 10-foot depth.

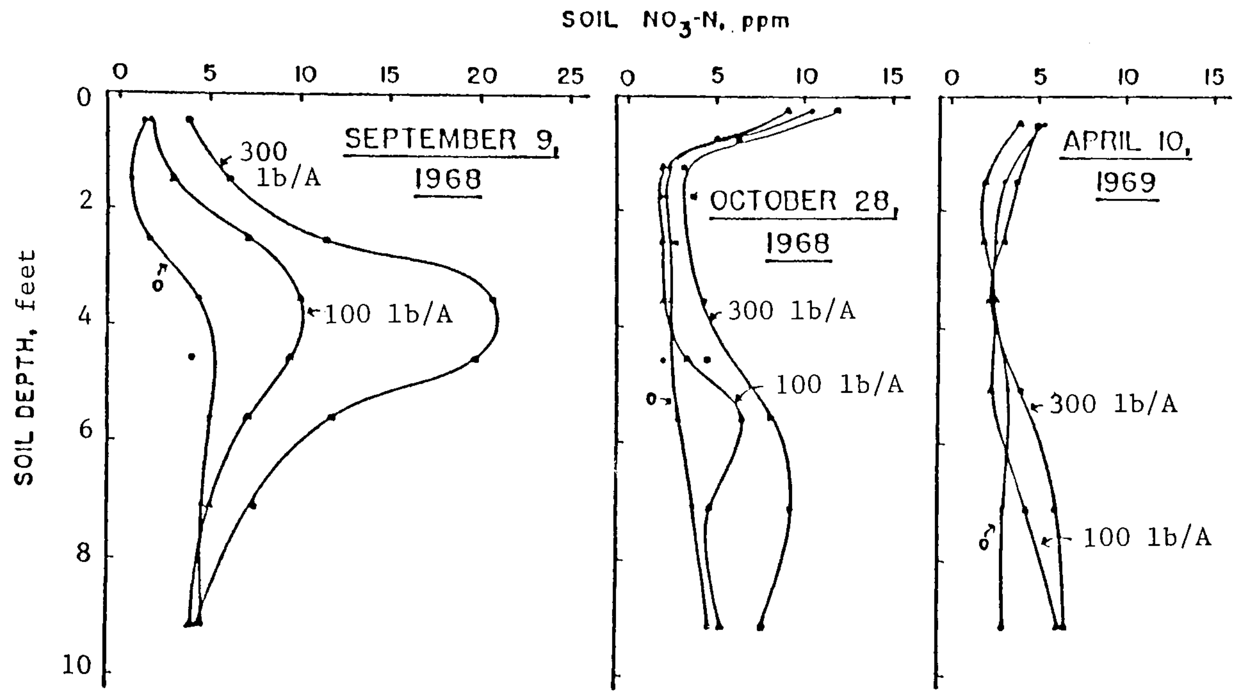

Fig. 1 - Movement of NO_3-N in a fallowed Plainfield sand over an 8-month period following the application of N on 1 August 1968 (Olsen et al., 1970).

Somewhat similar studies were conducted in Minnesota to determine if proper N rates and split applications would reduce NO_3^- loss below the rooting zone and decrease the potential for NO_3^- movement to the aquifer (Gerwing et al., 1979). They spring-applied two rates of N as either single or split applications to a Sverdrup sandy loam soil planted to corn. This soil is underlain by mixed layers of sand and gravel down to the aquifer at 15 feet. Rainfall and irrigation totaled 31.5 inches during the growing season. Their results indicated substantially higher NO_3-N concentrations in the soil solution at 5' and 8' depths with the single application (Table 1). In addition the percent of N derived from the labeled 15-N fertilizer was less with the split applications. By early September NO_3-N concentrations in the aquifer (15' deep) were increased by 7 and 10 mg/L with the 160 and 240 lb N/A rates, respectively, when added as single applications. Split applications had minimal effect on the aquifer. No accumulation of NO_3-N was detectable in soil samples taken to a depth of 10 feet after harvest.

Table 1. N derived from fertilizer in the soil solution at 5 and 8-foot depths at the season maximum NO_3-N concentration (Gerwing et al., 1979).

Application[1/] method	Sampling depth	NO_3-N	N derived from fertilizer
	feet	mg/L	%
Single	5	116	69
Split	5	71	47
Single	8	77	25
Split	8	48	13

[1/] N applied at 160 lb N/A as urea.

These two studies indicate that substantial quantities of N from fertilizers can be leached as NO_3^- from the root zone of sandy soils into the subsoil or aquifer during one growing season.

MEDIUM-TEXTURED SOILS

Studies in the early 1980's in northeastern Iowa on predominately silt loam soils indicate that significant quantities of NO_3^- have already reached the ground water (Hallberg et al., 1984). Nitrate measurements in the water from the Big Spring Basin showed annual losses of 27 and 43 lb N/A in water-years 1982 and 1983, respectively. Flow weighted mean NO_3-N concentration in the groundwater increased from 8.7 mg/L in 1982 to 10.2 mg/L in 1983. This occurred even though the PIK program was in place in 1983 and fertilizer N usage was down. Thus, the dynamics of NO_3^- movement over the long-term is complicated by the travel time as well as by additional N sources, i.e., manure, legumes, mineralized N from soil organic matter, rainfall, etc. The highest concentrations and largest mass of NO_3^- was delivered via infiltration through the soil (95%) while the run-in component (sink holes, fractures in bedrock, etc.) delivered only 5%.

A followup survey of the farming operations in the Big Spring Basin by Iowa State University scientists showed that average N applied to corn exceeded the actual needs by 63 lb N/A on a basinwide basis. This was primarily because 41% of the livestock farmers did not adjust their fertilizer N rates for N in the manure they applied and because 50% of the farmers did not give sufficient credit to N from alfalfa when it preceeded corn in the rotation.

Studies conducted by Jokela (1985) with continuous corn on a Mt. Carroll silt loam in Goodhue County also showed sizable losses of NO_3-N from the 0-5' soil profile (Table 2). Approximately 65% of the NO_3-N in the profile in early November was not found in early May of the following spring and suggests that it may have leached below 5' between the growing seasons. The substantial portion not accounted for could have been lost by denitrification or converted to organic N (immobilized), but these possibilities would have been limited by the relatively cold soil temperatures during much of the November to May period. Some loss, particularly by denitrification, may have occurred in the early spring when temperatures were beginning to rise and soil moisture was high. Rainfall during April was above normal in both years.

Table 2. Nitrate-N in 0-5' Profile in Goodhue Co. as Influenced by Time of Sampling (Jokela, 1985).

N rate	1982 F	1983 S	1983 F	1984 S	Two-Yr Avg.Change
lb/A	lb NO_3-N/A				%
0	150	60	126	35	64
67	221	89	152	37	68
134	225	77	178	57	67

Based on these results residual NO_3-N remaining in the fall is highly susceptible to leaching from the rooting profile. In addition, any fall-applied fertilizer N which nitrifies to NO_3 by early May would also be lost. These conditions suggest spring application of N to be more efficient and environmentally sound than fall application in southeastern Minnesota.

These studies indicate that N movement in silt loam soils is considerably slower than in sandy soils. However, with continuous N application NO_3^- has been found to move through the soil profile and into the groundwater below.

FINE-TEXTURED SOILS

Nitrogen movement thru fine-textured soils has been studied in Minnesota since the early 1970's. Gast et al. (1974) studied NO_3^- accumulation and distribution in a fertilized tile drained Webster clay loam in south-central Minnesota. They concluded that there was relatively little loss of NO_3^- from tile lines and that most of the unaccounted for fertilizer N applied over that removed by the crop was lost by denitrification.

Lamberton

To verify that conclusion, tile drainage plots were established on a Webster clay loam at the Southwest Experiment Station, Lamberton in 1972 by isolating 15 - 45 x 50' plots with plastic to a depth of 6'. A tile line was placed 5' from the end in each plot to simulate a 90' tile spacing. Nitrogen rates of 18, 100, 200, and 400 lb/A were applied annually to continuous corn from 1973 through 1979. Results from the first three years indicate relatively little NO_3-N accumulation in the soil profile (Table 3) or loss from the tile lines (Table 4) at the recommended 100 lb N/A rate of application (Gast et al., 1978). At rates of 200 and 400 lb N/A losses to the tile lines were increased by 140 and 380%, respectively. Maximum NO_3-N in the soil profiles occurred at about 3' with little evidence of movement below 7'.

Table 3. Nitrate-N accumulation in the 0-10' soil profile at Lamberton, MN as influenced by N rate.

Annual N rate (1973-79)	Time: Fall '75	Fall '79	Fall '83
lb N/A	lb NO_3-N/A		
18	48	44	59
100	89	127	ND[1/]
200	379	362	195
400	687	1203	533

[1/] ND = Not determined

Table 4. Cumulative nitrate-N losses thru tile drainage water at Lamberton, MN as influenced by N rate.

Annual N rate (1973-79)	Period: 1973-75	1973-79	1973-84
lb N/A	lb NO_3-N/A		
18	37	80	167
100	47 (4)[1/]	161 (14)	299 (23)
200	83 (8)	299 (17)	538 (29)
400	161 (11)	639 (21)	1276 (41)

[1/] () = Percent of applied N

At the end of the 7-year N application period (1973-79), NO_3-N concentrations in the tile water averaged 16, 47, 106, and 172 mg/L from the 18, 100, 200 and 400-lb N rates, respectively (Table 5). Nitrate-N in the 0 - 10' profile totaled 44, 127, 362, and 1203 lb/A for the N treatments, respectively (Table 3). Most of the NO_3-N accumulated in the 2 - 6' zone with some movement below 8'. Very dry years (1975 and 1976) resulted in low corn yields and no tile flow. This influenced the NO_3^- concentrations and losses over the 7-yr period.

Table 5. Average NO_3-N concentrations in tile drainage water at Lamberton, MN as influenced by N rate.

Annual N rate (1973-79)	Year 1973	1979	1984
lb N/A	-------------	mg NO_3-N/L	-------------
18	13	16	12
100	15	47	15
200	13	106	18
400	12	172	33

To study the carryover effect of the residual NO_3^- remaining in the soil profile, continuous corn was grown without N applied to the plots from 1980 to 1984. In 1984 tile flow still averaged 12, 15, 18, and 33 mg NO_3-N/L (Table 5). After 11 years NO_3-N had moved deeper than 20' in the 400-lb treatment (Fig. 2). Over the 12-year period approximately 23, 29, and 41% of the applied N was lost through the tile lines from the 100-, 200- and 400-lb N treatments, respectively (Table 4). Under the somewhat dry conditions of Southwestern Minnesota these results clearly indicate that: (1) fertilizer N not used by the crop accumulates in the soil profile, (2) this residual NO_3-N is available for succeeding crops but is very susceptible to loss via tile lines in years with excess precipitation, and (3) NO_3-N concentrations were higher than 10 mg/L even though N had not been applied to this area prior to the study (Nelson and Randall, 1983).

Waseca

A similar set of tile drainage plots were established in 1974 on a Webster clay loam at Waseca. This site has an annual precipitation of 30" compared to 25" at Lamberton. Nitrogen was applied annually at rates of 0, 100, 200 and 300 lb N/A from 1975 through 1979 to continuous corn. Conditions were very dry the first two years; consequently, yields were low, (Table 6), tile lines did not flow and substantial amounts of NO_3-N accumulated in the 0 - 3' profile (Table 7). Precipitation during 1977-81 was sufficient for downward movement of NO_3^- and tile flow. By November, 1977, NO_3^- had moved into the 3 - 6' zone (Table 7) and resulted in average NO_3-N concentrations in the tile water of 13, 41, 58 and 85 mg/L for the 0, 100, 200, and 300-lb treatments, respectively (Table 8). By the end of 1981 the majority of the NO_3-N in the 0 - 10' profile was below 6' (Table 7). During this time NO_3-N concentrations in the tile water slowly returned to background concentrations except for the 300-lb treatment (Table 8). Nitrate-N lost thru the tile lines over this period totaled 12, 16, and 22% of the applied fertilizer N with the 100, 200 and 300-lb rates, respectively (Table 9).

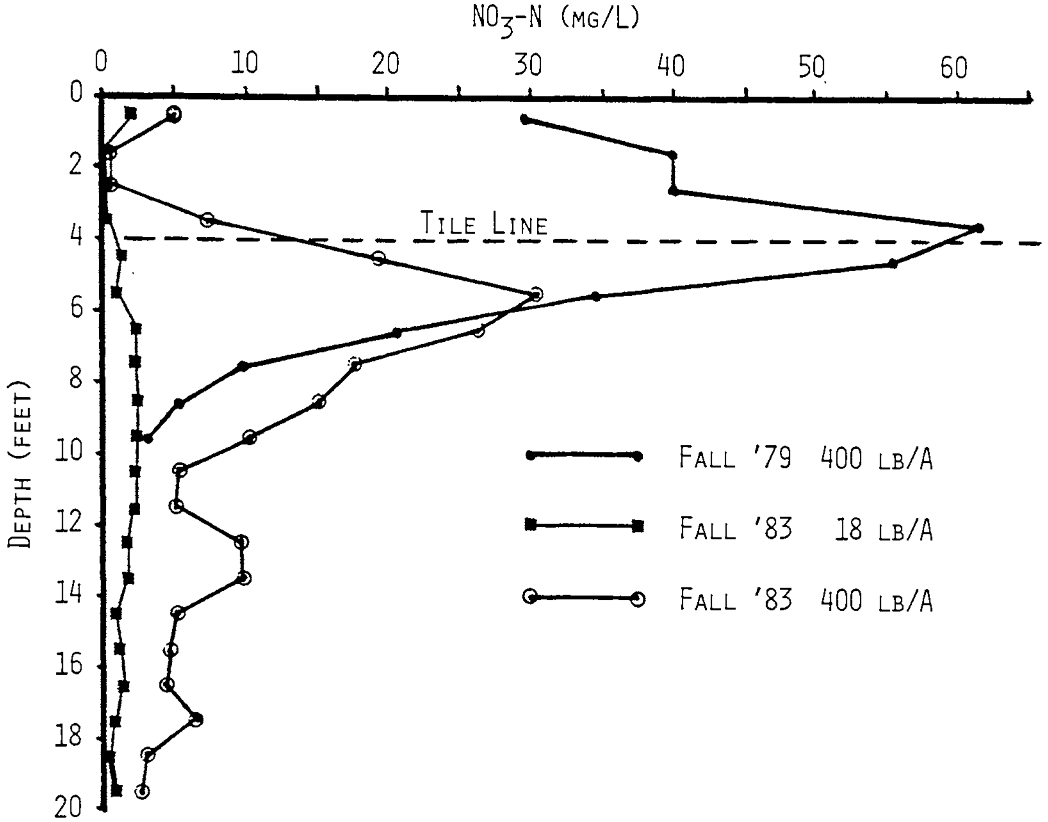

Fig. 2.- Soil NO_3-N after 7 (1979) and 11 (1983) years as influenced by annual N rates from 1973 to 1979 at Lamberton.

Table 6. Corn yield as influenced by N rates in N movement study at Waseca.

N rate[1/]	Year					
	1975	1976	1977	1978	1979	1980
lb N/A	bu/A					
0	57	30	94	81	78	57
100	53	44	146	144	160	65
200	55	57	146	150	173	91
300	75	64	144	156	175	136
Signif:	NS	*	**	**	**	**
BLSD (.05)	--	24	14	12	22	27

1/ Annual rate applied as urea in 1975 through 1979. No N applied in 1980.

Table 7. Nitrate-N accumulation and movement in the soil profile at Waseca, MN with an annual N rate of 300 lb/A.[1/]

Depth	Year 1976	1977	1979	1981
feet	NO_3-N (lb/A)			
0-3	519	343	104	53
3-6	107	236	179	106
6-10	100	80	190	181

[1/] From 1975-1979.

Table 8. Average NO_3-N concentration in tile drainage water at Waseca, MN as influenced by N rate.

Annual N rate (1975-79)	Year 1977	1979	1980
lb/A	mg/L		
0	13	13	9
100	41	19	10
200	58	32	12
300	85	44	23

Table 9. Nitrate-N lost thru tile lines at Waseca, MN from 1975-1980 as influenced by N rate.

Total N applied 1975-79	Total NO_3-N lost	
lb/A	lb/A	% of applied
0	81	--
500	141	12
1000	236	16
1500	411	22

In summary, this study showed that (1) dry years will lead to accumulation of residual NO_3-N which is susceptible to leaching and tile loss, (2) NO_3-N concentrations greater than 10 mg/L are common even without N fertilization on these high organic matter soils but are increased markedly by fertilizer applications which exceed crop N removal, (3) losses of N by other transformations, i.e., denitrification, are more prevalent under the more humid conditions of south central Minnesota compared to southwestern Minnesota, and (4) application of N at the recommended rate for continuous corn resulted in approximately at 15% loss thru the tile lines.

Another study using labeled ammonium sulfate as the N source was conducted at Waseca from 1977 thru 1982. Continuous corn and continuous soybeans were grown and tile water discharge was monitored. Corn yields were increased and NO_3-N losses decreased by the spring preplant, disked-in applications compared to the early November, plowed-down applications (Table 10). The 180-lb N rate maximized corn yield but also resulted in higher NO_3^- losses thru the tile lines. Continuous soybeans lost as much NO_3-N in the tile water as the average of the two 180-lb N treatments applied to corn. These data clearly indicate (1) an advantage for spring application of N and (2) substantial N can be lost thru the tile lines when soybeans are grown continuously.

Table 10. Corn and soybean yields and NO_3-N lost thru the tile lines as influenced by N rate and time of application at Waseca.

Crop	N Treatment Rate	N Treatment Time	1978-82 Avg. Yield	1978-81 NO_3-N lost thru tile lines
	lb/A		bu/A	lb/A
Corn	0	----	66	28
"	120	Fall	130	107
"	120	Spr.	150	75
"	180	Fall	159	136
"	180	Spr.	167	106
Soybeans	0	----	44	119

These studies on fine-textured soils indicate that NO_3^- can move out of the plant root system by either leaching below the maximum rooting depth or through tile water discharge. In addition, significant losses of N can occur via denitrification on these soils. The proportion of NO_3^- lost by leaching to that lost by denitrification will depend on water flow characteristics of the soil, soil organic matter level, depth of NO_3^- in the soil profile, and soil temperature.

NITROGEN MANAGEMENT SUGGESTIONS

Various management decisions can be made by both the farmer and the fertilizer dealer to improve N efficiency and minimize environmental contamination. They are as follows:

1. Time of application: Greater N efficiency and less N loss are generally obtained with spring-preplant, postemergence-sidedress, and split applications prior to the period of greatest plant uptake. For corn most uptake occurs during July and August in Minnesota. Spring and sidedress applications show greatest benefit on sandy soils and on those medium and fine textured soils where the potential for N loss is significant (rapid percolation rates, high rainfall, saturated soils, poor drainage, etc.). Conditions in western Minnesota are often sufficiently dry in both the fall and spring so that fall applications are as good or better than spring or sidedress application. Fall applications should be made after soil temps have dropped below 50°F.

2. Application method: With surface residues becoming more commonplace due to adoption of conservation tillage systems, losses or tie-up of surface-applied N will frequently occur. Consequently, N should be injected to

minimize loss and to improve N uptake. This is especially true when surface residue accumulation is high or if soil conditions are dry following late sidedress applications.

3. Sources of N: Only ammonium sources of N, e.g., anhydrous ammonia, urea, ammonium sulfate, should be fall-applied. Fall application of nitrate sources, e.g., 28% N solutions (UAN) and ammonium nitrate, should not be considered. Surface application of urea or UAN to residue covered soils should be followed by incorporation to reduce volatilization losses. Direct injection of UAN may be preferable to surface broadcasting and additional tillage or cultivation.

4. Credit other sources of N: Significant quantities of N are contained in livestock manure. Knowing the nutrient concentration of the manure and with appropriate application techniques, the farmer can estimate the amount of N being applied and credit that amount against the total N needs of the crop.

Legumes such as soybeans and alfalfa biologically fix N. Consequently, soybeans can be credited with supplying 30 to 40 pounds, clover and poor alfalfa with 60 pounds and good alfalfa with 100 pounds N for the following corn crop.

5. Nitrification inhibitors: Under conditions where potential loss of N is high due to either leaching or denitrification of NO_3^-, nitrification inhibitors should be considered. This is especially true with fall application to wet, poorly drained soils and with spring application to sandy soils. Nitrification inhibitors can be considered as "insurance policies" against potential losses.

6. Proper yield goals and application rates of N: The application rate is often the single, most important factor in improving efficiency and fertilizer economics. To arrive at the proper fertilizer application rate, carefully consider a realistic yield goal in conjunction with the previous crop, and a soil NO_3^- test in western Minnesota. Unrealistic yield goals lead to N inefficiency, potential environmental harm, and poor production economics.

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POWDERY MILDEW OF SOYBEANS

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Powdery Mildew (PM) was first reported on soybeans in Germany in 1921. The disease is commonly seen on greenhouse-grown soybeans and has been a problem in many fields in the United States. PM was widespread and severe in Georgia in 1972 and 1973; Wisconsin first observed it in August of '74. The first report of PM in Minnesota was in 1973 and again in 1974 from field plots at the St. Paul Agricultural Experiment Station.

PM is caused by the fungus Microsphaera diffusa on soybeans and can also infect other legumes, such as bean (Phaseolus vulgaris), mung bean (Vigna radiata), pea (Pisum sativum), cowpea (V. unguiculata) and other species in the Honeysuckle family and Nightshade family. PM is an obligate parasite that produces mycelium and conidia on plant surfaces, with root like structures in the host epidermal cells. The mycelium and conidia are clear to white and when abundant appear as white powder like patches on the surface of leaves, stems and pods. Some soybean hosts are reported to develop chlorosis, green islands, defoliate or just are covered by visible mycelium and conidia as was seen in Minnesota. The fungus produces an overwintering structure "Cleistothecia", which when mature has branched appendages useful in identification.

PM was not observed on soybeans in Iowa from 1953 to 1973 and other than a report of PM in plots at St. Paul no record of the disease in Minnesota was published prior to 1975. In central Iowa in 1975 PM was found in 23 counties in 311 fields of the 38 counties sampled. The disease was present in 19% of the soybean fields and an average of 79% of the plants were infested. The symptom was first found in Iowa the first week of June and PM increased steadily during July and August until entire fields of susceptible varieties were infested. PM was first reported in early August in SE Minnesota and soon after mid-August reports of PM were received from all Minnesota soybean growing areas. Early in September a general concern was expressed about the widespread "blight" of soybeans.

Early yield loss studies in Iowa reported an average yield loss in 1975 of 10% for susceptible varieties. Data from Ames (central) 1976 and Kanawha (North Central) 1977-78, Iowa show a yield loss of 19.6% when growing the susceptible lines Corsoy or a 17.3% loss when growing Harosoy 63. Resistant lines Beeson and Lindarin 63 did not yield any significant increase when sprayed with Benomyl. The resistant plants did not show any PM symptoms and the seed yield was unaffected by treatment with Benomyl. Seed yield losses in susceptible varieties are believed to be due to PM. Seed losses were variable over the 3 years, ranging from no loss to a high of 26%.

A fungicide study at the Rosemount Agricultural Experiment Station - Plant Pathology Farm shows a yield increase of 8.0% when treating with Benomyl. Hodgson 78 was planted in 30 inch row, June 3 on a 1 acre site. The previous crops were soybeans and the area was designed to evaluate the effect of foliar fungicides. One application was made on 8/14 (late flowering, early pod fill stage) with Benomyl 8 oz., Mertect 8 oz. and Bravo 1 1/2 pts. Six replicates were treated and observed during the growing season. The major foliar disease present in 1985 was PM. Little evidence of Bacterial Blight, Septoria Brown Spot or Downy Mildew was observed, however, half the plants showed symptoms on September 4 of Brown Stem Rot.

Table 1.

	DISEASE SCORES					YIELD
TREATMENT	**BB**	**SBS**	**DM**	**BSR**	**PM**	**BU/A**
Benomyl	1	1	1	3	0.5	29.6
Mertect	1	1	1	3	1.8	27.9
Bravo	1	1	1	3	2.0	28.4
Check	1	1	1	3	3.0	27.4

1 = Trace, 2 = 1-30%, 3 = 31-60%, 4 = 61-90%, 5 = > 91%.

PM infection on a susceptible soybean leaf, i.e. Harosoy 63 does not produce a change in leaf color, shape or life span. The leaf however, when 82% covered by visible mycelia had less than one half the rate of photosynthesis and transpiration of a healthy control. The loss in net photosynthesis and transpiration is believed to be a result of a direct change in soybean metabolic activity induced by the pathogen. Since most PM infection is present on lower, poorly illuminated leaves it is unlikely that 50% losses will be present under field conditions, however, with a favorable environment for early infection and complete leaf cover by PM, losses can be large. Other field studies report loss range from 35% to 10%.

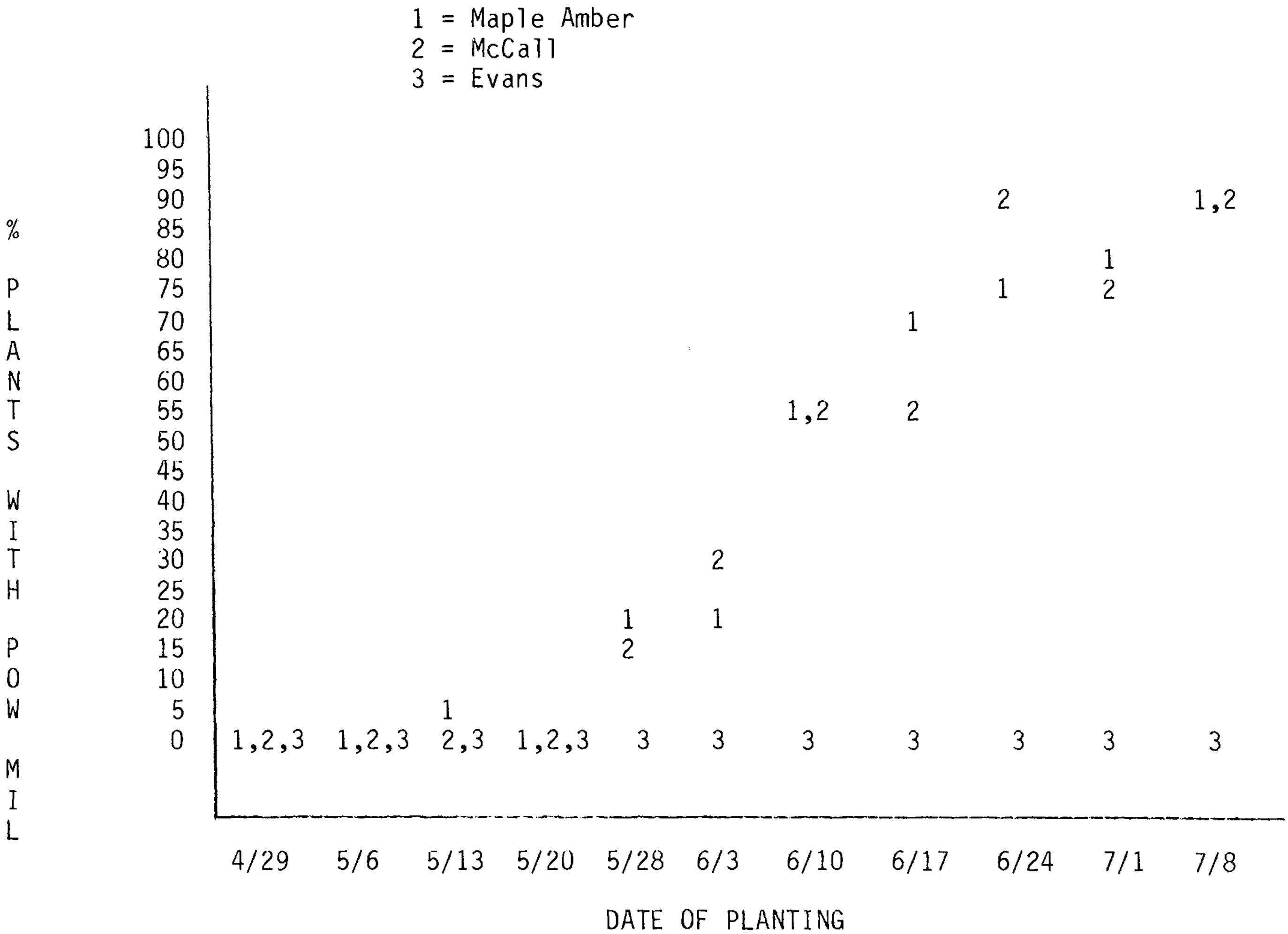
PM has not become a major disease in the past decade but it was very abundant on susceptible cultivars in Minnesota - 1973, Wisconsin - 1974, Georgia - 1972 & 73 and repeatedly in Iowa from 1973-78. Significant PM symptoms were seen in Wisconsin, Iowa, North Dakota and Minnesota again this year (85). The sudden occurrence of this disease in the early 70's and again its widespread development in 1985 should not be ignored. In the early 70's less was known about its potential destructiveness but today good estimates are available on the yield losses associated with PM.

Resistance to PM is available and it appears that there are two primary types of field resistance which are inherited as a single dominant genetic trait. The two forms of resistance may be described as "Resistant" and "Highly Resistant". These two forms of resistance cannot be differentiated in the field but do appear different in the greenhouse. In greenhouse testing "HR" reaction has no mycelium on the leaf while the "R" reaction has sparse mycelium and limited sporulation and the "S" (susceptible) reaction has extensive mycelial development and sporulation.

Symptom development is also affected by temperature. Resistant soybeans remained resistant at the 3 temperatures used while susceptible varieties had disease progress most rapidly at 18°C (64°F) at both 9 and 17 days after inoculation. The susceptible varieties were severely infected in 17 days at 18°C while similar disease ratings were obtained in 24 days at 24°C (75°F) and 30°C (86°F). Disease development is slightly slower at higher temperatures for susceptible varieties. The most favorable temperature for PM development was 18°C (64°F).

Symptom development differences of soybean varieties that are greenhouse susceptible but field resistant may be due to adult plant resistance. Growth of PM mycelia on leaf tissue was followed by remission of fungal growth at later stages of plant development. Plants inoculated at 8 days had remission of fungal growth in 28 days while plants inoculated at 29 days of age showed fungal growth remission in 18 days. Development of visible mycelia was negligible if plants were inoculated at 50 days of age. The adult plant resistance expression becomes apparent near flowering. Soybeans that have adult plant resistance are also valuable in areas where the PM disease arrives late in the growing season.

This adult plant resistance is nicely seen from data collected at Crookston by Drs. Wiersma and Orf. A date of planting study with 3 varieties was observed on September 16 for PM. The soybean Evans is resistant while Maple Amber and McCall are susceptible. Note from the graph that all varieties appear resistant when planted 4/29 through 5/20 and the two susceptible varieties show increasing PM with delayed planting while Evans remains resistant.



The following public and private varieties were observed for PM reaction at Waseca on August 30. The mean of 3 observations is presented.

VARIETY	SOURCE	PM RATING[a]
AH2244	Arrowhead Inc.	3
AH8650	Arrowhead Inc.	1
Agripro AP10	Agripro Seeds	4
Agripro AP200	Agripro Seeds	0
Agripro Ex 034	Agripro Seeds	0
Agripro HP 20-20	Agripro Seeds	4.5
Asgrow A1525	Asgrow Seed Company	4
Asgrow A1937	Asgrow Seed Company	0
Asgrow A2187	Asgrow Seed Company	3
Asgrow A2522	Asgrow Seed Company	2
BSR 101	Iowa A.E.S.	1
BSR 201	Iowa A. E. S.	0
CB EXP-1301	Country Brand Seeds Inc.	1
CB Stetson	Country Brand Seeds Inc.	3
CB Wrangler	Country Brand Seeds Inc.	0
Cenex 8017	Cenex	0
Cenex 8212	Cenex	1
Cenex 8422	Cenex	1
Challenge CSV 15	Challenger Seed LTD	0
Challenge CSV 20	Challenger Seed LTD	3
Corsoy 79	Illinois A.E.S.	4
DK-PF CX155	Dekalb Pfizer Genetics	4
DSR-151	Dairyland Seed Company Inc.	4
DSR-171	Dairyland Seed Company Inc.	0
DSR-205	Dairyland Seed Company Inc.	3
DSR-207	Dairyland Seed Company Inc.	3
Dekalb CB151P	Dekalb Pfizer Genetics	3
Dekalb CX174	Dekalb Pfizer Genetics	3
Desoy 302B	Kruger Seed Company	3
Desoy 414	Kruger Seed Company	3
Diamond D-140B	Diamond Brand Seed	3
Diamond D-201	Diamond Brand Seed	0
Elgin	Iowa A.E.S.	0
Ehrich E-84	Ehrich Seed Farms	1
Ehrich E-85	Ehrich Seed Farms	4
Enterprise II	Farmacy Seed Company	1
FFR 10248	FFR Cooperative	0
FFR 12003	FFR Cooperative	1
FFR 13004	FFR Cooperative	0
FSF Exp1770	Field Seed Farms	2
FSF-150	Field Seed Farms	1
Farmacy Eve	Farmacy Seed Company	3
Funk 12231	Funk Seeds International	0
Funk 63145	Funk Seeds International	3
Funk G3213	Funk Seeds International	4
Hack	Illinois A.E.S	1
Hardin	Iowa A.E.S.	4
Hodgson 78	Minnesota A.E.S.	3.5

VARIETY	SOURCE	PM RATING[a]
Hoffman 8300	Hoffman Seed Farms Inc.	3
Hoffman 8501	Hoffman Seed Farms Inc.	4
Hoffman Dawn	Hoffman Seed Farms Inc.	0
Hoffman EX61161	Hoffman Seed Farms Inc.	0
Hy-Vig Derby 9	Hy-Vigor Seeds Inc.	4
Hy-Vig Row T-9	Hy-vigor Seeds Inc.	3
Hy-vig 901	Hy-Vigor Seeds Inc.	4
Jacques E8590	Jacques Seed Company	4
Jacques E8590	Jacques Seed Company	4
Jacques E8597	Jacques Seed Company	4
Jacques J-2386	Jacques Seed Company	0
KB125	Kaltenberg Seed Farms Inc.	0
KB231	Kaltenberg Seed Farms Inc.	3
Kruger KB220	Kruger Seed Company	3
LOL 60-44	Land O'Lakes	0
LOL L180B	Land O'Lakes	0
LOL LL0023	Land O'Lakes	0
Lakeside 104	Rossbach Lakeside Seeds	3
Lakeside 105	Rossbach Lakeside Seeds	4
Lakeside 107	Rossbach Lakeside Seeds	3
Latham 301	Latham Brothers Farms	0
Latham 500	Latham Seed Company	3
Latham 551	Latham Seed Company	3
Latham 650	Latham Brothers Farm	3
Latham 851	Latham Seed Company	2
Latham Ex-330	Latham Brothers Farm	0
Lynks 8190	Lynks Seeds	2
Lynks 8202	Lynks Seeds	1
Midwest 2620	Midwest Oilseed Inc.	0
Midwest Oil 1480	Midwest Oilseeds Inc.	4
Mustang 1220A	Domestic Seed and Supply Inc.	0
Mustang 1225	Domestic Seed and Supply Inc.	3
Mustang Exp-9	Domestic Seed and Supply Inc.	4
NK S14-60	Northrup King Company	3
NK S15-50	Northrup King Company	3
NK S23-03	Northrup King Company	2
PS 0019	Payco Seeds Inc.	1
PS 0021	Payco Seeds Inc.	1
Pride 225 Brand	Pride Company Inc.	2
Pride B203	Pride Company Inc.	1
Pride B216	Pride Company Inc.	2
Pride PEX110	Pride Company Inc.	0
Profi Trisoy 84	Profiseed Inc.	4
Profiseed 1138	Profiseed Inc.	4
Profiseed 1152	Profiseed Inc.	3
Riverside 1405	Lynnville Seed Company	0
Riverside 303C	Lynnville Seed Company	3
Riverside 4042	Lynnville Seed Country	4
Riverside 404P	Lynnville Seed Company	3
Robinson H-1233	J. C. Robinson Seed Company	3
Robinson X190	J. C. Robinson Seed Company	0
Robinson X198	J. C. Robinson Seed Company	3.5
Roebke R-180	Roebke Seed Company	4

VARIETY	SOURCE	PM RATING[a]
Sand Soi 226	Sand Seed Services Inc.	3.5
Sand Soi 254	Sand Seed Services Inc.	0
Sand Soi Exp. 255	Sand Seed Services Inc.	1
Schech EX40A	Schechinger Seed Company	0
Schech EX41B	Schechinger Seed Company	0
Schechinger S-41	Schechinger Seed Company	0
Select Seeds 189	Bruellman Select Seeds	0
Select Seeds 213	Bruellman Select Seeds	0
Select Seeds 286	Bruellman Select Seeds	3
Select Seeds 288	Bruellman Select Seeds	3
Sexauer BR SX29		3
Stine 2220	Stine Seed Farm Inc.	2
Stine 2720	Stine Seed Farm Inc.	0
Thompson T-12	Thompson Farms Seeds	4
Thompson T-15	Thompson Farms Seeds	1
Thompson T-25	Thompson Farms Seeds	0
Thompson T-30P	Thompson Farms Seeds	3
Vickery	Iowa A. E. S.	4
Weber 84	Iowa A. E. S.	0
Wil'N Blend 1650	Wilson Hybrid Inc.	3
Wil'n Blend 2010	Wilson Hybrids Inc.	1
Wil'n Blend 2101	Wilson Hybrid Inc.	2
Wilsoy 84	Willette Seed Farm Inc.	3
Ziller BT2300	Ziller Seed Company	1
Ziller Exp. 20	Ziller Seed Company	1
Ziller Exp. 21	Ziller Seed Company	3

a Mean of 3 replications. Rating based on scale ranging from 0 = no symptoms, 1 = two plants with a few isolated lesions, 2 = 1 -- 30%, 3 = 31 -- 60%, 4 = 61 -- 90% and 5 = > 91% of leaf areas covered by the fungus.

BROWN STEM ROT OF SOYBEANS

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Brown stem rot (BSR) was discovered on soybeans in the United States in the mid-1940s. The disease has since spread to include most of the soybean growing areas of the United States. According to a 1978 survey, approximately 80 percent of the soybean fields in southern and 95 percent of the fields in northern Iowa are infested with the BSR fungus. It is likely that soybean fields in Minnesota are infested to a similar degree.

Cause

The disease is caused by the fungus *Phialophora gregatum*. The fungus survives primarily in infected residue in the soil, particularly woody stem tissue. The major means of dissemination or movement of the fungus from place to place is thought to be by any means that transports infected residue. Fungus spores are produced from mycelium in residue and may also serve as a means of dissemination.

Infection occurs through roots and lower stems early in the growing season. Mycelium grows upward or spores are carried upward in the xylem or water-conducting vessels of the plant. Toxin may also be produced inside the plant by the fungus. Movement of water and nutrients from the roots to upper parts of the plant is prevented.

These effects are compounded by the ability of *P. gregatum* to grow faster in the plant during moisture stress conditions. During May and June, moisture stresses are uncommon due to adequate rainfall and subsoil moisture. Moisture stress normally begins about July when rainfall decreases, subsoil moisture diminishes, and temperatures rise. It is under these conditions that the fungus seems to thrive and disease symptoms begin to develop. Infested land with good drainage is more likely to have higher BSR prevalence and severity than poorly drained land and heavy dry soil.

Symptoms

Diseased plants usually do not show outward disease symptoms. The only positive way to tell if plants are infected is to split the lower 6 inches of the stem longitudinally 10 to 30 days before soybeans mature. This symptom can begin to be seen in late July or early August in Minnesota.

Healthy stems have white tissue in the center; infected tissue is brown. Often there may be an internal browning only at the nodes while internodal tissue may be white.

Browning of the tissue progresses upward in the stem during the growing season. Usually the more extensive the discoloration, the greater the yield reduction. Later in the growing season, the lower part of the stem may show external browning with wilting and premature leaf drop. According to research at Iowa State University conducted by Dr. Hideo Tachibana, there is a 1.6 bushel yield loss per 10 percent of infected plants.

Leaf symptoms are not ordinarily a reliable diagnostic tool since they are relatively uncommon and may be confused with other leaf disorders. Leaf symptoms develop when infected plants are subjected to high temperatures or drought stress following a period of cool weather. Leaves may wilt and tissue between the veins turns brown and dries rapidly, usually about 3 weeks before maturity, while tissue adjacent to veins remains green. Eventually the whole leaf dies.

An infected field of soybeans turns brown, suggesting early frost in contrast to the yellow-green of a normally maturing field. Since the disease is usually difficult to identify by visible outward symptoms, most growers blame a low yield on other causes such as drought or early maturity.

Another method of disease diagnosis is called the stubble method. After a field has been harvested, look at the cut end of the stubble. A brownish discoloration of the center invariably indicates diseased plants; healthy plant stubble is usually white in its center. This method will give a good indication of the incidence of disease in a field but not how severe the disease is.

The BSR symptoms generally become more evident in soybean stems after the middle of August. The ability of the fungus to grow faster under moisture stresses and other stress conditions in the latter part of the growing season seems to be a synergistic effect, causing typical stem-browning symptoms. If BSR symptoms are not observed in August, the disease probably will not be a problem.

Control

1. Crop rotation. If possible, infested soil should not be planted to soybeans, alfalfa, or red clover for at least 3 years since alfalfa and red clover also become diseased. Infested residue decomposes within this time, and the fungus cannot survive in soil outside of infested residue. Rotation studies have indicated a yield reduction up to 44 percent for continuous soybeans when compared to a corn-soybean rotation.

2. Resistant varieties. Resistant varieties should be grown only on infested soil. Soybean varieties resistant to BSR have a significant yield advantage over susceptible varieties when grown in infested soil but not when grown in non-infested soil. As a "rule of thumb," resistant varieties can be grown in a field if 75 percent or more of the plants are diseased. Varieties resistant to BSR are considered to have a general resistance. This means that resistant plants will be infected but will have about half as much stem browning and consequently will not be as severely diseased as susceptible plants.

The concept of growing a resistant variety only in infested soil is termed "prescribed resistant variety." Yields of susceptible varieties average 10 percent less than resistant varieties when grown in infested soil.

WHEAT LEAF SPOT DISEASES AND THEIR CONTROL WITH FUNGICIDES

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Maximum yield wheat management programs require a knowledge of all factors that affect crop culture. It is of interest to note, that only in recent years has the grower or the industry recognized the importance of cereal leaf diseases. It is interesting because leaf spot diseases occur after all of the production inputs have been made. Even in the best wheat production management programs; the occurrence of cereal leaf spot diseases can reduce yields by 25% to 50%. The protection of the wheat crop from losses caused by disease protects the potential yield that may be obtained from maximum management programs thus increasing the economic return to the grower. So as growers look to economic high yielding systems for wheat production, disease control programs will have to be developed, understood and used.

A disease control program includes the intelligent use of cultural practices, disease resistant varieties and agricultural chemicals known as fungicides. Such a program begins with clean disease-free seed and seed treatment.

Disease control programs have economic considerations, in that prevention of crop yield and quality losses results in higher returns for the crop production inputs.

However, as seed treatment and clean seed practices are established, I will relate this paper only to the newer practices of controlling the leaf spot diseases. Taking editorial liberty I will group such diseases as Powdery Mildew, Septoria Leaf and Glume Blotch, Helminthosporium Leaf Blights, Cephalosporium Stripe, Eyespot, Tan Spot, Stripe, Leaf and Stem Rust as leaf spot diseases. For the most part, wheat varieties have a high degree of resistance Stem Rust and plant breeders are in the position to manipulate sources of resistance into new varieties, so it is basic that a disease control program should include Stem Rust resistant varieties. With some types of wheat, Durum, Spring and Hard Red Winter, Leaf Rust resistance is also well identified; if such resistance is available the use of resistant varieties reduces the potential for loss and is part of the management decision. The successful use of a disease control program will depend upon a high degree of knowledge of these diseases, disease control concepts and the proper use of this knowledge by farmers and crop consultants. I would also include the Agricultural Businesses industry and Service sectors.

There are some basic considerations that growers will have to examine to put into practice a successful disease control program. The selection of the wheat variety to grow has become very challenging with the introduction of private Breeder varieties. In the past with only public varieties, growers have had the advantage of long testing programs as a decision aide, such public testing programs may not be available with the private breeding programs. However, the private breeding program is making available to growers many new, high yielding and high quality varieties; some of which will be valuable and acceptable to growers.

The disease control program will also require very close attention to the growing conditions, stage of plant growth and disease presence, in order to plan fungicide application and chemical selection.

The economical method of fungicide application will have to be identified to fit particular areas and the individual growers capabilities. Fungicides may be applied by high pressure ground sprayers. Usually weed-sprayers are not adequate. Aerial application has been very successful in large field situations. But like the ground sprayers, techniques for weed spraying may be inadequate for fungicide treatment. In order to obtain adequate application with agricultural aircraft, the aircraft must develop a uniform spray swath and the spray must be delivered to the crop at close range to ensure deposition on the target leaves. Whether a grower elects to apply fungicides by ground equipment or by aircraft, this new technology will require some experience. Even though the "best" material may not be available at this time, it is to a growers advantage to get started with the available chemical so as to gain experience and learn what to expect.

Everyone is interested in "new things" in the area of fungicides there are some "new things", systemic type chemicals. The older protectant type chemicals being used are active on the surface of the plant. The systemic chemicals are active inside of the plant. These materials may be redistributed within the plant to some degree, in the plant's xylem system. systemic chemicals present advantages and disadvantages. The chemical must gain entrance into the plant in sufficient quantity to kill or inhibit the invading fungus. The chemical being inside the plant is protected from the environment and thus may persist in an active stage longer than protectant chemicals thus requiring fewer applications.

In general the systemic-type fungicides are very effective. The point of activity (interference with the fungus) may be very narrow. When a very effective chemical with a narrow area of activity challenges a population of the fungus pathogen, as might be expected, the fungicide exert pressure on the population that may result in the selection of fungicide resistance within the population. Systemic fungicide resistant populations of fungal pathogens have been identified in the laboratory and have developed in the field. In the field such changes in the pathogen populations reduce the efficiency of the fungicide.

The pathogen resistance phenomena does not have to eliminate the use of systemic fungicides, but rather identifies that very precise use of systemic fungicides will be necessary to prolong their beneficial effects on crop pathogens. Some systemic chemicals may have hormonal or growth stimulating effects which may be positive or negative. The mode of action of some of the systemic fungicides have some similarities even though they make up a hetrogenious group of chemicals.

Experience has or should have taught us that the fungi have the ever-present potential to survive the best attempts of man to control them. The method or site of action of the systemic fungicides will have to be understood when using these chemicals. In order to keep the fungus population "off balance", it may be advantagious to alternate or use different chemicals when more than a single application is to be used.

Some of the same systemic fungicides that will be recommended for foliar applications will be promoted as seed treatment fungicides. Therefore, it will be important to make sure that the same chemical is not used for both treatments. If the plant contains a low rate of the fungicide from the seed treatment, there will be "presence" on the native population of the pathogen, with the possibility of favoring the development of resistant segments of the population. Then when a foliar application is made a further extension of the selection "pressure" is in effect. Such a situation may bring about the development of a fungicide resistant field population of the pathogen.

Benzimidazole - MCB - Active in the Nucleus

Ergosteral Inhibitors	--	Disrupt the cell membrane of the fungus.
Piperazines Pyridines Pyrimidines Imidazoles Triazoles		
Morpholines	--	Ergosteral inhibitors but different from (above)
Hydroxopyrimidines	--	Inhibit and disrupt approsoria formation.

Where have we been and where are we going? Not to belabor all of the research and field work that has been done to identify the benefits of fungicide control programs, I will present only a few examples of my own experience over 25 years work.

Early work, 1962 resulted in some very slim beginnings. In the Spring Wheat areas, Selkirk wheat had been grown for 12 years. It was resistant to Stem Rust race 15. By the late 1950's. Leaf Rust and Septoria Leaf Blotch were affecting the leaves. Early fungicide tests did result in yield increases (Table 1). During the 60's and early 70's the only fungicides available were the Ethylene Bisdithiocarbamates materials. These fungicides are protectants and still provide good control for most of the leaf spot pathogens, with the exception of Mildew (Table 2).

Some selected data from Experiment Station research for the detection of disease control activity is presented in Table 3. Obviously this work was not done to identify maximum yields. Note the differences in yields, between treated and untreated. The variety Marquis (1940's), a very old variety rust and Septoria susceptible was used to see if a variety without disease resistance could be improved with fungicide treatment. It appears that there is a limit to what may be expected, thus demonstrating that we should use the most resistant varieties to effect a favorable fungicide response.

Results from on-farm research (1985) with a cooperating grower are in Table 4. This data, like that in Table 2 reflects efforts to obtain maximum yields. In Table 4, Cerone was used to reduce the loss resulting from lodging. The only tall variety, Stoa, responded very favorable to such a treatment, while the semi dwarf varieties (Marshall, Oslo, Pioneer 2369 and Wheaton) did not have similar response. All varieties responded to fungicide treatment. Oslo, Pioneer 2369 and A99 are private varieties, Marshall, Wheaton, and Stoa are public varieties.

Although the growth inhibiting hormone Cerone may not provide a regular positive yield response, the use of such a chemical may reflect it's economic value, by reducing the time required for harvesting a crop. This is a value that the grower will have to identify.

The affect of such chemicals has not been positive on all varieties, therefore a grower should identify whether or not there has been negative effects on the particular variety he will be treating.

For many of these leaf spotting diseases the inoculum, in the form of spores or mycelium, persists from one crop to the next crop on the previously infected plant debris. The current "wave" of reduced tillage or no-till cultural practices can provide a very serious disease potential. The use of these tillage practices should include a system of crop rotation. Where wheat is to follow wheat in the cropping sequence some other system of erosion control should be followed.

The yield of wheat can be favorably influenced by the use of fungicides for the control of leaf spot diseases. For maximum yield programs the growers must pay attention to variety, selection, fertility requirements, weed control, cultural practices, and disease control practices.

Plant diseases are shifty enemies that cause economic crop loss.

TABLE 1. CEREAL LEAF DISEASE CONTROL ON FARMS (2) WITH AERIAL APPLICATION OF ZINEB FUNGICIDES, ARGUSVILLE, NORTH DAKOTA, 1962 - 1963.

	YIELD BU/A		
VARIETY	UNTREATED	TREATED	% INCREASE
1962			
SELKIRK	31.9	35.9	12.5
SELKIRK	34.2	38.2	11.7
1963			
SELKIRK	18.3	25.8	40.9

TABLE 2. DISEASE CONTROL WITH MANCOZEB TYPE FUNGICIDES ON CURRENTLY GROWN SPRING WHEAT VARIETIES IN MINNESOTA.

	Yield (bushels/acre)				
1984	Treated[1]		Untreated		
Variety	bu/a	Protein	bu/a	Protein	Difference
Marshall	82.5	14.6	75.1	14.3	7.4*
Oslo	93.8	14.8	79.3	14.4	14.5*
Pioneer 2369	91.6	14.7	84.2	14.3	7.4*
Era	84.8	14.7	81.9	14.2	2.9
Marshall	68.5		58.2		10.3*
Wheaton					
Minimum Tillage	93.4		81.4		12.1*
Plowed	95.7		96.2		--
1983					
Len	79.1		63.5		15.6*
Marshall	85.6		75.9		9.7*

1/ 2 pounds Dithane M-45 per acre, 2 applications, early heading and 10 days later.

* Statistically significant 1% level of significance.

TABLE 3 **SOME SELECTED DATA FROM FUNGICIDE TESTS AT THE ROSEMOUNT EXPERIMENT STATION TO IDENTIFY FUNGICIDAL ACTIVITY.**

1979	Era	% Increase	Angus	% Increase	% Leaf Necrosis Era	% Leaf Necrosis Angus
BTS 40542	31.9	8%	21.6	10%	12	--
Dithane M-45	31.2	6%	21.4	8%	25	--
Check	29.4		20.0		30	
	Era		Marquis		Era	Marquis
340 F	36.1	22%	16.2	12%	10	100
ME147	33.4	13%	15.3	6%	15	100
	Era		Marquis		Era	Marquis
CGA-64250	36.3	12%	23.2	52%	10%	30%
Check	32.5		15.3		25%	100%
	Era		Marquis		Era	Marquis
Bravo	26.6		11.8		7	100%
Dithane	26.6		12.7		10	95
Check	25.1		11.6		15	100%

TABLE 4. NORMAN COUNTY, (GORDNER FARM) - 1985

DISEASE CONTROL WITH MANCOZEB FUNGICIDES ON CURRENTLY GROWN SPRING WHEAT VARIETIES IN MINNESOTA.

	BU/A					
	Marshall	Oslo	Pioneer	Stoa	Wheaton	A99
80#/a Seed Rate						
Untreated						
Check	73.4	66.4	61.4	54.9	74.5	60.0
Cerone	76.2	68.1	64.3	62.9	71.4	60.5
Treated						
2X	75.9	81.0	70.9	63.1	76.8	67.9
3X	86.9	79.4	73.1	61.3	79.7	69.2
2X + C	85.1	82.1	72.4	69.0	82.3	65.1
3X + C	80.1	86.1	69.3	72.0	85.2	63.8

2X = 2 Applications Dithane M-45, 2#/acre
3X = 3 Applications Dithane M-45, 2#/acre

EUROPEAN CORN BORER:
STATUS AND INSECTICIDE PERFORMANCE IN 1985

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INTRODUCTION

Just two summers ago European corn borer populations reached record infestation levels. During 1984, infestation levels declined across most of the state. Based on historical patterns in the fall ECB survey, I projected this spring that infestation levels should decline further in 1985. What was the ECB situation in Minnesota during 1985? How has research on economic thresholds and insecticide performance progressed during 1985?

THE EUROPEAN CORN BORER IN 1985

Although ECB populations declined from 1983 to 1984, sufficient numbers of overwintering larvae were present this spring to cause real problems. Adult abundance this spring reached normal levels according to lighttrap captures. Yet, severe infestations never materialized. Why?

Failure of any problem to develop in southern and central Minnesota reflects the interaction between spring weather, planting dates, and weather during the adult flight. A warm, early spring beginning with >90°F days in April hastened ECB emergence. Although corn planting dates were normal to early throughout southern Minnesota, the early developmental advantage to the ECB provided by warm April temperatures was not erased. Thus ECB emergence relative to corn development was early compared to the normal synchrony between ECB and corn. Because "young" corn possesses higher levels of a resistance factor called DIMBOA, low larval survival was expected. More importantly, extremely cool nights and frequent rainfall during the adult flight in June provided inhospitable conditions for mating and egg laying. For these reasons, first generation infestation levels were extremely low and economic infestations were essentially nonexistent.

After a dismal first generation, adult captures in lighttraps during the second flight were extremely low. Second generation larvae never posed a significant economic threat. As indicated in Table 1, we enter the 1985-1986 winter with low numbers of overwintering borers.

First generation ECB populations in northern Minnesota also declined. Expectations of early ECB emergence were tempered by cool, rainy weather and peak emergence date was near last year's date. As in the south, cool nighttime temperatures (< 50 degrees Farenheit) disrupted mating and oviposition. Economic infestations, although more prevalent than in southern Minnesota, were less common than in 1984. The difficulties of making sound treatment decisions were compounded by uneven infestations within fields, subtle buildups in infestation, and speculation on whether corn would reach maturity after the cool spring. Taller corn in sheltered areas attracted the heaviest infestations. Cool weather and retarded ECB development eliminated the potential for a second flight, as seen in 1983 and 1984.

Table 1. Results of Minnesota's fall survey for European corn borer, Oct. 14-25, 1985. Data supplied by the Minnesota Department of Agriculture - Plant Industry Division.

District	% plants infested	# ECB larvae 100 plants	% shanks infested	# ears on ground
WC	22	22	3.5	0.0
C	17	16	2.2	0.0
EC	6	3	0.6	0.0
SW	6	3	0.8	0.0
SC	10	6	1.7	0.1
SE	18	12	3.8	0.1
State Average	13	11	2.1	0.03

PROGRESS IN DEVELOPING ECONOMIC THRESHOLDS

Economic thresholds provide a valuable tool in deciding whether treatment of an ECB infestation will provide yield benefits exceeding control costs. Currently, most growers are familiar with older, nominal thresholds for the ECB. These thresholds advise treatment when 50% of the plants exhibit shotholing. Although a practical guide, this threshold is static and does not reflect changing yield potentials, crop prices, or control costs. Consequently, there's a potential for costly mistakes in making treatment decisions. More precise economic thresholds can be calculated from the following formula:

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

Using this threshold formula improves the chances of making a profitable decision about ECB control because control costs, yield potential, and expected crop price can be tailored to the individual farming operation.

Using calculated thresholds to Minnesota's ECB situation requires research on insecticide performance and yield loss per borer. Although values gleaned from other states provide a satisfactory first approximation, the Minnesota situation is sufficiently unique that additional research is required. For example, the yield loss values appearing Table 2 were derived from Iowa and Kansas studies using longer maturing varieties. Although the relative trends between growth stages may be correct, the magnitude of yield loss per tunnel may differ between 130 day varieties in Kansas and 75 day varieties in northern Minnesota. Similarly, differences in crop stage and larval location when insecticide application is made could alter insecticide performance. For these reasons, my research in 1985 focused on insecticide performance and yield loss.

Table 2. Corn yield loss, expressed as % loss per borer, caused by European corn borer larvae infesting various corn growth stages. Reproduced from Iowa and Kansas data summarized in NCR Publication no. 22.

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

INSECTICIDE PERFORMANCE

Four insecticide trials were conducted in northern Minnesota against first generation larvae. Three of the trials, located near Twin Valley, Crookston, and Euclid, evaluated the performance of aerially applied insecticides. Heavy rainfall within 48 hours postapplication reduced performance of all insecticides at Euclid. For example, Penncap-M and Furadan 15G reduced larval abundance at Euclid 34% and 10%, respectively, compared to 81% and 84%, respectively, at Crookston. Therefore, data from Euclid will not be presented. Insecticide performance at Crookston and Twin Valley sites is summarized in Tables 3 and 4, respectively.

Table 3. Effectiveness of aerially-applied granular and liquid insecticides against first-generation European corn borer in northern Minnesota. Northwest Experiment Station, Crookston, Polk Co. - 1985.

Treatment	Rate (lbs ai/A)	Larvae per 50 plants	% Control
Furadan 15G	1.000	22.33 c	83.5
Pounce 3.2EC	0.150	23.67 c	82.5
Penncap-M 2EC	0.500	25.67 c	81.0
Lorsban 4E	1.000	49.33 b	63.5
Pydrin 2.4EC	0.150	55.00 b	59.3
Untreated Check	----	135.00a	----

Control ranged from 38 to 84%. Individual insecticides were farily consistent in their performance between the two trials. Furadan 15G, Penncap-M, and Pounce 3.2 EC provided better control than either Lorsban 4E or Pydrin 2.4EC. Over both sites, Furadan 15G, Penncap-M, and Pounce 3.2EC provided a minimum of 70% control. This was better than expected from last year's small plot trials where Furadan 15G, Penncap-M, and Pounce 3.2EC provided 68%, 50% and 50% respectively. Performance may have improved becuase the corn was in late whorl stage in 1985 rather than a pretassel or early tassel stage as in 1984.

Table 4. Effectiveness of aerially-applied liquid insecticides on first-generation European corn borer in northern Minnesota. Christenson farm, Twin Valley, Norman Co. - 1985.

Treatment	Rate (lbs ai/A)	Larvae per 10 plants	% Control
Pounce 3.2EC	0.15	5.00 d	74.1
Penncap-M 2EC	0.50	5.67 d	70.7
Penncap-M 2EC	0.25	6.33 cd	67.3
Lorsban 4E	1.00	10.33 bc	46.6
Pydrin 2.4EC	0.15	11.33 b	41.4
Pydrin 2.4EC	0.10	12.00 b	37.9
Untreated Check	----	19.33a	----

One small-plot insecticide trial was conducted near Gonvick, Beltrami Co., to evaluate the preformance of both labelled and unlabelled compounds against first-generation ECB in northern Minnesota. The performance of these insecticides is presented in Table 5.

Table 5. Effectiveness of granular and liquid insecticides on first generation European Corn Borer in small plot trials in northern Minnesota. John Brook farm, Gonvick, Beltrami Co. - 1985.

Treatment	Rate (lb ai/A)	Tunnels per 10 plants	% Control	Larvae per 10 plants	% Control
Baythroid 2EC	0.025	0.00 f	100.0	0.50 ef	95.9
Ammo 0.75G	0.075	0.25 ef	98.7	1.00 def	91.8
Furadan 15G	1.000	0.50 def	97.4	1.25 cdef	89.7
Ammo 2.5EC	0.075	0.75 def	96.1	0.00 f	100.0
Lorsban 4E	1.000	0.75 cdef	96.1	0.50 ef	95.9
Pounce 1.5G	0.150	0.75 cdef	96.1	0.50 ef	95.9
Lorsban 15G	1.000	1.00 bcdef	94.8	0.75 ef	93.8
Karate 1EC	0.015	1.00 bcdef	94.8	1.00 def	91.8
Capture 2EC	0.010	1.25 bcdef	93.5	1.25 cdef	89.7
Diazinon 14G	1.000	1.25 bcdef	93.5	1.75 cde	85.6
Larvin 3.2EC	0.500	1.25 bcdef	93.5	1.25 def	89.7
Furadan 4F	1.000	1.50 bcdef	92.2	1.50 cdef	87.7
Pounce 3.2EC	0.150	1.50 bcdef	92.2	0.75 def	93.8
Dipel 10G	1.000	2.50 bcd	87.0	2.50 bcd	79.4
Aastar 15G	1.000	3.00 bc	84.4	3.25 bc	73.2
Counter 15G	1.000	3.00 b	84.4	3.00 bcd	75.3
Thimet 20G	1.000	3.00 b	84.4	2.33 bcd	80.8
Pydrin 2.4EC	0.150	9.75a	49.2	5.25 b	56.7
Dyfonate 20G	1.000	10.00a	47.9	5.63 b	53.6
Untreated check	----	19.19a	----	12.13a	----

Two compounds, Pydrin 2.4EC and Dyfonate 20G, provided only a 45-50% reduction in tunnels and did not differ significantly from the check in the number of tunnels per 10 plants. All remaining compounds provided at least an 84% reduction in tunnels and a 73% reduction in larval abundance. Although statistical analysis indicates some difference in performance between these remaining compounds, all except Pydrin and Dyfonate performed satisfactorily. Of the compounds evaluated, Baythroid, Ammo, Karate, Capture, Larvin, Aastar, and Counter are currently unlabelled for first generation ECB control.

Low larval abundance in southern and central Minnesota during 1985 eliminated the opportunity to evaluate insecticide performance against both first and second generation. Plans for 1985 include continued evaluation of insecticides against ECB throughout Minnesota. Specific attention will focus on general performance in aerial trials against first and second generation ECB, comparison of granule and liquid formulations, and comparison of application methods against first generation in southern Minnesota.

YIELD LOSS EXPERIMENTS IN 1985

Experiments quantifying the yield loss per tunnel continued in northern Minnesota. After two years of research, preliminary analysis of the data suggests an average loss of 7-8% per tunnel. This exceeds the value of 6.6% reported for pretassel corn in Table 2. Research in 1986 will continue to explore the yield-loss relationship with ECB tunneling in northern Minnesota and, if resources are available, expand these studies to southern Minnesota.

CORN ROOTWORM INSECTICIDE PERFORMANCE IN 1985

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INTRODUCTION

The combined strategies of crop rotation and soil insecticide use usually limit corn rootworm (CRW) damage effectively. This report presents the results of soil insecticide trials against northern and western corn rootworms in Minnesota.

PERFORMANCE IN 1985 TRIALS

The performance of corn rootworm insecticides was evaluated at three locations in Minnesota: Waseca, Lamberton, and Morris. Table 1 presents the results of these trials for labelled insecticides and insecticides with an experimental use permit (Lance 15G). Only Lamberton experienced excellent pressure from CRW populations , receiving a root rating of 3.97 on the Iowa 1-6 rating scale. CRW pressure was greatly reduced at both Morris and Waseca compared to previous years with root ratings of only 2.14 and 2.38 respectively.

Table 1. Summary of corn rootworm insecticide performance in 1985 trials at University of Minnesota Experiment Stations in Lamberton, Waseca, and Morris*.

Treatment	Rate (oz/1000 row-ft)	Root Ratings		
		Lamberton	Morris	Waseca
Aastar 15G	8.0	2.69 cde	1.95 de	1.85 cde
Broot 15G	8.0	2.69 cde	1.98 cde	1.83 cde
Counter 15G	8.0	2.39 de	1.88 e	2.05 bcd
Dyfonate 15G	8.0	2.56 de	1.93 de	2.28ab
Dyfonate 20G	6.0	2.58 de	2.00 bcde	2.03 bcde
Dyfonate 4.6MS	***	3.39ab	2.13abcd	----
Furadan 15G	8.0	2.78 cde	2.23a	1.98 bcde
Furadan 4F	***	2.81 bcde	----	----
Lance 15G	8.0	2.29 e	1.98 cde	1.80 cde
Lance 15G	6.0	2.48 de	2.03abcde	1.73 de
Lorsban 15G	8.0	3.01 bcd	2.05abcde	2.00 bcde
Lorsban 4E	***	3.23 bc	----	----
Mocap 15G	8.0	2.95 bcd	2.18abc	2.13 bc
Thimet 20G	6.0	2.65 cde	2.08abcde	2.03 bcde
Untreated Check	----	3.97a	2.14abcd	2.38a

* Planting dates: Morris - May 24, Lamberton - May 13, Waseca - May 10.
Cultivation treatments applied June 7.
Roots rated: Morris - Aug. 8, Lamberton - July 30, Waseca - Aug. 5.
*** Liquids applied at cultivation time at a rate of 1.0 lb ai/A in ca. a 10 inch band centered over the row, using a CO_2 powered backpack sprayer set at 30 psi and delivering 17 gallons of water per acre.

Yield loss and lodging associated with corn rootworm injury are generally associated with root ratings exceeding 3.0. Insecticide performance at Waseca and Morris will not be discussed because corn rootworm pressure was not sufficient to produce root damage exceeding 3.0. At these sites, although significant differences occur in root damage ratings, these differences are not economically meaningful. Low damage ratings at Morris probably resulted from late planting combined with earlier than normal corn rootworm hatch. The most critical time in the life of a corn rootworm larvae is its movement from the egg to a suitable host root. Failure to find a suitable root means death. When corn development is retarded compared to corn rootworm hatch, the root systems are much smaller, more difficult to find, and damage is reduced because mortality is increased. Generally, earlier planting is associated with greater injury. Low injury ratings at Waseca, however, do not seem related to planting date but to low population levels.

At Lamberton, all planting-time applications significantly reduced root damage but Lorsban 15G and Mocap 15G failed to acceptably protect the root systems (root rating > 3.0). All other granular materials applied at planting provided acceptable control. This year, three cultivation time treatments (Lorsban 4E, Furadan 4F, and Dyfonate 4.6MS) were evaluated at Lamberton. Of these treatments, only Furadan 4F provided acceptable root protection. Both Lorsban 4E and Dyfonate 4.6MS at cultivation provided unacceptable root protection.

CONSISTENCY OF CORN ROOTWORM INSECTICIDE PERFORMANCE

Corn rootworm insecticides vary in their performance from year to year. The consistency of an insecticide in keeping root ratings below a 3.0 is very important. Both consistency and price should be considered when choosing a corn rootworm insecticide. Consistency of insecticide performance during recent years in summarized in Table 2.

Table 2. Consistency of corn rootworm insecticide performance in Minnesota, 1977-1985, as measured by the proportion of trials where the insecticide maintained a root rating < 3.0 (Iowa 1-6 rating scale).

Insecticide	# Ratings < 3.0 / # Trials	%
Counter 15G	22/23	96
Thimet 20G	21/22	95
Broot 15G	19/20	95
Dyfonate 20G	18/22	82
Furadan 15G	18/23	78
Mocap 15G	16/22	73
Lorsban 15G	13/22	59
Untreated Check	6/23	26

SITUATION FOR 1986

Results of the adult corn rootworm survey conducted by the Minnesota Department of Agriculture - Plant Industry Division are presented in Table 3. Adult populations increased substantially in SE Minnesota, remained comparable in WC,C, and SC Minnesota, and decreased substantially in SW and EC Minnesota. The statewide ratio of northern to western corn rootworms stayed constant at 90:10 respectively. However, in SE Minnesota, western corn rootworm beetles increased in relative abundance to 28%.

Table 3. Corn rootworm adult survey (Aug. 1-20) in Minnesota.

District	Fields	Corn plants per acre	Adult beetles/acre		Percent lodging
			1984	1985	
WC	43	21,516	43,437	45,616	0.2
C	43	22,407	46,432	43,345	0.4
EC	34	22,398	43,535	23,011	0.5
SW	29	21,209	55,278	28,145	Trace
SC	62	22,411	44,883	42,505	Trace
SE	53	22,676	50,298	72,197	Trace
State Average		22,103	42,636	47,310	<1%

NORTHERN CORN ROOTWORM INJURY IN FIRST-YEAR CORN: CURIOUSITY OR THREAT ?

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INTRODUCTION

The risk of corn rootworm injury in first-year corn is generally considered minimal and, consequently, the use of soil insecticides is generally considered unwarranted. Yet, during 1985, northern corn rootworm damage produced significant lodging in over 150 fields within a three state area (Iowa, Minnesota, and South Dakota). How severe was the problem? What are its causes? Is this problem likely to persist or does it represent a unique curiousity?

BRIEF HISTORY OF THE PROBLEM

Northern corn rootworm injury in corn following soybean or small grains is not new. As early as 1883, Forbes reported injury in corn following oats. Bigger reported a similar occurrence in a corn-corn-oat rotation in Iowa in 1932. Injury in corn following soybean, however, was not reported until 1971. For the most part, northern corn rootworm problems were usually isolated incidents. These problems were usually attributed to egg laying in soybean fields with grassy weeds or volunteer corn or in small grain regrowth after harvest.

During the late 1970's, lodging problems in first-year corn were reported with increasing frequency in SC Minnesota. This area of Minnesota has a strong corn/soybean rotation. Corn rootworm egglaying in weedy soybean fields was suggested as the cause of the problem. Consultants in the area, who had monitored weed populations in the soybeans disagreed, however, because the fields were essentially clean. During 1984, 6 problem fields, with root damage rating between 3.5 and 5.5, were reported by consultants in SC Minnesota. These fields accounted for ca. 1% of the first-year corn that these consultants scouted. For many of these growers, rootworm damage to corn following soybeans was not new. The frequency of this problem in SC Minnesota for a 5 year period indicated that we were facing something different, different enough to warrant investigation.

The occurrence of rootworm damage in first-year corn during 1985, therefore, was not surprising. However, both the magnitude and the distribution of the problem were totally unexpected. Not only did the problem reoccur with greater magnitude in SC Minnesota but it was distributed throughout southern Minnesota, northwestern Iowa, and eastern South Dakota. Over 150 fields with lodging attributed to northern corn rootworm injury have been reported to date. The distribution of fields with confirmed northern corn rootworm injury in Minnesota is presented in Fig. 1. In all three states, damage was not

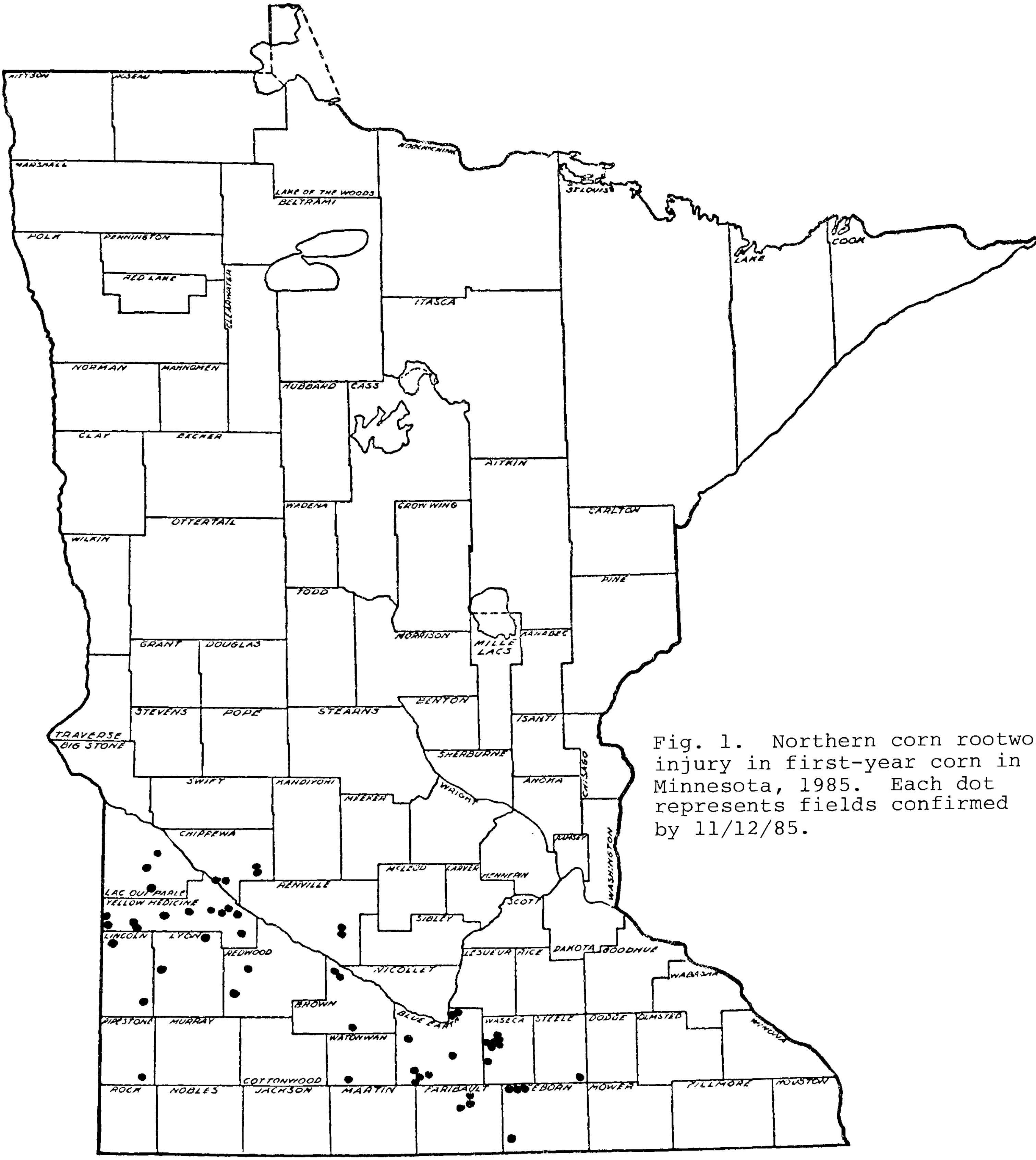

Fig. 1. Northern corn rootworm injury in first-year corn in Minnesota, 1985. Each dot represents fields confirmed by 11/12/85.

distributed uniformly. Instead, the problem tended to occur in pockets with several fields affected in each area. The pockets were widely scattered, surrounded by apparently undamaged fields. The majority of corn rootworms observed in these fields were northern corn rootworms. Abundance of adult northern corn rootworms in these first-year corn fields reached up to 6 beetles per plant. Recent research in South Dakota, indicating that over 98% of emerged beetles from first-year corn were northern corn rootworms, agrees with these observations.

The dramatic increase in northern corn rootworm problems in first-year corn raises some serious questions. Does this increase represent a unique situation that is unlikely to repeat itself? or Does this increase represent the tip of a long-term problem that threatens to negate the advantages of a corn/soybean rotation?

CAUSES OF THE PROBLEM

How can rootworm larvae end up in corn following soybean or small grains? Because northern corn rootworms have an annual life cycle, it was thought that adults laid their eggs in soybean and small grain fields the previous summer and fall. Many early investigators of this problem observed that northern corn rootworms, particularly females, left corn fields and foraged for pollen on broadleaf and grassy weeds, volunteer corn, and soybean. The investigators assumed that egg laying occurred where the rootworms were foraging. Later studies showed that northern corn rootworms predominately laid their eggs near the bases of corn plants, including volunteer corn. Although frequently seen on a variety of plants, few eggs were found in association with these plants. Thus, evidence suggests that egg laying is closely tied to corn and, to a much lesser extent, some grasses. So, why do problems occur following grass-free soybeans? Perhaps the best explanation of this problem involves "extended diapause".

Northern corn rootworms normally have an annual life cycle. The eggs laid in late summer and early fall go into a resting stage, called diapause, that allows them to successfully survive Iowa and Minnesota winters. These eggs either die during the winter or hatch the next spring. Over 10 years ago, Dr. Chiang, of the University of Minnesota, found that a small proportion of northern corn rootworm eggs (<0.3%) could successfully overwinter two winters. Thus, these rootworms have an extended diapause and a two-year life cycle.

Why would extended diapause benefit northern corn rootworms? In continuous corn, extended diapause has no real benefit. However, in a corn/soybean or corn/small grain rotation, all larvae that hatch after the first winter face starvation because they can survive only on corn and a few grassy weeds. Larvae that hatch after the second winter survive on the corn. Thus, extended diapause has a real advantage in a corn/noncorn rotation. Over time, the proportion of rootworms would be expected to increase. Evidence from recent rearing studies indicate a shift is taking place. Examination of northern corn rootworms from 3 areas of Minnesota and South Dakota where farmers routinely rotate corn and soybean indicate 40-50% of the rootworms have the 2-year life cycle. In contrast, less than 10% of the northern corn rootworms from 1 continuous corn area exhibited a 2-year life cycle. These data suggest northern corn rootworms are adapting to the common corn/soybean rotation.

A SURVEY OF FIELDS INJURED BY NORTHERN CORN ROOTWORMS

As the problem developed this past summer, entomologists in Minnesota, Iowa, and South Dakota concentrated on gathering as much information as possible about the extent of the problem and its possible causes. Area and county-based extension personnel, consultants, agronomists, and ag chemical dealers helped pinpoint, diagnose, and gather field histories on problem fields. These field histories provided our first clues on causal factors and cultural practices associated with the problem. At this time, results are still arriving but the preliminary findings are highly interesting.

Based on 28 initial histories from Minnesota and extrapolating to the number of reported fields, I estimate that less than 0.1% of the state's corn acreage is affected. For 89% of these farmers, it was the first time they had experienced the problem. Strict corn/soybean or corn/small grain rotations were practiced on 86% of the fields over the last 5 years. 96% of the farmers used some form of conservation tillage following soybean including 29% who used no fall tillage. Fall tillage following corn was more diverse, with 46% using a moldboard plow, 50% using a chisel plow or soil saver, and 4% using a disk. Spring tillage was fairly uniform, usually including ca. 1.6 passes with a field cultivator or disk.

Preliminary results also indicate that extended diapause offers the most consistent explanation of the problem. For example, 85% of the soybean fields did not have problems with grass control. More importantly, 100% of the problem fields were in corn during 1983. The necessity of corn two years previously strongly supports the extended diapause hypothesis. If the problem were caused solely by oviposition in soybean, I would have expected a greater proportion of fields, ca. 35% in Minnesota, enrolled in PIK or diversion programs in 1983.

PRELIMINARY FIELD RESEARCH

During 1985, a pilot study was initiated to determine if the problem would reoccur, its severity, and the economics of soil insecticide as a preventive measure. Conversations with these farmers indicated sporadic reoccurrence of the problem on the farm. Three corn fields were selected on farms with a prior history of thhe problem. Each field received 4 treatments, including 3 soil insecticides (Counter, Lorsban, Thimet) and an untreated check, replicated across the field.

Root ratings in early August confirmed corn rootworm injury, averaging ca. 3.0, in 2 of the 3 fields. Lodging was also evident in these two fields. Preliminary yield data indicates a significant yield benefit was not realized at any locations during 1985. However, the level of damage was not considered high enough to produce yield effects.

These findings confirm the tendency for problems to reoccur for a given farmer. In fact, the one farmer whose field escaped corn rootworm injury in our study had a nearby first-year corn field damaged by northern corn rootworms.

RECOMMENDATIONS FOR 1986

My concern about this problem is that we don't know what to expect in 1986. Is the magnitude of the problem in 1985 unique and unlikely to reoccur? Does it represent a unique combination of early planting, high egg numbers surviving from 1983, and ideal conditions for lodging? Or are we facing a problem that will persist?

Most likely, we'll see similar problems in 1986. Throughout the affected area, northern corn rootworm populations increased in 1984. However, mortality through two winters, crop rotation, planting dates, and weather will all influence the magnitude of the problem.

Prediction of individual fields that will experience damage in 1986 is impossible at this point. We do know that the problem tends to remain in pockets, because of the limited dispersal of northern corn rootworms, and the problem tends to reoccur on farms. Therefore, farmers, who had corn following soybean or small grain damaged in 1985 or who lived near a farmer with problems, should carefully consider the following options for first-year corn. Basically, a farmer has three options for first-year corn fields (that were in corn during 1984):

1. Lengthen the rotation sequence by planting another noncorn crop. This will break the cycle but, unfortunately, the noncorn crop options are limited.
2. Use a soil insecticide. This will protect the 1986 crop but the relative economic benefit is unknown.
3. Do not change your plans for 1986. Reoccurence in SC Minnesota is sporadic and hot spots seem to shift over the years. Although the overall risk is small, e.g., <0.1% in Minnesota during 1985, infestation rates as high as 50% occurred in one pocket in SC Minnesota.

Choose the option best suited to your farming operation, its financial situation, and your perception of the risk in your area. I wish I had a more definitive recommendation to offer but our knowledge of the problem, its pattern of occurrence, and ability to predict it are limited. As research progresses and our experience increases, I envision the ability to predict first-year corn problems and take cost-effective measures. The solution may be as simple as scouting first-year corn fields for adults and making decisions about cropping practices two years away.

Farmers who did not have a problem in their fields or did not live near a farmer with problems should not change their plans for 1986. Generally, I still advise against the use of soil insecticides on corn following soybeans or small grains.

RECOMMENDATIONS FOR 1986

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The major change in insecticide labels for 1986 is the placing of several granular materials in the Restricted use Category (RUC). Carbofuran (Furadan), ethoprop (Mocap), fonofos (Dyfonate), phorate (Thimet, Phorate), and terbufos (Counter) will all have RUC labels when packaged after Sept. 1, 1985. The EPA, however, has wisely permitted the continued sale of supplies of these compounds whose packaging retains the pre Sept. 1, 1985 general use label.

It will be legal to use such general use labeled materials in 1986 without applicator certification. However the grower (ie private applicator), from a purely practical standpoint, would be well advised to obtain private applicator certification for use of RUC insecticides rather than gamble on being able to obtain some general use label material. It is clearly evident that more pesticides will be placed in the RUC as time goes on. It is also reasonable to assume that certification and probably licensing will be improved (ie toughened) in the years ahead.

SALE AND APPLICATION OF RESTRICTED USE CATEGORY (RUC) PESTICIDES

The volume of sales of the granular materials and the addition of RUC labels to several, but not all, of the commonly used granular materials may tempt some to use this reclassification as a sales argument. We would strongly discourage such an approach for a number of reasons.

First it is probably not legal to say, in writing or verbally, that product A (a general use product) is safer than product B (a restricted use category material). Yet that is the implication when a dealer is encouraged to stock and the applicator use the general use material. Furthermore we have to keep in mind that classification in the RUC may have come about for reasons other than hazards to man. The pyrethroids, such as Pydrin and Ambush, are enormously toxic to aquatic organisms for example, and as a result will probably remain in the RUC.

Secondly some general use products have environmental effects which are to be avoided. A classic example of this is honey bee poisoning by such products as Sevin, Malathion ULV, Dursban, and Cygon. Each of these insecticides is quite safe for man. With minor exceptions most insecticides have a negative impact on non-target insects many of which are beneficial.

We, in extension, feel that the choice of an insecticide should first be based on the fact it is labeled on the crop. We further believe that insecticide choice should be determined by consistent effectiveness, by cost, and by the least potential environmental damage possible. This last factor is determined as much by the manner in which the product is used as by (mammalian) toxicity of that chemical.

Safety to man, the crop and the environment is always a concern when applying pesticides. All pesticides are to some degree hazardous when handled improperly. Without question our entire industry will benefit from improved understanding and improved application of the products with which we work.

The key to reduced numbers of pesticide incidents is improved knowledge of the product being considered for use. Improved knowledge comes through applicator training, through obtaining as much information about the chemical from as many sources as possible, and from reading the label.

Applicator training and certification is a major method for improvement of both private and commercial applicator knowledge. We believe that the chemical industry, applicators of all types, consultants agronomists and public sources such as extension should encourage all pesticide users to obtain additional training. All of us working with chemicals should re familiarize ourselves with the products we use each new season. We believe the record of safe pesticide use is exceptional. But we also believe we can further improve this record.

HONEY BEE PROTECTION

Carbaryl (Sevin), ULV malathion, methidathion (Supracide), methyl parathion (Penncap M), and parathion, for example, are very toxic to bees. Crops in bloom should not be treated and applications should not be made near bee yards or when bees are present in fields to be treated. Do not move bees into alfalfa fields treated with Furadan 4F within 7 days of treatment. A listing of insecticides and their toxicity to honey bees is contained in Entomology AG-FS-1028, Protecting Honey Bees from Insecticides and in AG-BU-0499, Insecticides.

INSECTICIDE MOVEMENT IN SOIL

Insecticides applied to steep slopes often move with soil and water in the erosion process. Greatest movement occurs where slope is greatest and erosion control (eg. tillage, contouring, and terracing) is least. The magnitude of movement will be related to amount of run-off and the concentration of the insecticide in the soil. Early season run-off shortly after application, for example, will move the greatest amounts of pesticides.

In the Karst area in southeastern Minnesota the same factors that contribute to soil-pesticide run-off may also potentially contribute to movement of pesticide into aquifers.

A third situation exists where pesticides have potential to move into shallow aquifers. In this case pesticide solubility and the volume of water moving past the root zone are major variables in moving pesticides to the water table. Areas of Minnesota where greatest potential for this to take place are the glacial outwash sand plains in the central part of the state. Care should be taken to use as little pesticide as is practical and perhaps to be concerned about both pesticide solubility and amounts of water added to these soils.

HANDLING OF HIGHLY TOXIC INSECTICIDES

Aldicarb (Temik), demeton (Syston), disulfoton (DiSyston), mevinphos (Phosdrin), methomyl (Lannate, Nudrin), methyl parathion, parathion, phorate (Thimet), and phosphamidon (Dimecron) are highly toxic chemicals. They should be handled only by persons knowledgeable in their safe use. Posting of fields in which these chemicals are foliarly applied is advisable. Protective measures outlined on the label, including clothing and method of application, should be followed carefully. Granular formulations are less hazardous during application than are liquids. However, in all cases avoid inhaling dusts or vapors, avoid skin contact with the chemical, and change clothing and shower thoroughly after applying insecticides.

INSECT AND INSECTICIDE MANAGEMENT TO REDUCE RESISTANCE POTENTIAL

Insect resistance develops in insect populations as a result of intense selection (near 100% kill) by the insecticide. Selective pressure is increased when dosage is increased, spray frequency is increased and more life stages of the insect are exposed to the insecticide. Immigration of insecticide susceptible insects into treated populations is the major factor preventing the build-up of resistance.

The question of how to manage pest insect populations in such a manner that initially effective insecticides remain effective for a longer period suggests the possibility of two patterns of insecticide use. Both patterns have been subjected to tests through modeling a theoretical insect population with various assumed constraints.

The first strategy can be called the "high dose" strategy. This is, in simple terms, the use of an insecticide at a level that "eliminates" a resident pest population (i.e. 100% control). In addition, the insecticide is assumed to have no persistence so that immigrants are not subjected to any selective pressure, and there is no outward migration of treated (i.e. resistant) individuals. Finally, it is assumed the insecticide dosage does not lead to collateral resistance in other pest species in the target area.

Authors who have spent considerable thought on these problems have the general consensus that it is not likely all, or very many, of the assumptions upon which the "high dose" strategy is based are valid in nature. And, if they are, they are not likely to continue once chemical selective pressure is placed on a population. Thus, at best, a high dose strategy could only be used very early in an insecticide history.

The second of these strategies has been termed the "low dose" strategy. It is assumed low dosage treatments remove susceptible insects only. High immigration of susceptible insects into the area treated is again assumed. Insecticide is used at the least dosage which provides maximum economic benefit.

Because most workers feel the assumptions upon which the "low dose" strategy are based are most likely to be operative in nature we feel it prudent to encourage its use. It is basically the use of an insecticide only when net profit can be realized by the grower from the use of the insecticide. Furthermore, the insecticide dosage should not be higher than is necessary for the greatest net return to chemical dollar. Professionally speaking, this means insecticide use should be based on field monitoring and the obtaining of precise pest counts.

INSECTICIDE SUGGESTIONS TO CONTROL INSECT PESTS OF FIELD CROPS IN 1986

Abbreviations used in tables: phi - pre harvest interval, EC or E - emulsifiable concentrate, D - dust, G - granules, S - solution, WP - wettable powder, and SP - soluble powder. Dosages of insecticides are actual chemical per acre, with some exceptions.

ALFALFA

Insect	Insecticide	Formulation		Dosage	Limitations
		Recomm.	Product/acre		
Alfalfa weevil	azinphosmethyl (Guthion)	50% WP only	1 - 1 1/2 lb	1/2-3/4 lb	21 day phi, not more than one application per cutting.
	*carbofuran (Furadan)	4F	1/2 - 1 pt	1/4-1/2 lb	7 day phi 1/4 lb, 14 days 1/2 lb. Not more than 2 application per season, nor 1 per cutting. Note crop rotation restrictions in label.
	chlorpyrifos (Lorsban)	4E	1 pt	1/2 lb	14 day phi. Not more than 1 application per cutting.
	*methyl parathion (Penncap M)	2F	1 pt	1/4 lb	15 day phi
	phosmet (Imidan)	50 WP	2 lb	1 lb	7 day phi. Not more than one application per cutting.
	carbaryl	XLR plus	2 - 3 pt	1-1 1/2 lb	3 day phi. Note plant damage precautions on label.
	malathion plus methoxychlor	2E + 2E	3 pt	3/4 lb+3/4 lb	7 day phi-available as a ready-to-use mixture.
	*methidathion (Supracide)	2E	2 pt	1/2 lb	10 day phi.
	malathion (Cythion)	5E	2 pt	1 1/4 lbs	No time limitations.

* Restricted-use material

Cut first crop early to avoid most losses. Treat when more than 30 percent of plant tips show feeding. Treat stubble if there are more than 8 larvae per square foot or when regrowth has 50 percent of the terminals with feeding or if larvae are delaying regrowth. Do not treat alfalfa in bloom.

Aphids	*carbofuran (Furadan)	4F	1/2 - 1 pt	1/4-1/2 lb	7 day phi 1/4 lb, 14 days 1/2 lb. Not more than 2 applications per season nor 1 per cutting. Note crop rotation restrictions in label.
	chlorpyrifos (Lorsban)	4F	1 pt	1/2 lb	14 day phi. Not more than 1 application per cutting.
	diazinon	4E	1 pt	1/2 lb	7 day phi.
	dimethoate (Cygon, Defend, Rebelate, Dimex 267)	4E 2.67E	1/2 pt 3/4 pt	1/2 lb	10 day phi, one application per cutting.
	malathion (Cythion)	5E	1 3/5 pt	1 lb	No time limitations.
	*parathion	4E	1/2 pt	1/4 lb	15 day phi.
	*methyl parathion (Penncap M)	2F	1 pt	1/2 lb	15 day phi.

Control pea aphids if populations 2 weeks prior to harvest exceed an average of 1.2 per stem and plants are under drought stress. Spotted alfalfa aphids may severely damage new seedings.

Armyworms, cutworms	carbaryl (Sevin)	XLR plus	3 pts	1 1/2 lb	3 day phi, spray or bait. Note plant damage precautions of label.
	chlorpyrifos (Lorsban)	4E	1 pt	1/2 lb	14 day phi. Not more than 1 application per cutting.
	malathion (Cythion)	5E	2 pts	1 1/4 lb	No time limitations.
	trichlorfon (Dylox,	4E	2 pts	1 lb	No time limitations. Not more than

* Restricted-use material

	Proxol)				3 applications per cutting.
	*methomyl (Lannate, Nudrin)	90% SP 1.8E	3/8 lbs 1 - 2 pts	1/4-1/2 lb	7 day phi. Note plant damage precautions on label.
	*methyl parathion (Penncap M)	2F	2 pts	1/2 lb	15 day phi.

Treat when more than 5 per square foot.

Leafhoppers	azinphosmethyl (Guthion)	50% WP only	1/2 - 1 lb	1/4-1/2 lb	16 day phi. Not more than one application per cutting.
	carbaryl (Sevin)	XLR plus	2 pts	1 lb	3 day phi. Note plant damage precautions on label.
	*carbofuran (Furadan)	4F	1/2 - 1 pt	1/4-1/2 lb	7 day phi 1/4 lb; 14 days 1/2 lb. Not more than 2 applications per season, nor one per cutting. Not crop rotation restrictions in label.
	chlorpyrifos (Lorsban)	4E	1 pt	1/2 lb	14 day phi. Not more than 1 application per cutting.
	diazinon	4E	1 pt	1/2 lb	7 day phi.
	methoxychlor (Methoxchlor, Marlate Prentox)	2E	4 pts	1 lb	7 day phi.
	*methidathion (Supracide)	2E	2 pts	1/2 lb	10 day phi.
	phosmet (Imidan)	50WP	2 lbs	1 lb	7 day phi, one application per cutting.
	dimethoate (Cygon, etc)	4E	1/2 - 1 pt	1/4-1/2 lb	10 day phi, the application per cutting.

Apply when potato leafhoppers average or exceed 0.3 per pendulum sweep on alfalfa less than 3" tall, 0.4 per sweep on alfalfa 3-5" tall, 0.5 per sweep for 6-7" alfalfa, 1.0 per sweep for 8-11"

* Restricted-use material

alfalfa, and 2 per sweep on alfalfa 12" or taller. New seedings are most susceptible to injury.

Grasshoppers	azinphosmethyl (Guthion)	50% WP only	1 - 1 1/2 lb	1/2-3/4 lb	21 day phi. Not more than 1 application per cutting.
	carbaryl (Sevin)	XLR plus	2 - 3 pts	1-1 1/2 lb	3 day phi.
	*carbofuran (Furadan)	4F	1/4 - 1/2 pt	1/8 - 1/4 lb	7 day phi, one application per season.
	chlorpyrifos (Lorsban)	4E	1 pt	1/2 lb	14 day phi. Not more than 1 application per cutting.
	diazinon	4E	1 pt	1/2 lb	7 day phi
	dimethoate (Cygon, Rebelate)	4E 2.67E	1/2 - 1 pt 3/4 - 1 1/2 pt	1/4-1/2 lb	10 day phi, one application per cutting.
	malathion (Cythion)	5E	2 pts	1 1/4 lbs	No time limitations.

Control when there are more than 8 grasshoppers per square yard in the field, or treat margins after cutting at more than 20 per square yard.

Spittlebug	malathion (Cythion)	5E	1 3/5 - 2 pts	1-1 1/4 lbs	No time limitations.
	methoxychlor (Methoxychlor, Marlate, Prentox)	2E	4 pts	1 lb	7 day phi.
	chlorpyrifos (Lorsban)	4E	1 - 2 pts	1/2-1 lb	14 day phi 1/2 lb; 21 day phi 1 lb. Not more than 1 application per cutting.
	methyl parathion (Penncap M)	2F	1 - 3 pts	1/4-3/4 lb	15 day phi.

Apply on first crop when spittle masses average more than one per stem.

* Restricted-use material

Insect	Insecticide	Recomm.	Product/acre	Dosage	Limitations
Plant bugs	malathion + methoxychlor	2E + 2E	3 pts	3/4 lb + 3/4 lb	7 day phi
	trichlorfon (Dylox)	4E	2 pts	1 lb	

Control seldom needed except on seed crop. Cut early to avoid injury.

ALFALFA, CLOVER
(FOR SEED ONLY)

Insect	Insecticide	Formulation Recomm.	Formulation Product/acre	Dosage	Limitations
Plant bugs	chlorpyrifos (Lorsban)	4E	1 pt	1/2 lb	14 day phi. Not more than 1 application per cutting.
	endosulfan (Thiodan)	3E	3 pts	1 lb	Do not harvest for forage or graze.
	trichlorfon (Dylox)	4E	2 - 3 pts	1-1 1/2 lbs	7 day phi. Chaff may be used for feed or forage, but do not cut green crop for these purposes.

Do not treat crop in bloom

CORN, FIELD

Insect	Insecticide	Formulation Recomm.	Formulation Product/acre	Dosage	Limitations
			(per 1000 row ft.)		
Corn rootworm larvae	*carbofuran (Furadan)	15G	8 oz	1.2 oz = 1 lb/acre in 40" rows	May be applied in furrow or banded.

* Restricted-use material

	chlorpyrifos (Lorsban)	15G	8 oz	All same as above	Apply as band in front of press wheel.
	*ethoprop (Mocap)	15G	8 oz		Phytotoxic - Do not apply in-furrow or band over open seed furrow.
	*fonofos (Dyfonate)	20G	6 oz		Phytotoxic - Do not apply in-furrow or band over open seed furrow.
	*phorate (Thimet)	20G	6 oz		Phytotoxic - Do not apply in-furrow or band over open seed furrow.
	*terbufos (Counter)	15G	8 oz		May be applied in-furrow or in band.
	trimethacarb (Broot)	15G	8 oz		Phytotoxic - Do not apply in-furrow or band over open seed furrow.

The potential for rootworm infestation can be predicted by scouting corn fields weekly for adult beetles during August. If adult counts average less than one beetle per plant during August, a soil insecticide used the next spring will rarely increase yield. If adult counts average more than 5 beetles per plant, rotate to a crop other than corn. Rootworm control may be unsatisfactory during heavy rootworm infestation. If a field was not scouted last year, use a soil insecticide where corn follows corn.

Soil insecticides may be applied during cultivation. Cultivator application of Broot, Counter, Dyfonate, Furadan (15G, 4F), Lorsban (15G, 4E), Mocap, or Thimet/Phorate may provide effective control if applied before larvae hatch in mid-June. Apply at base of stalks and cover with soil. This method may provide poor control if dry soil conditions prevent effective insecticide movement into the root zone.

Avoid continuous use of the same soil insecticide. Continuous use may condition the soil to rapidly degrade the insecticide and result in unsatisfactory control. Rotate insecticides, especially if poor performance occurs.

			(per 1000 row ft.)		
Wireworms	*carbofuran (Furadan)	15G	16-24 oz	2.4-3.6 oz	Apply in-furrow
	*chlorpyrifos (Lorsban)	15G	16 oz	2.4 oz	Band or in-furrow at planting.
			13.4 lbs/acre	2 lbs/acre	Broadcast ppi
	*ethoprop (Mocap)	15G	8 oz	1.2 oz	As for rootworm - 7" band only

* Restricted-use material

	*terbufos (Counter)	15G	8-16 oz	1.2-2.4 oz	As for rootworm - 2.4 oz in 7" band, 1.2 oz in furrow
	*phorate (Thimet)	20G	6 oz	1.2 oz	As for rootworm - Apply in 7" band only
			(per 1000 row ft.)		
White grubs	chlorpyrifos (Lorsban)	15G	8-16 oz	1.2-2.4 oz	Apply in-furrow
		4E	4 pts/acre	2 lbs/acre	Liquid, broadcdast and incorporate before planting.
	*phorate (Thimet)	20G	6-12 oz	1.2-2.4 oz	Apply in 7" band. Do not place in contact w/seed.
	*terbufos (Counter)	15G	16 oz	2.4 oz	Apply 1-2 lbs in 7"band or 1 lb in-furrow.
Seed-corn maggot, seed-corn beetle	chlorpyrifos (Lorsban)	50 SL	1/2 lb/bu	1 oz per bu.	Seed treatment only. Will not control wireworms.
	diazinon		See Label	1-1 1/2 oz per bu.	Use slurry treatment with cyclo-planters. Will not control wireworms.
	lindane		See Label	1 oz per bu.	Has some wireworm activity.

Seed treatments are strongly recommended for fields where manure was applied or where cover crops were recently plowed. Planting time applications of some corn rootworm insecticides (Counter, Dyfonate, Furadan and Lorsban) will also control these insects.

Stalk Borer	*fenvalerate (Pydrin)	2.4E	5.3-10.6 fl oz	.1 - .2	21 day phi. Treat at spike stage. If paraquat used, apply before corn emerges.

Insecticide treatment only reduces, not eliminates, stand loss. Long term elimination of in-field trouble spots requires control of perennial grassy weeds (e.g. quack grass). Corn rootworm insecticides, applied at planting, will not prevent stand loss.

* Restricted-use material

Hop Vine Borer	None Labelled				

Where repeated infestations occur, perimeter or spot treatments of grassy areas when corn is spiking and again two weeks later, using fenvalerate (Pydrin), permethrin (Ambush, Pounce) and flucythrinate (Payoff) can reduce stand loss. Long term elimination of infield trouble spots depends on control of perennial grassy weeds (e.g. quack grass, woolly cupgrass) and crop rotation.

Cutworms	carbaryl (Sevin)	5% Bait	20-40 lbs	1 - 2 lb	No time limitations. Carbaryl bait is more effective than sprays for cutworms except under dry conditions.
	chlorpyrifos (Lorsban)	4E	2 - 3 pt	1 - 1 1/2 lb	35 days forage or silage
	*fenvalerate (Pydrin)	2.4E	1/3 pt	0.1 lb	21 day phi
	*flucythrinate (Payoff)	2.5E	2 - 4 oz	0.04-0.08 lb	60 day phi
	*permethrin (Pounce, Ambush)	3.2E 2E	1/4 pt 6.4 fl oz }	0.1 lb	Apply before brown silk. Effective as rescue or planting time sprays.

Apply when 3% to 6% of the plants are cut.
NOTE: Lorsban 15G, Dyfonate 20G, Counter 15G, Furadan 15G and Mocap 15G are also registered for cutworm control or suppression. With these "at-planting" treatments, additional treatment may be required under moderate to heavy infestations. "Rescue" sprays provide more consistent and cost-effective control than do granules applied at planting. Surface treatments are usually ineffective against subterranean species (e.g. glassy cutworm).

Armyworm	carbaryl (Sevin)	All e.g. XLR	3-4 pts	1 1/2 - 2 lb	No time limitations.
	chlorpyrifos (Lorsban)	4E	1 pt	1/2 lb	35 day phi
	*fenvalerate (Pydrin)	2.4E	1/3 pt	1/10 lb	21 day phi
	*methomyl (Lannate, Nudrin)	All e.g. 90% SP	4.5-9oz	1/4 - 1/2 lb	3 day phi, forage
	*methyl parathion (Penncap-M)	2F	2 pts	1/2 lb	12 day phi
	*parathion	8E	1/4 - 3/8 pt	1/4 - 3/8 lb	12 day phi

* Restricted-use material

	*permethrin (Pounce, Ambush)	3.2E 2E	1/4 pt 4/10 pt	1/10 lb	12 day phi
	trichlorfon (Dylox)	80% SP	1 1/4 lb	1 lb	No time limitations.

Treat when more than 25% of the plants are infested with 2 or more larvae per plant. Higher rates are for large worms.

European corn borer (First & second brood)	<u>Bacillus thuringiensis</u> (Dipel)	10G	10 lb	1 lb	No time limitations
	carbaryl (Sevin)	All	e.g. XLR - 3 pts	1 1/2 lb	No time limitations.
	*carbofuran (Furadan)	15G 4F	6.7 lb 2 pts	1 lb	30 day phi forage or grain. No more than 2 foliar applications.
	chlorpyrifos (Lorsban)	15G 4E	6.7 lb 2 pts	1 lb	35 day grain, 14 days forage. Does not perform well with low gallonage.
	diazinon	14G	7.1 lb	1 lb	No time limitations grain, 10 day phi forage.
	*fonofos (Dyfonate)	20G	5 lb	1 lb	30 day phi.
	*methyl parathion (Penncap-M)	2E	1 - 2 pt	1/4-1/2 lb	12 day phi. Do not apply when foraging honeybees or granules are present.
	*permethrin (Pounce, Ambush)	3.2E 2E 1.5G	1/4 - 1/2 pt 6.4-12.8 fl oz 6.7 - 13.4 lbs	.1 - .2 lb	Spray or granules. Do not apply after brown silk stage.
	*phorate (Thimet)	20G	5 lb	1 lb	First generation only, 1 application, 30 day phi.

FIRST GENERATION: Treat when 50% of the plants are infested with fresh egg masses or show shotholing of whorl leaves. Thresholds may be lower for high-value seed fields (25%) or fields of exceptional yield potential (35%). Dissect several whorls to insure larvae are present and accessible to insecticides. Direct first-generation corn borer treatment into the whorl. Granules

* Restricted-use material

usually perform better than sprays.
SECOND GENERATION: Treat when 50% of the plants are infested with fresh egg masses or newly hatched larvae. Sprays should be applied with sufficient water to insure thorough coverage in the ear zone. Repeat applications usually are required. If fields are heavily infested, harvest early.
CENTER PIVOT APPLICATION: Sevin 80S, Lorsban 4E, Penncap-M, and Pounce 3.2E are labelled for center pivot application. Make sure your system is properly equipped. Follow label directions.
NOTE: Carbofuran (Furadan), fonofos (Dyfonate), or phorate (Thimet) should not be used in seed production fields to be detasseled by hand.

Aphids	chlorpyrifos (Lorsban)	4E	1 pt	1/2 lb	35 days to feeding
	diazinon	50% WP	2 lb	1 lb	No time limitations.
		4E	2 pts		
	*disulfoton (DiSyston)	5E	1/2 pt	1/2 lb	28 day phi
	malathion (Cythion)	5E	1 1/2 pt	1 lb	5 day phi
	*methomyl (Lannate)	All e.g. 90% SP	4 oz	1/4 lb	3 day phi
	*methyl parathion (Penncap-M)	2F	1 pt	1/4 lb	12 day phi. Aerial application only.
	*parathion	8E	1/4 pt	1/4 lb	12 day phi

Chemical control of corn leaf aphids is seldom economically justified. If 10% of the plants have more than 500 aphids per plant prior to tasseling during drought stress, treatment may pay.

Corn rootworm adults	carbaryl (Sevin)	All e.g.	80S - 1 1/4 lb	1 lb	No time limitations
	chlorpyrifos (Lorsban)	4E	1 pt	0.5 lb	35 day phi
	diazinon	50% WP	2 lbs	1 lb	No time limitations
		4E	2 pts		
	*fenvalerate (Pydrin)	2.4E	1/3 - 2/3 pt	0.1 - .2	21 day phi
	malathion (Cythion)	5E	1 1/2 pt	1 lb	5 day phi
	*methyl parathion (Penncap-M)	2F	1 - 2 pt	1/4 - 1/2 lb	12 day phi. Do not apply when foraging honeybees are present.
	*permethrin (Pounce	3.2E	1/4 - 1/2 pt	0.1 - .2 lb	Apply before brown silk

* Restricted-use material

	Ambush)	2E	6.4 - 12.8 oz}		
	phosmet (Imidan)	50% WP	1/2 - 1 lb	1/4 - 1/2 lb	14 day phi

Treat when beetles clip silks so as to prevent proper pollination. This usually occurs with populations of 10 or more beetles per plant on corn which has less than 50% silk emergence. Seed fields may benefit from treatment at lower levels of beetle infestation.

Grasshoppers	carbaryl (Sevin)	All e.g. XLR - 3 pts		1 1/2 lb	No time limitations.
	chlorpyrifos (Lorsban)	4E	12-16 oz	1/3 - 1/2 lb	No more than 3 parts per season
	*carbofuran (Furadan)	4F	4 - 8 oz	1/8 - 1/4 lb	30 day phi.
	diazinon	4E	2 pt	1/2 lb	No time limitations.
	dimethoate (Cygon)	4E	1 pt	1/2 lb	14 day phi.
	*fenvalerate (Pydrin)	2.4E	5.3 oz	1/10 lb	No time limitations.
	malathion (Cythion)	5E	1 1/2 pt	1 lb	5 day phi.
	*methyl parathion (Penncap-M)	2E	2 pt	1/2 lb	12 day phi.

Treat field margins early when grasshoppers are small.

CORN, SWEET (for processing) NOTE: See precaution on bees, p. __.

Insect	Insecticide	Formulation Recomm.	Formulation Product/acre	Dosage	Limitations
Corn rootworm	chlorpyrifos (Lorsban)				
	*ethoprop (Mocap)				
	*fonofos (Dyfonate)			See field corn.	
	*phorate (Thimet)				
	*terbufos (Counter)				
	trimethacarb (Broot)				

* Restricted-use material

Seed corn maggot	diazinon		See label	1/4 oz/bu	Seed treatment.
	chlorpyrifos (Lorsban)	50 SL	1 oz/bu	1/2 oz/bu	Slurry seed treatment.
Cutworms	carbaryl (Sevin)	5 or 20%	20 or 5 lb	2 lb. bait	No time limitations.
	chlorpyrifos (Lorsban)	4E	2 - 3 pts	1 - 1 1/2 lb	35 day phi.
	*fenvalerate (Pydrin)	2.4E	5 1/3 fl oz	0.1 lb	1 day phi.
	trichlorfon (Dylox)	4E	2 pts	1 lb	No time limitations. Not more than 3 applications/season.
	*permethrin (Pounce, Ambush)	3.2E 2E	4.0 fl oz 6.4 fl oz	0.1 lb	1 day phi.
Armyworm	carbaryl (Sevin)	All eg. XLR plus	3-4 pts	1 1/2 - 2 lbs	No time limitations. Not Sevin 4-oil.
	*fenvalerate (Pydrin)	2.4E	5 1/3 fl oz	0.1 lb	1 day phi. Do not exceed 2 lbs ai/A per season.
	malathion (Cythion, malathion)	5E	1 1/2 pts	1 lb	5 day phi.
	methomyl (Lannate, Nudrin)	90% SP	1/4-1/2 lb	4-7 oz	No time limitations. 3 days, forage. Note plant damage precaution in label.
	*permethrin (Ambush, Pounce)	2E 3.2E	6.4 fl oz 4 fl oz	0.1 lb	1 day phi. Not more than 6 applications.
	trichlorfon (Dylox)	4E	2 pts	1 lb	No time limitation. Not more than 3 applications/season.
	chlorpyrifos (Lorsban)	4E	1 pt	1/2 lb	35 day phi.
Aphids	diazinon	4E	1 pt	1/2 lb	No time limitations. Not Sevin 4-oil.
	malathion (Cythion)	5E	1 1/2 pt	1 lb	5 day phi
	*parathion (Penncap-M)	4E 2F	1/2 pt 1 pt }	1/4 lb	12 day phi

* Restricted-use material

European corn borer	*Bacillus thuringiensis* (Dipel)	10G	10 lbs	1 lb	No time limitations.
	carbaryl (Sevin)	All eg. XLR plus	2-4 pts	1 - 2 lbs	No time limitations. Not Sevin 4-oil. Sevin XLR is safe for honey bees.
	*carbofuran (Furadan)	4F	1 pt	1/2 lb	7 day phi. Apply weekly; no more than four applications. Do not enter field within 14 days without protective clothing. Machine harvest only. Do not graze or harvest stalk within 21 days.
	diazinon	14 G	10 1/2 lbs	1 1/2 lb	No time limitations. Do not feed treated folder for 10 days.
	*methomyl (Lannate Nudrin)	90% SP	1/2 lb	7 oz	No time limitations. 3 days, forage. Note plant damage precaution in label. Other formulations restricted.
	*methyl parathion (Penncap M)	2F	2 pts	1/2 lb	3 day phi (12 days, forage or grazing).
	*permethrin (Pounce Ambush)	3.2E 2E	4 - 8 fl oz 6.4-12.8 fl oz	0.1 - 0.2 lb.	1 day phi. Not more than 6 applications.
Corn earworm	carbaryl (Sevin)	All eg. XLR plus	3-4 pts	1 1/2 - 2 lbs	No time limitations. Not Sevin 4-oil.
	diazinon	4E	2-2 1/2 pts	1 - 1 1/4 lbs	No time limitations.
	*fenvalerate (Pydrin)	2.4E	5 1/3 fl oz	0.1 lb	1 day phi.
	*methomyl (Lannate, Nudrin)	90% SP	1/4-1/2 lb	5-7 oz	No time limitations. 3 days, forage. Note plant damage precaution in label. Other

* Restricted-use material

	Insecticide	Recomm.	Product/acre	Dosage	Limitations
					formulations are restricted use.
	*methyl parathion (Penncap M)	2F	2 pts	1/2 lb	3 day phi. 12 days, forage or grazing. Highly toxic to honey bees.
	*permethrin (Pounce, Ambush)	3.2 2E	4 - 8 fl oz 6.4-12.8 fl oz	0.1 - 0.2 lb	1 day phi. Not more than 6 applidcations.

SOYBEANS

Insect	Insecticide	Formulation Recomm.	Formulation Product/acre	Dosage	Limitations
Seed corn maggot	diazinon		See Label	0.7-1 oz per bu.	Seed treatment only.
Bean leaf beetle, flea beetles blister beetle	carbaryl (Sevin)	All	e.g. XLR - 2 pts	1 lb	No time limitations.
	chlorpyrifos (Lorsban)	4E	1 - 2 pts	1/2 - 1 lb	28 day phi
	*fenvalerate (Pydrin)	2.4E	5 1/3 fl oz	0.1 lb	21 day phi
	Treat when defoliation exceeds 50% during seedling stages, 25% during pod fill, or when pod feeding is extensive.				
Cutworms, armyworms	carbaryl (Sevin)	All	e.g. XLR - 3 pts	1 1/2 lb	No time limitations.
	chlorpyrifos (Lorsban)	4E	1 - 2 pts	1/2 - 1 lb	28 day phi
	*fenvalerate (Pydrin)	2.4E	5 1/3 fl oz	0.1 lb	21 day phi
	*permethrin (Ambush, Pounce)	2E 3.2E	6 1/2 or 4 fl oz	0.1 lb	60 day phi
	thiodicarb (Larvin)	3.2E	1 1/4-1 7/8 pt	1/2 - 3/4 lb	28 day phi. Do not feed forage to livestock.
Potato leafhoppers	carbaryl (Sevin)	All	e.g. XLR-2pts	1 lb	No limitations.
	*fenvalerate (Pydrin)	2.4E	2 2/3 fl oz	0.05 lb	21 day phi

* Restricted-use material

	malathion (Cythion)	5E	1 1/2 pt	1 lb	7 day phi
	*methyl parathion (Penncap-M)	2F	1/2 - 1 1/2 pt	1/4-3/4 lb	20 day phi
Green cloverworm	acephate (Orthene)	75W	2/3 lb	1/2 lb	14 day phi
	<u>Bacillus thuringiensis</u> (Dipel, Thuricide, Sok Bt, Clean Crop BT)				As labeled.
	carbaryl (Sevin)	All	e.g. XLR - 1 pt	1/2 lb	No limitations.
	chlorpyrifos (Lorsban)	4E	1/2 - 1 pt	1/4 - 1/2 lb	28 day phi
	dimethoate (Cygon)	4E	1/2 - 1 pt	1/4 - 1/2 lb	7 day phi
	*fenvalerate (Pydrin)	2.4E	2 2/3 fl oz	0.05 lb	21 day phi
	malathion (Cythion)	5E	1 1/2 pt	1 lb	No time limitation
	*permethrin (Ambush, Pounce)	2E 3.2E	3.2 fl oz 1/8 pt }	0.05 lb	60 day phi
	*methomyl (Lannate, Nudrin)	All	e.g. 1.8L-1pt	1/4 lb	14 day phi
	*methyl parathion (Penncap M)	2F	1 pt	1/2 lb	20 day phi
	thiodicarb (Larvin)	3.2E	5/8 - 1 pt	1/4 - 4/10 lb	28 day phi. Do not feed forage to livestock.
	Treat when defoliation exceeds 25% or when worms number more than 15 per foot of row during pod fill.				
Spider mites	carbophenothion (Trithion)	8E	1/2 pt	1/2 lb	7 day phi. Do not feed treated foliage.
	dimethoate (Cygon)	4E	1 pt	1/2 lb	21 day phi (5 days to feed livestock).
Grasshoppers	acephate (Orthene)	75W	3/8 - 3/4 lb	1/4 - 1/2 lb	14 day phi. Do not feed foliage.
	carbaryl (Sevin)	All	e.g. XLR - 3 pts.	1 1/2 lb	No limitations.
	chlorpyrifos (Lorsban)	4E	1/2 - 1 pt	1/4 - 1/2 lb	28 day phi
	dimethoate (Cygon, Defend)	4E	1/2 - 1 pt	1/4 - 1/2 lb	7 day phi

* Restricted-use material

*carbofuran (Furadan)	4F	1/4 - 1/2 pt	1/8 - 1/4	
*methyl parathion (Penncap M)	2F	1 - 3 pt	1/4 - 3/4	

SMALL GRAIN

Insect	Insecticide	Formulation Recomm.	Formulation Product/acre	Dosage	Limitations
Aphids	malathion	5E	1 1/2 pt	1 lb	7 day phi
	*methyl parathion	4E	1/2 pt	1/4 lb	12 day phi
	*methyl parathion	4E	3/4 - 1 pt	3/8 - 1/2 lb	15 day phi
	(Penncap M)	2F	1 1/2 - 2 pt		
	*parathion	8E	1/4 pt	1/4 lb	15 day phi
	*disulfoton (DiSyston)	8E	1/4 - 3/4 pt	1/4 - 3/4 lb	30 day phi, for wheat only, do not graze

Treatment most economical before heading with more than 25 aphids per 6" stem (15 greenbugs) or with 35 aphids/stem from 6" to boot. Do not treat after heading as there is no yield change.

Armyworm, cutworms	*methomyl	All			
	(Lannate, Nudrin)	e.g. 90% SP	3/8 - 3/4 lb	1/4 - 1/2 lb	7 day phi
	*parathion	8E	1/4 - 3/8 pt	1/4 - 3/8 lb	48 hour re-entry; 12 day phi
	*methyl parathion	4E	1 pt	1/2 lb	24 hour re-entry; 12 day phi
	(Penncap M)	2F	2 pt	1/2 lb	15 day phi
	trichlorfon (Dylox)	4E	2 pt	1 lb	21 day phi, maximum of 3 applications.

Treat when number of worms exceeds 5 per sq. ft. For armyworm control in non-crop land see p. 19.

Grasshoppers	*acephate (Orthene)	75W	1/4 lb	1/6 lb	Wheat only.
	*carbofuran (Furadan)	4F	1/4 - 1/2	1/8 - 1/4 lb	Wheat, oats, barley. Do not apply after heading.

* Restricted-use material

Insect	Insecticide	Recomm.	Product/acre	Dosage	Limitations
	dimethoate (Cygon)	4E	1/2 - 1	1/4 - 1/2 lb	Wheat only, 60 day phi.
	malathion	5E	1 1/2 pt	1 lb	7 day phi.
	*methyl parathion	4E	1 pt	1/2 lb	15 day phi.
	(Penncap M)	2F	2 pts		
	Treat when more than 8 per sq. yd. in field or more than 20 in margins.				
Wireworms	lindane			1 oz per bu.	Seed treatments only.

SUGARBEET

Insect	Insecticide	Formulation Recomm.	Product/acre	Dosage	Limitations
Webworm	carbaryl (Sevin) All	e.g. XLR plus-	3 pts	1 1/2 lb	14 day phi, tops.
	endosulfan (Thiodan)	3E	2 2/3 pts	1 lb	Do not feed tops.
	*parathion	8E	1/4 - 1/2 pt	1/4 - 1/2 lb	20 day phi
	trichlorfon (Dylox)	4E	2 pts	1 lb	14 day phi
	Treat when worms exceed 5 per sq. ft.				
Spider mites	carbophenothion (Trithion)	8E	1 1/2 pt	1 1/2 lb	7 day phi
	dimethoate (Cygon)	4E	1 pt	1/2 lb	7 day phi
	disulfoton (DiSyston)	8E	1 pt	1 lb	30 day phi
Cutworms	carbaryl (Sevin) All	e.g. XLR plus	4 pts	2 lb spray	14 day phi, tops, bait formulation preferred.
		e.g. 20% bait	50-100 lb	1 - 2 lb bait	
	chlorpyrifos	15G	8-16 oz/1000 row ft.	1.2-2.4 oz/ 1000 row ft.	Row treatment at planting time.
	(Lorsban)	4E	2 pts	1 lb	Broadcast foliar spray.
	trichlorfon (Dylox)	4E	2 pts	1 lb	14 day phi

* Restricted-use material

			(per 1000 row ft.)		
Root maggots	*aldicarb (Temik)	15G	6.5-9.5 oz 4.3 oz	1.2 oz = 1 lb in 40" rows	Apply in 2-4" band at planting and incorporate. Modified in-furrow.
	*carbofuran (Furadan)	15G	4.3-5.3 oz		Modified in-furrow
	chlorpyrifos (Lorsban)	15G	4.5-9 oz		In furrow treatment has activity against cutworms.
	diazinon	14G	4.7-9.4 oz	All same as above	Apply in 7" band or as a furrow treatment after seed is covered.
	*fonofos (Dyfonate)	20G	3.5-5.0 oz		Apply in 7" band and lightly incorporate. Do not place in contact with seed.
	*terbufos (Counter)	15G	4.5-9 oz		Apply in 7" band and lightly incorporate. Do not place in contact with seed.
Wireworms	*terbufos (Counter)	15G	4.5-9 oz/1000 row ft.		Banded in 7" band & incorporate.
	diazinon	14G	14.3-28.6 lb	2 - 4 lbs	Broadcast incorporated.
	*fonofos (Dyfonate)	20G	20 lb	4 lbs	Soil treatment preplant.
	lindane			1 oz per bu.	Seed treatment only.

SUNFLOWER

Insect	Insecticide	Formulation Recomm.	Formulation Product/acre	Dosage	Limitations
Wireworm	lindane			1-1 1/2 oz.	(2 3/4 oz DB green per bu.) seed treatment.
Cutworm	carbaryl (Sevin)	5 or 20%	20 or 5 lb	1 lb	Use 5% or 20% bait
	chlorpyrifos (Lorsban)	4E	2 pts	1 lb	Rescue treatment with as much water

* Restricted-use material

					as practical.
	*fenvalerate (Pydrin)	2.4E	5 1/3 fl oz	0.1 lb	
	Treat when there is more than 1 cutworm per 2 sq. ft. and before plant population goes below 75% of that recommended for area. Granular preventive treatments are not normally economical.				
Grasshoppers	carbaryl (Sevin) All	eg. XLR plus	2-3 pts	1 - 1 1/2 lb	60 day phi.
	*carbofuran (Furadan)	4F	1/4 - 1/2 pt	1/8 - 1/4 lb	28 day phi.
	chlorpyrifos (Lorsban)	4E	1 pt	1/2 lb	42 day phi.
	*fenvalerate (Pydrin)	2.4E	5 1/3-10 2/3 fl oz	0.1 - 0.2 lb	28 day phi.
	Treat before 25% defoliation at all plant stages, irrespective of insect stage.				
Sunflower beetle	*carbofuran (Furadan)	4F	1/4 - 1/2 pt	1/8 - 1/4 lb	Lower rates will provide 90% control.
	*fenvalerate	2.4E	1/2-1 1/2 fl oz.	.01-0.03 lb.	240-80 acres per gallon E
	Two adult sunflower beetles per 4 leaf plant or 15 SB larvae per plant will cause 25% or more defoliation. Do not exceed 25% defoliation. Ground application banded on row at last cultivation is most economical treatment.				
Thistle caterpillar	*fenvalerate (Pydrin)	2.4E	5 1/3 fl oz	0.1 lb	28 day phi
	carbaryl (Sevin)	XLR plus	2 - 4 pts	1 - 2 lbs	60 day phi prior to harvest
	Do not exceed 25% defoliation.				
Spotted and black sunflower stem weevil	Extensive trials in 1982-1985 suggest we do not improve yields enough to recommend treatment with soil systemic. However if action level of 1 adult spotted stem weevil per plant is exceeded, an aerial application of .1-.2 lb fenvalerate (Pydrin) may be worthwhile.				
	Action level = 1 adults per plant at 10 to 20 leaf stage. Droughty fields are most subject to stem weevil injury. Normal fields show no yield effects.				
Sunflower midge	Control with insecticides has been unsuccessful and attempts are not recommended. Use tolerant				

* Restricted-use material

sunflower hybrids (AD-MR-1953- Varietal Trials of Farm Crops) and delay planting until late May or early June.

Sunflower moth and banded sunflower moth larvae	*carbofuran (Furadan)	4F	1 pt	1/2 lb	28 day phi, 14 days before reentry.
	chlorpyrifos (Lorsban)	4E	1 pt	1/2 lb	42 day to harvest.
	*methyl parathion	4E	1 - 2 pt	1/2 - 1 lb	30 day phi.

DO NOT TREAT WHEN FORAGING BEES ARE IN FIELD.

Treat with 2 adult/sunflower moths per 5 plants or when banded moth is noticeable in field margins. Application when between 3 and 5 plants have first made florets extended (30-50% bloom) provides best control.

Sunflower seed weevil	*carbofuran (Furadan)	4F	1 pt	1/2 lb	28 day phi, 14 days before reentry.
	*fenvalerate (Pydrin)	2.4E	5 1/3-10 2/3	0.1-0.2 lb	30 day phi.
	*methyl parathion	4E	1 - 2 pt	1/2 - 1 lb	30 day phi.

DO NOT TREAT WHEN FORAGING BEES ARE IN FIELD.

Treat when between 3 and 5 of ten plants have a ring of female flowers in bloom. Action level for oil hybrids is 10 to 20 weevils per plant, and confection with 2 to 4 weevils per plant. Respray if action level is exceeded.

* Restricted-use material

SUNFLOWER BEETLE (SB) CONTROL

Sunflower beetle numbers were low in 1985 and as a result Minnesota growers probably received no economic benefit from any controls for this insect. Because we have found control of SB to be so easy and inexpensive our 1985 SB control trials were designed to use the least dosage of each insecticide that we believed would provide 90% or better control at 96 hours posttreatment. Hence you may be a little surprised at the dosages reported in Table 1 and there may be little relationship to labeled rates.

The age distribution of the larval population treated was as follows:

Instar	% of population
1	9.5
2	15.4
3	29.6
4	45.6
	100.1

Numbers were not high (see pretreatment counts) but the age distribution was such that mature lavae constituted nearly 1/2 the population at treatment time. Pretreatment counts were not significantly different between treatments.

Table 1. Sunflower beetle control - Minnesota 1985 (Preliminary data)

Insecticide & formulation	Dosage in lb ai/A	Number live larvae per 10 plants		
		Pretreat	24h post	120h post
Ambush 2E	.01	113	.6	0
Cymbush 3E	.005	99	.6	0
Scout .3E	.01	110	1.0	3.0
Ammo 2.5E	.005	117	1.6	0
Pydrin 2.4E	.005	84	3.6	0
Capture 2E	.01	87	3.6	0
Larvin 3.2F	.4	94	4.0	0
Thiodan 3E	.4	105	4.0	0
Penncap M 2F	.4	89	4.6	0
Capture 2E	.005	127	5.2	0
Furadan 4F	.125	115	5.2	0
Zectran 2E	.4	70	5.2	0
Spur 2E	.0025	86	5.2	.5
Baythroid 2E	.0025	95	5.2	1.5
Supracide 2E	.25	112	5.6	0
Karate 1E	.001	121	6.6	1.0
Pounce 3.2E	.01	111	7.0	0
Capture 2E	.001	103	7.6	0
Sevin XLR 4F	.75	96	7.6	0

Pay-Off 2.5E	.001	84	9.0	0
Lorsban 4E	.4	107	10.0	0
Scout .3E	.005	104	11.0	10.0
Untreated -	-	81	27.6	7.5
Untreated -	-	83	48.0	10.3

In our final analysis we will convert individual plots to % reduction, transform the data and compare % control. The individual insecticides will rearrange themselves somewhat in this process. However it is fairly clear that excellent control of SB larvae was obtained by most insecticides at the dosages we selected. It is possible to design control methods that will reduce cost in view of these low dosages.

THE VALUE OF STICKER FOR LARVAL SUNFLOWER BEETLE (SB) CONTROL

Questions had been directed toward us regarding the value of sticker-extender in enhancing Pydrin persistance for the control of sunflower beetle. Two separate trials were run one of whose preliminary data is reported in Table 2.

The sticker-extender used was Bond, a synthetic laytex type, at the rate of 4 oz per acre. Two insecticides, Pydrin and Karate were used at labeled dosage and at 1/10, 1/100, and 1/1000 labeled dosages. Counts of live larvae were collected pretreatment and 24 and 120 hours posttreatment.

Table 2. A comparison of sunflower beetle larval control using Pydrin and Karate with and without sticker. Minnesota 1985.

		Number live larvae/10 plants					
Insecticide &	Dosage in	Pretreat		24h post		120h post	
formulation	lb ai/A	w/Bond	w/o Bond	w/Bond	w/o Bond	w/Bond	w/o Bond
Pydrin 2.4E	.1	79	57	3.0	1.0	0	0
	.01	95	63	3.6	5.0	0	.3
	.001	71	66	17.0	9.6	1.8	1.3
	.0001	72	79	21.0	6.6	32.3	20.8
Karate 1E	.02	81	88	1.0	4.0	0	0
	.002	77	74	2.0	1.5	.5	0
	.0002	91	60	31.6	3.6	0	.5
	.00002	74	72	24.0	29.6	8.3	12.8
Untreated	-	77	81	24.0	32.1	29.3	24.3

Even without statistical analysis one would have to conclude that Bond adds nothing in addition to the usual excellent performance of either Pydrin or Karate against SB larvae.

FURADAN SOIL TREATMENT VS FOLIARS FOR SUNFLOWER INSECT CONTROL
D. Noetzel, H. Ford, D. Warnes and J. Wiersma.

Soil systemic plots were established at 10 locations in 1985. These sites extended from Lamberton in the south to Lancaster and Greenbush in the north. Excess rainfall destroyed plots at two locations. Of the remaining eight sites yield data from 5 locations are summarized in Table 3.

I compared the high and low labeled rates of Furadan 15G & 4F. We included a 1/2 rate soil applied of the lowest labeled dosage (ie .65 lb ai/A) as I was interested in seeing how that method of application performed vis a vis a foliar against adult beetle feeding. Treatment 7 is our recommended dosage of Pydrin for larval beetle control usually applied at the 16-20 leaf stage. Treatment 8 was a split treatment (both 0.1 lb ai/A Pydrin) one early to act against stem weevil, and the second to provide larval beetle control. Treatment 9 used Furadan .65 lb per acre as a foliar for adult beetle control on 2 leaf plants followed by our recommended rate of Pydrin (0.01 lb ai/A) against larval beetle at the 16 leaf stage.

Table 3. Furadan soil treatment vs foliars for sunflower insect (sunflower beetle, stem weevil, etc.).

Treatment & formulation	Dosage in oz/1000 row ft. or lb ai/A	Yield in lb/A by treatment at 5 different locations					Average yield in lb/acre
		A	B	C	D	E	
1) Furadan 15G	16	2617	2644	1753	1388	1043	1889
2) " "	8	2803	2832	1947	1331	1201	2023
3) " "	4	2655	2668	2028	1192	1023	1913
4) Furadan 4F	5 fl oz	2806	2982	1884	1621	1060	2071
5) " "	2.5 fl oz	2505	2839	1825	1197	865	1846
6) " "	1.25 fl oz	2866	2718	1872	1562	1030	2010
7) Pydrin 2.4E	.01	2870	2612	1638	1406	1113	1928
8) " "	0.1	2644	2850	1922	1406	856	1936
9) Furadan 4F	.65	2624	2800	1765	1283	1151	1925
Pydrin 2.4E	.01						
10) Untreated		2596	2689	1554	1305	1041	1837
Average		2698	2764	1819	1369	1038	

Both formulations of Furadan are labeled as soil applied systemics for sunflower beetle, stem weevil and grasshopper control. We observed 30 - 40% defoliation in the untreated plots at locations D and E. Stem cross sections showed stem weevil injury to be much below levels where we observed breakage to be present in 1984. Thus I have not included injury readings in this preliminary summary.

The data suggest that under a wide range of environmental conditions including insects and weather, we did not derive any yield benefit for Furadan use against the sunflower insect complex in Minnesota in 1985. We probably received no benefits from foliars in 1985 either.

In summary in Minnesota in 1984 and 1985 and based on replicated comparisons at seventeen locations statewide we did not obtain a single significant yield benefit through the use of Furadan as a soil systemic in sunflower. It is quite likely that this was also the case for growers those years as well.

The major reason for the lack of yield benefit was the lack of damage by insects which Furadan has the potential to control. Where one makes an insecticide application commitment at planting time there must be a predictable average annual yield benefit that exceeds the cost of chemical and application, in this case $10 - $15/acre. If sunflower seed is $.08 per pound then yield differences must be 125 to 185 pounds per acre annually or 250 to 370 lbs every other year in order for the grower to break even. In Minnesota it is extremely unlikely this is occurring.

BANDED SUNFLOWER MOTH (BSM) CONTROL

Banded sunflower moth (BSM) numbers declined dramatically at Lamberton as well as throughout our major sunflower producing areas. Indeed numbers of most sunflower insects declined probably in response to the unusually moist and cool conditions. Even so our highest banded moth infestations may have been in southern Minnesota this year.

The late season and number of trials have not permitted analysis of these data in time for this publication. However preliminary Lamberton data produced in cooperation with Harlan Ford Southwest Experiment Station Agronomist is reported (see Table 4).

Table 4. Banded sunflower moth (BSM) control Lamberton 1985
D. Noetzel and H. Ford.

Treatment & formulation	Dosage in lb ai/A	Average number damaged seeds per 100
Capture 2E	.04	1.8
Karate 1E	.025	2.8
Ammo 2.5E	.05	2.8
Baythroid 2E	.05	3.0
Penncap M 2F	.5	3.0
Furadan 15G	1.3 (soil)	
+ Baythroid 2E	.05	3.5
Furadan 15G	2.6 (soil)	
+ Baythroid 2E	.05	3.8
Karate 1E	.01	4.3
Cymbush 3E	.05	4.3
Pounce 3.2E	.1	4.5
Pydrin 2.4E	.1	5.0
Ambush 2E	.1	5.0
Lorsban (HF) 4E	.5	5.3
Furadan 4F	.5	5.3
Baythroid 2E	.025	5.3
Capture 2E	.01	5.5
Pay-Off 2.5E	.05	5.5
Scout .3E	.019	5.8
Scout .3E	.015	7.8
Thiodan 3E	1.0	8.0

Dipel -	2 pts	10.5
Furadan 15G	1.3 (soil)	12.3
Furadan 15G	2.6 (soil)	13.0
Untreated -	-	13.0

We would not expect soil treatments to affect BSM and they did not. We included these in order to provide an additional site for statewide soil systemic comparisons reported elsewhere.

There are no surprises in these BSM control data. The synthetic pyrethroids are clearly outperforming our older insecticides against BSM. Capture (biphenthrin) a new pyrethroid from FMC appears to be as effective as Karate, Ammo (cypermethrin) and Baythroid (cyfluthrin). Of our presently labeled materials methyl parathion is at the top of the list in effectiveness and cost.

BANDED SUNFLOWER MOTH (BSM) CONTROL - FIELD MARGIN AS ENTIRE FIELD TREATMENT

We sampled a paired set of sunflower fields in 1985 to determine how field border treatment perform. Pretreatment counts of adult moths suggested similar pretreatment populations with field 1 (field completely treated) having slightly more females than field 2 (border and edge treatments). There were two border applications based on visual counts of adults of 0.1 Pydrin each. A single application consisted of two plane passes on the field edge and one pass on adjoining roadside, etc. The whole field application was made at 20% bloom using .75 lb methyl parathion per acre.

Table 5. Control of banded sunflower moth-whole field (field 1) vs border applications (field 2). Minnesota 1985.

Feet from field edge	Number infested seeds per 200 seeds	
	Field 1	Field 2
25	12.0	28.0
100	1.5	.75
200	.75	9.0
Center	0	11.5

Replicated 1/1000 acre samples were taken from four locations in each field. Heads were dried, a pre-threshing sample removed and BSM damaged seeds counted. Yields were also taken but are not reported here.

We would suggest a conservative use of these data as a single comparison of paired fields has some shortcomings. However the data are consistent with what we have reported in the past. Both fields 1 & 2 had economic levels of BSM if sunflower seed yields exceeded 1500 lbs per acre. There is a "border effect" as indicated by greater damage in field edges at both locations. The border effect remained following both treatments but did not appear to extend beyond 100 feet (40 rows) into the field. Whole field treatment (field 1), assuming 1500 lb yields, gave an economic return to the grower while border treatment did not. It is not clear whether these differences are due to possible poor performance of Pydrin against this insect. However other methods of evaluating border applications suggest them to be inadequate.

STATUS OF CHANGES IN PESTICIDE REGULATIONS

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The Minnesota Department of Agriculture (MDA) is at this time considering proposed changes to the existing Minnesota Pesticide Control Law. The Minnesota Pesticide Control Law was enacted in 1976 and designates the MDA as the lead state agency relating to the control of pesticides. The Law has provided a broad regulatory base relating to pesticide control. Since the enaction of this legislation, times have changed with regard to problems associated with pesticide use and the way the general public perceives the question of pesticides.

In order to better deal with new concerns and issues, the Department has drafted changes in the Law relating to the total pesticide regulatory process. Areas affected would include:

1) State level jurisdiction of pesticide control;
2) Pesticide registration;
3) Licensing of restricted use pesticide dealers;
4) Licensing of commercial, noncommercial, and structural pest control applicators;
5) Private applicator certification;
6) Use, storage, handling, and disposal of pesticides and pesticide containers, pesticide application equipment;
7) Incidents involving pesticides;

Let's elaborate on each of these particular areas of pesticide regulatory requirements:

1) **State level jurisdiction of pesticide control:** State regulators and the user industry is being challenged throughout the United States with regard to local (county, city, township) ordinances that impact on existing state and federal requirements. These ordinances vary in form and content, but overall attempt to place restrictions on pesticide use that are above and beyond existing requirements. Private industry is placed in a precarious position of having to know, understand, and comply with a multitude of varied regulatory requirements. It would be very difficult to operate effectively if local units of government start implementing a variety of different requirements. The MDA is of the opinion that pesticide regulation should be addressed as a statewide concern, and that within Minnesota pesticides should be regulated in a uniform manner at the state level of government. Some examples of local ordinances include:

1) City of St. Paul
2) City of Moorhead

2) **Pesticide registration:** Every pesticide must be registered with the MDA prior to being distributed or used within Minnesota. Major areas of change would relate to the submission of Material Safety Data Sheets (MSDS) for each pesticide product at the time of registration and the requirement of a fee placed on the registration of a pesticide to meet a special local need.

3) **Licensing of restricted use pesticide dealers:** Any person distributing a restricted use pesticide to an ultimate user must obtain a restricted use pesticide dealer's license. The applicant must successfully complete and pass a closed book, monitored examination administered by the MDA to prove that he is knowledgeable in this area. Once licensed, the dealer must record each sale of restricted use pesticide on forms provided by the MDA. Each sale would required the recording of the following information: date of sale; certification card number; customer name, address; pesticide purchased, amount; target site to be treated; and pest to be controlled. At present the MDA licenses 475 dealers, thus enabling them to sell restricted use pesticides. This program area has major importance within the MDA and we feel that the number of licensed dealers will more than double within the next few years. Why the expansion? The United States Environmental Protection Agency (U.S. EPA) is in the process of classifying more pesticides as restricted use. Many of these pesticides are high use products within Minnesota. Examples of pesticides recently classified restricted use would be fumigants and corn rootworm materials. Thus, more agricultural chemical dealers will be needing this license allowing them to sell restricted use pesticides.

4) **Commercial, noncommercial, and structural pest control applicators:** Two areas of proposed change relating to commercial and noncommercial applicators would be A) testing requirements, and B) who needs to be licensed.

Who needs to be licensed? At present, the owner or manager of a business could meet the licensing requirement and purchase addtional identification cards in his name for use by employees within the business. Under the proposed changes of the existing Law, this would no longer be allowed. Every person applying pesticides for hire will now have to meet licensing requirements as stipulated in the proposed draft of the Minnesota Pesticide Control Law. Each individual must meet initial licensing and renewal requirements.

In addition, the examinations used for initial licensing will be changed based on the development of new reference materials and will be closed book.

5) **Private applicator certification:** In past years the State of Minnesota had a loose system relating to certification of private applicators wanting to use restricted use pesticides. The system was somewhat effective for the main reason that Minnesota farmers had relatively no need to use those few products classified as restricted use. With the increased activity of the U.S. EPA in the area of classification of restricted use pesticides, MDA had to propose changes relating to private applicator certification. Private applicators wanting to use restricted use pesticides must attend and be knowledgeable in the content of training sponsored by the University of Minnesota Extension Service conducted at the local county level **or** successfully complete and pass a correspondence study course. Once the private applicator has satisfactorily completed one of these options, the applicant will be issued a private applicator certification card with a permanent card number. This card and number will allow the farmer to purchase restricted use pesticides from licensed dealers. At the time of the sale the private applicator must provide the dealer with proof that he indeed has met the certification requirements.

6) **Use, storage, handling and disposal of pesticides, pesticide containers, and application equipment:** MDA is proposing a general strengthening of regulatory requirements dealing in this area. Some of the main points covered relate to the following:

A) **Pesticide misuse:** No person may use, store, handle or dispose of a pesticide or container in a manner inconsistent with labeling or so as to endanger the environment.

B) **Disposal procedures:** All pesticides, pesticide rinsate and containers, must be disposed of in accordance with state and federal law.

C) **Pesticide use:** All pesticides must be applied in accordance with product label and in a manner which will not cause unreasonable adverse effects on the environment.

D) **Chemigation:** Protection of groundwater when pesticides are going to be applied through an irrigation system.

E) **Posting:** Require posting of sites treated with pesticides having labeling restrictions relating to a re-entry interval.

F) **Display and storage:** Pesticides must be stored separated from food, feed, seed, livestock remedies, drugs, and other products so as to prevent contamination of those products.

G) **Bulk pesticide storage:** Persons storing bulk pesticides in containers of rated capacity of 500 gallons or more must receive written approval from the MDA and provide a means of containment.

7) **Incidents:** Persons controlling a pesticide at the time of an incident must notify the MDA. The person responsible must take corrective action to minimize or abate the release of the pesticide(s) into the environment. The MDA may take remedial actions to control or correct the conditions involved in an incident and may seek reimbursement for any costs incurred for actions taken.

The above are some of the changes being considered by the Minnesota Department of Agriculture with regard to regulatory requirements relating to pesticides in Minnesota. Further details may be secured by contacting the Minnesota Department of Agriculture, Agronomy Services Division.

NEW AND PROBLEM WEEDS IN MINNESOTA

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Abstract

Almum grass (Sorghum almum), prickly smartweed (Polygonum bungeanum Turcz.) and atrazine resistant common lambsquarters (Chenopodium album L.) are three weed species which have recently been found in southern Minnesota.

Almum grass, a perennial grass native to Africa, grows as an annual in Minnesota. It is found in Redwood, Fillmore, Wabasha, Freeborn, Watonwan, and Lyon counties, and is most prevalent near Plainview in Wabasha county. It is a tall growing (6 to 10 feet) member of the grass family (Graminea) which strongly resembles domestic sorghums. Unlike domestic sorghum, Almum grass develops short, red rhizomes which grow profusely out from the main stalk. The seed is red to black in color and very shiny.

Prickly smartweed, an annual smartweed, resembles Pennsylvania smartweed (P. pensylvanicum L.) and ladysthumb (P. persicaria L.) in general growth habit and form. The flowers on prickly smartweed are more crimson than either of the other two species and it has destinctive protruding spines scattered along the stem. It has been identified in Yellow Medicine, Lyon, Brown, Martin, Blue Earth, Faribault and Waseca counties.

Atrazine resistant common lambsquarters has been identified in Goodhue, Olmsted and Fillmore counties. It is morphologically identical to atrazine susceptible common lambsquarters and is positively identified only after noting the efficacy of a high rate of atrazine on the plant.

Small Grain and Sunflower
Weed Control Update - 1985

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Broadleaf weeds, foxtails, and wild oats continue to cause yield losses in most of the small grain fields in the state. Control of these weeds is important to maximize yields. A combination of cultural and chemical weed control is needed for an effective weed control program. Small grains should be seeded as early in the season as possible so the cool season small grain crop can compete effectively with weeds. Normal height wheat varieties are more competitive with weeds than semidwarf varieties, and barley is more competitive with weeds than wheat. Seeding tall wheat or barley can reduce yield losses due to weeds and may increase the effectiveness of herbicide treatments. Timely application of the appropriate herbicides is needed for effective weed control. Extension Folder AG-FO-0771, "Weed Control in Small Grains," included in this paper, can help you plan an effective and economical weed control program.

Weeds can cause substantial yield losses in sunflower as sunflower does not develop ground cover rapidly enough to prevent weeds from becoming established. However, most weeds can effectively be controlled in sunflower by a combination of cultural, mechanical, and chemical weed control methods. Extension Folder, AG-FS-0920, "Weed Control in Sunflower," included in this paper, can help you plan an effective and economical weed control program. Although there are many herbicides available for weed control in sunflower, wild mustard remains a problem. Assert (AC222, 293) is an experimental herbicide being developed by American Cyanamid for postemergence control of wild oats and wild mustard in wheat, barley, and sunflower. Because wild mustard is such a serious problem in sunflower, a section 18-Emergency Exemption has been requested for 1986. If the EPA approves this request, Minnesota farmers would be allowed to use Assert for wild mustard control in sunflowers before it is officially registered for this use. The use rate will probably be 0.38 lb/A. Research at the University of Minnesota has shown that sunflower tolerance and wild mustard control at this rate of Assert are excellent.

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WEED CONTROL IN SMALL GRAINS

Effective weed control in field crops can usually be accomplished with a combination of cultural, mechanical, and chemical practices. In row crops, tillage can be an integral part of weed control. However, in close-sown small grain crops, tillage is not feasible, except that early germinating weeds may be destroyed by tillage during seedbed preparation. Therefore, more dependence on cultural and chemical weed control practices is needed.

Cultural Practices

Sowing clean seed at an adequate seeding rate will help to reduce weed populations in small grains. Also, small grain must be seeded early so the cool season small grain crop can compete effectively with weeds. Early spring seeding reduces warm season annual grass weed problems, such as foxtail, that are increased by late seeding. However, early spring seeding does not help to reduce wild oats or most annual or perennial weed problems. These weeds must be controlled with herbicides because delayed seeding with repeated tillage to control these weeds results in reduced small grain yields.

Perennial Weed Control

Most herbicides available for use in small grains will control annual weeds at safe usage rates for small grain, but will not control established perennials. Perennial weeds such as Canada thistle or quackgrass should be controlled prior to (preferably the year before) seeding small grains. Glyphosate (Roundup) may be used to control most perennials prior to seeding small grain. (See herbicide label.) Also, many perennial broad-leaf weeds can be controlled with 2,4-D or dicamba (Banvel) in the fall prior to seeding small grain.

Herbicides for Weed Control in Small Grains

(This folder summarizes herbicide treatments controlling weeds in small grians. For additional information, refer to herbicide labels.)

Herbicide use on small grains in Minnesota is extensive, with more than 75 percent of the acreage treated annually. However, several weeds are not being effectively controlled (Table 1).

Herbicide Combinations

The weed control of many postemergence herbicides often is increased when applied to fields already treated with a preemergence or preplant herbicide. Combinations of certain postemergence or preemergence may give better weed control than the use of the individual herbicide alone. For example, a tank mix of bromoxynil and MCPA gives greater wild mustard control than either of these herbicides alone. However, loss of weed control or increased crop injury may also result from the use of certain herbicides in combination. For example, the mixing of diclofop (Hoelon) and 2,4-D will decrease the grass control of diclofop. Herbicide combinations should be used with caution until experience or research has shown that the herbicide is effective and safe.

All agricultural pesticides which are tank mixed should be registered for use as a mixture by the Environmental Protection Agency. However, you may tank mix any agricultural pesticides if all pesticides in the mixture are registered for use in the crop by the Environmental Protection Agency. However, you must assume liability for crop injury, inadequate weed control, and illegal herbicide residues.

Spring Wheat, Durum Wheat, Oats, and Barley

If small grain is not underseeded with a legume, more herbicides and higher rates may be used (Table 2). Table 3 includes herbicides that can be used when legumes are underseeded.

Winter Wheat and Rye

For winter wheat and rye, apply most weed control chemicals in the spring. Apply triallate, bromoxynil or chlorsulfuron to winter wheat, not rye, in either fall or spring (Table 2).

Consider Effectiveness, Crop Tolerance, and Cost

Accurately identify the weed problem and then select the most effective herbicide (Table 4). Consider crop tolerance as well as effectiveness of the herbicide (Table 5). For example, wheat and oats are more tolerant to dicamba (Banvel) than barley. Herbicide cost should also be a consideration when planning a weed control program. Many herbicides will control the same weeds; however, one herbicide may be more economical than the other. Accurate calibration of your spray equipment will also help control weed control costs and increase the effectiveness of the herbicides used. Under application of herbicides often result in poor weed control, and overapplication increases your costs and may result in grain injury. See Table 6 which lists common names and trade names of herbicides and their formulations.

Table 1. The ten most prevalent weeds in small grain in Minnesota with current weed control practices (1979 survey - 1,021 fields sampled).

Weed species	% fields infested	Weed density infested fields (plants/m^2)
Green foxtail	60	35
Common lambsquarters	56	9
Smartweed sp.	55	7
Wild buckwheat	53	7
Yellow foxtail	47	42
Pigweed sp.	44	6
Canada thistle	39	2
Wild oat	30	6
Wild mustard	28	3
Ragweed sp.	27	10

Table 2. Herbicide choices for use in durum, winter or spring wheat, oats, barley, and rye with no underseeded legumes.

Herbicide	Active ingredient, lb/A or (formulation/A)	Remarks
No-Till or Minimum Till		
chlorsulfuron (Glean)	.016 to .05 (.33 to .5 oz)	Controls broadleaves and grasses, except wild oats. Apply during fallow in the fall or sping prior to seeding wheat. **Do not use on soils over pH 7.5. See rotational crop restrictions on the label that are required due to carryover. Do not use on rye.**
glyphosate (Roundup)	.19 to .75 (.5 to 2 pts)	Controls emerged grass and broadleaf weeds with no soil residual. Apply prior to grain emergence. Add surfactant to lower herbicide rates. Avoid spray drift.
Labeled) mixtures*		
dicamba (Banvel)	(.12 to .25)	Improves control of emerged broadleaf weeds when low glyphosate rates used.
2,4-D	(.25 to .5)	Improves control of emerged braodleaf weeds when low glyphosate rates used.
paraquat (Paraquat Plus, Gramoxone)	.25 to .5 (1 to 2 pts)	Controls emerged grasses and broadleaf weeds with no soil residual. Apply prior to grain emergence. Add surfactant. Restricted Use Pesticide.
Preplant Incorporated or Preemergence		
chlorsulfuron (Glean)	.008 to .02 (.16 to .5 oz)	For broadleaf weeds and grasses except wild oats in winter or spring wheat and barley only. Apply in fall or sping. Use shallow tillage only after application. **Do not use on soils over pH 7.5. See label for rotational crop restrictions due to carryover.**
diallate (Avadex)	1.25 (1.25 qts)	For wild oat control in barley. Apply preplant incorporated in the fall or in the spring after seeding barley. Restricted Use Pesticide.
triallate (Far-Go EC) (Far-Go Gran)	1 to 1.5 (1 to 1.5 qts) (10 to 15 lbs)	For wild oat control in durum, winter or spring wheat and barley applied fall or spring before or after seeding. Use higher rate on barley only.
trifluralin (Treflan) (Treflan 10G)	.5 to .75 (1 to 1.5 pts) (5 to 7.5 lbs)	For annual grasses, except wild oats and some broadleaves in durum or spring wheat and barley. Apply fall, granules perferred, or postplant spring, liquid formulation preferred. Must be incorporated. Apply beginning Sept. 1 for all labeled fall applications.
Labeled mixture*		
triallate (Far-Go)	1	Adds wild oat control in spring applications to durum or sping wheat and barley.

Table 2. continued

Herbicide	Active ingredient, lb/A or (formulation/A)	Remarks
Postemergence		
barban	.25 to .75	Postemergence control of wild oats in all wheats and barley. Apply to wild oats in the 2-leaf stage.
(Carbyne 2EC)	(1 to 1.5 pts)	
Labeled mixtures*		
bromoxynil (Buctril, Brominal)	.25	Adds control of emerged annual broadleaf weeds.
chlorsulfuron (Glean)	.008 to .024	Adds broadleaf weed control. See label for rotational crop restrictions.
diclofop (Hoelon)	.25 to .5	Improves wild oat and adds annual grass control in wheat and barley. Restricted Use Pesticide.
difenzoquat (Avenge)	.25 to .5	Improves wild oat control.
bromoxynil	.25 to .5	Postemergence control of most small annual broadleaf weeds in wheat, oats, and barley. May also be applied to winter wheat and rye in the fall for control of winter annuals.
(Brominal ME4)	(.5 to 1 pt)	
(Buctril)	(1 to 2 pts)	
Labeled mixtures*		
barban (Carbyne)	.38	Adds postemergence control of wild oats in the 2-leaf stage in wheat and barley.
chlorsulfuron (Glean)	.01 to .02	Adds residual weed control in wheat and barley. See rotational crop restriction on label.
dicamba (Banvel)	.06 to .12	Improves broadleaf weed control in all wheats and oats. May injure barley.
diclofop (Hoelon)	.75 to 1.25	Adds wild oat and foxtail control in wheat and barley. Restricted Use Pesticide.
difenzoquat (Avenge)	.62 to 1	Adds wild oat control in barley and wheat. See label for wheat variety tolerance.
MCPA	.25 to .5	Improves broadleaf weed control, especially perennials.
2,4-D	.25 to .5	Improves broadleaf weed control, especially perennials.
chlorsulfuron	.008 to .02	Controls broadleaf weeds ans suppresses grasses, except wild oats in durum, winter or spring wheat, barley and spring oats. See label for restrictions on Vic durum. **Do not use on soils over pH 7.5. See label for rotational crop restrictions due to carryover.**
(Glean)	(.16 to .5 oz)	
Labeled mixtures*		
barban (Carbyne)	.25 to .75	Adds wild oat control in all wheats and barley. Apply to wild oats in the 2-leaf stage.
bromoxynil (Brominal, Buctril)	.25	Improves broadleaf weed control. Apply postemergence to small weeds.
dicamba (Banvel)	.06 to .12	Improves broadleaf weed control in durum, spring or winter wheat.
difenzoquat (Avenge)	.62 to 1	Adds wild oat control in durum or spring wheat and barley. See difenzoquat label for wheat variety clearances.
diclofop (Hoelon)	?	For use on winter wheat only. **See rotational crop and pH restrictions on the label.**
dicamba	.06 to .12	Controls many broadleaf weeds including wild buckwheat and smartweeds in durum, winter or spring wheat and oats. See label for crop growth stage restrictions. Used most frequently in tank mixes. Lower dicamba rates used in tank mixes. Avoid spray drift onto nearby sensitive plants.
(Banvel)	(.12 to .25 pt)	
(Banvel II)	(.25 to .5 pt)	
Labeled mixtures*		
chlorsulfuron (Glean)	.008 to .02	Adds residual weed control and annual grass suppression, except wild oats. **See rotational crop and pH restrictions on the label.**

Table 2. continued

Herbicide	Active ingredient, lb/A or (formulation/A)	Remarks
MCPA (Mondak)	.25 to .38	Improves broadleaf weed control, especially wild mustard.
2,4-D	.25 to .38	Improves broadleaf weed control, especially mustard. Do not use on oats.
diclofop	.75 to 1.25	Controls wild oat and other annual grasses in durum, winter or spring wheat and barley.
(Hoelon)	(2 to 3.3 pts)	Use lower rate in barley. Restricted Use Pesticide.
Labeled mixtures*		
bromoxynil (Buctril, Brominal)	.37 to .5	Adds broadleaf weed control.
chlorsulfuron (Glean)	?	For use on winter wheat only. **See rotational crop and pH restrictions on the label.**
difenzoquat	.62 to 1	For wild oat control only in durum, winter or spring wheat and barley. See difenzoquat
(Avenge)	(2.5 to 4 pts)	label for use limitations on wheat varieties.
Labeled mixtures*		
bromoxynil	.375 to .5	Adds broadleaf weed control.
chlorsulfuron (Glean)	.008 to .02	Adds broadleaf control and grass suppression. **See label for rotational crop and soil pH restrictions.**
MCPA	.25 to 1	Adds broadleaf weed control.
2,4-D	.25 to .75	Adds broadleaf weed control.
MCPA		Controls many broadleaf weeds in all small grains. Apply from 2-leaf to early boot stage
(Amines)	.25 to .66	of crop. Safer to grain than 2,4-D or dicamba. Use lower rates of the ester formula-
(Esters)	.16 to .5	tions. Weak on wild buckwheat and smartweeds. Avoid drift onto nearby sensitive crops.
Labeled mixtures*		
bromoxynil (Buctril, Brominal)	.25 to .38	Improves control of wild buckwheat and smartweeds.
dicamba (Banvel, Banvel II)	.12	Improves control of wild buckwheat and smartweeds.
difenzoquat (Avenge)	?	Adds wild oat control.
propanil + MCPA pre-mix (Stampede CM)	.94 to .25	For early postemergence control of foxtail and some broadleaf weeds. Apply at 2-5 leaf stage of spring wheat and 2-4 leaf stage of durum and barley. Temporary yellowing of grain may occur.
2,4-D		Controls many broadleaf weeds in all small grains but weak on wild buckwheat and smart
(Amines)	.25 to .66	weeds. Oats more sensitive to 2,4-D. Use lower rates of ester formulations. Avoid
(Ester)	.16 to .5	drift onto nearby sensitive crops.
Labeled mixtures*		
bromoxynil (Buctril, Brominal)	.25 to .38	Improves control of wild buckwheat and smartweeds.
dicamba (Banvel, Banvel II)	.12	Improves control of wild buckwheat and smartweeds. Barley may be injured.
picloram (Tordon)	.015 to .023	Improves control of wild buckwheat in wheat and barley. Picloram is persistent and will carry over in the soil. Do not rotate other crops on treated grain fields. Not cleared for use on durum wheat. Restricted Use Pesticide.
difenzoquat (Avenge)	?	Adds wild oat control.

* Follow label directions and precautions of all products in a mixture.

Table 3. Herbicide choices for weed control in spring sown small grains underseeded with legumes.

Herbicide	Active ingredient, lb/A or (formulation/A)	Remarks
diallate (Avadex)	1.25 (1.25 qts)	Use on barley only for wild oat control. Apply preplant incorporated in the fall or in the spring after the barley is seeded. Restricted Use Pesticide.
MCPA (Amine)	.12 to .25	Postemergence control of broadleaf weeds. Legumes injured but usually recover. Use on heavy stands of broadleaf weeds. Do not use on sweet clover. Canopy of grain or weeds reduces legume injury.
2,4-D (Amine)	.12 to .25	Postemergence control of broadleaf weeds. Legumes may be severely injured so use only on heavy infestations of broadleaf weeds. Do not use on sweet clover. Canopy of grain or weeds reduces legume injury.

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

	barban (Carbyne)	**bromoxynil** (Brominal/Buctril)	**chlorsulfuron** (Glean)	**diallate** (Avadex)	**dicamba** (Banvel)	**diclofop** (Hoelon)	**difenzoquat** (Avenge)	**MCPA** (amine or ester)	**picloram** (Tordon 22K)	**propanil + MCPA ester** (Stampede CM)	**triallate** (Far-Go)	**trifluralin** (Treflan)	**2,4-D** (amine or ester)
Grasses													
Barnyard grass	N	N	G	N	N	G	N	N	N	G	N	G	N
Green foxtail	N	N	G	N	N	G	N	N	N	G	N	G	N
Wild oats	G	N	P	G	N	G	G	N	N	P	G	P	N
Yellow foxtail	N	N	G	N	N	F	N	N	N	G	N	G	N
Broadleaves													
Canada thistle	N	N	G	N	G	N	N	F	P	F	N	N	F
Cocklebur	N	G	G	N	G	N	N	G	F	F	N	N	G
Common ragweed	N	G	G	N	G	N	N	G	F	F	N	N	G
Eastern black nightshade	N	G	N	N	G	N	N	G	F	F	N	N	G
Field bindweed	N	P	F	N	G	N	N	G	P	P	N	N	G
Giant ragweed	N	G	G	N	G	N	N	G	F	F	N	N	G
Kochia	N	G	G	N	G	N	N	G	F	F	N	F	G
Lambsquarters	N	G	G	N	G	N	N	G	F	G	N	F	G
Marshelder	N	G	---	N	G	N	N	G	F	F	N	P	G
Perennial sowthistle	N	N	F	N	G	N	N	F	P	F	N	N	F
Pigweed	N	G	G	N	G	N	N	G	F	G	N	G	G
Russian thistle	N	G	G	N	F	N	N	N	F	P	N	F	F
Smartweed (annuals)	N	G	G	N	G	N	N	F	P	F	N	P	F
Sunflower	N	G	G	N	G	N	N	F	G	F	N	N	G
Wild buckwheat	N	G	G	N	G	N	N	F	G	G	N	P	P
Wild mustard	N	F	G	N	P	N	N	G	P	G	N	N	G

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

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

[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.

Table 6. Herbicide names and formulations used in small grains.

Common name	Trade name	Concentration and commercial formulation[1]
barban	Carbyne, Carbyne 2 EC	1 lb./gal.L, 2 lb./gal.L
bromoxynil	Buctril, Brominal ME4	2 lb./gal.L, 4 lb./gal.L
bromoxynil and MCPA	Bronate,	2 + 2 lb./gal. MCPA + bromoxynil
	Brominal Plus	3 + 3 lb./gal. MCPA + bromoxynil L
chlorsulfuron	Glean	75% DF
diallate	Avadex	4 lb./gal.L, 10% G
dicamba + MCPA	MonDak	1.25 lb./gal. dicamba + 2.50 lb./gal. MCPA L
diclofop	Hoelon	3 lb./gal.L
difenzoquat	Avenge	2 lb./gal.L
MCPA	Several, mixtures	See product label.
picloram	Tordon 22K	2 lb./gal.L
propanil + MCPA (pre-mix)	Stampede CM	3 lb./gal.L (propanil) + 0.85 lb./gal.L (MCPA)
triallate	Far-Go	4 lb./gal.L, 10% G
trifluralin	Treflan	4 lb./gal.L, 10% G
2,4-D	Several	See product label.

[1] G = granular; L = liquid; DF = dry flowable.

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

The information given in this publication is for educational purposes only. Reference to commercial products or trade names is made with the understanding that no discrimination is intended and no endorsement by the Minnesota Agricultural Extension Service is implied.

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Agricultural Chemicals
Beverly R. Durgan
Extension Agronomist-Weeds

WEED CONTROL IN SUNFLOWERS

Cultural Methods of Weed Control

Harrowing and cultivation are important methods of weed control in sunflowers. Sunflowers normally do not emerge for ten days to two weeks after planting, so weeds frequently emerge before the sunflowers do. Many weeds can be killed by shallow tillage by a spike tooth or coil spring harrow about one week after planting. Because sunflower seedlings are strongly rooted, these implements and others such as the weeder and rotary hoe can also be used to kill weeds after the sunflowers emerge. However, the tillage implements must be properly adjusted, and tillage after sunflower emergence should be delayed until the sunflower seedlings have two or more leaves. Harrowing may normally be done several times if weeds continue to emerge and if field conditions are suitable. Weeds missed by early tillage may be controlled by cultivation between the rows. However, for adequate weed control, chemical weed control is usually necessary in addition to tillage (Table 1).

Chemical Weed Control in Sunflowers

This fact sheet summarizes chemicals for weed control in sunflowers. For additional information, refer to the product label.

Proper herbicide application and favorable soil and weather conditions are necessary for optimum herbicide performance. The soil should be dry enough to be easily worked, not wet or cloddy, to ensure maximum mixing with soil particles during preplant herbicide incorporation. Adequate soil moisture is needed to ensure good herbicide activity. Dry conditions at the point where the germinating weed seedlings contacts the herbicide will reduce effectiveness.

There are a number of herbicides that are effective for annual grass control in sunflowers. Five of these, EPTC (Eptam), trifluralin (Treflan), fluchloralin (Basalin), ethalfluralin (Sonalan), and pendimethalin (Prowl) must be applied before planting. These herbicides should be worked into the top two to three inches of soil, twice at right angles with a disk, field cultivator, or similar implement at sufficient speed to ensure mixing the herbicide thoroughly with the soil. Trifluralin and EPTC are also labeled for late fall applications. Alachlor (Lasso) can be applied by either preplanting with shallow soil incorporation or preemergence. Preplant incorporation of alachlor has given more constant weed control. All of these grass herbicides control some broadleaf weeds such as pigweed and lambsquarter under favorable conditions.

Chloramben is primarily a broadleaf herbicide, but it also has activity on many annual grasses. Application may be preplant incorporated or preemergence. With preemergence applications, at least 0.5 inches of rainfall at least ten days after application is needed for effective weed control. Excessive rainfall can move the herbicide below the zone of weed seed germination, especially on coarse-textured soils. If a preemergence application of chloramben is followed by dry weather and weed seedlings start to emerge, then an early shallow cultivation will result in more consistent weed control.

Several of these herbicides are cleared for use in tank mixtures for preplanting incorporation use. These include: trifluralin + EPTC, trifluralin + chloramben, EPTC + chloramben, pendimethalin + chloramben, ethalfluralin + chloramben, and ethalfluralin + EPTC. In addition, chloramben is cleared as a preemergence treatment over trifluralin, pendimethalin and ethalfluralin, and the mixture of pendimethalin and chloramben may be applied preemergence. Also, alachlor and chloramben are cleared for use as a preemergence tank mixture.

Postemergence applications of sethoxydim (Poast) will control most annual grasses including wild oat and will also suppress perennial grasses. Sunflowers have good tolerance for sethoxydim. Caution: Though registration of sethoxydim for use in sunflowers is expected for the 1986 season, it has not been received as of October 1985.

Weed identification should be the first step in effective weed control. After weeds are identified, select the best herbicide for control (Table 2). If sunflower fields have several weed species or hard-to-control weeds, a combination of two herbicides is often more effective than one (Table 1). Be sure to compare herbicide prices. Make sure you are getting the best weed control possible at the best price.

Herbicide costs can be reduced by applying herbicides in a band over the sunflower row. However, timely cultivation is then needed to control weeds between sunflower rows. Accurate calibration of your spray equipment can also help reduce herbicide costs. Under application of a herbicide is costly due to ineffective weed control, and applying more herbicide than necessary not only adds to your herbicide costs, but may also result in sunflower injury.

Wild Oat Control in Sunflowers

Tillage effectively controls many early germinating wild oat seedlings, both before and after sunflower emergence. Wild oat not controlled by tillage may be controlled with barban or sethoxydim.

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

Table 1. Herbicides for weed control in sunflowers.

Herbicide	Active ingredient(lb/A) or (formulation/A)[1]	Time of application	Remarks
Paraquat (Ortho Paraquat + Plus/ Gramoxone)	0.5 (1 qt)	Preplant or anytime prior to crop emergence	Restricted use herbicide.
EPTC (Eptam/Genep)	2 to 3 (2.3 to 3.4 pt)	Preplant incorporated-Spring	Weak on wild mustard.
	4 to 4.5 (4.5 to 5.25 pt 7E, 40 to 45 lb 10G)	Fall incorporated after October 15 until freeze-up	Weak on wild mustard.
Trifluaralin (Treflan)	0.5 to 1 (1 to 2 pt 4E)	Preplant incorporated	No wild mustard control.
	0.5 to 1 (5 to 10 lb 10G)	Preplant incorporated, fall after September 1.	No wild mustard control.
Pendimethalin (Prowl)	1 to 1.5 (2 to 3 pt)	Preplant incorporated	Use the higher rate on fine textured soils. Do not feed treated forage to livestock. Weak on wild mustard.
Pendimethalin (Prowl) + EPTC (Eptam/Genep)	1 to 1.5 (1 to 3 pts) + 2 (2.3 pt)	Fall incorporated when soil temperature is 45° F or less.	Rate dependent on soil type. See label.
Fluchloralin (Basalin)	0.5 to 1.5 (1 to 3 pt)	Preplant incorporated	No wild mustard control. Do not feed treated forage to livestock.
Alachlor	3 (3 qt, 20 lb 15G)	Preplant incorporated or preemergence	Weak on wild mustard. Do not graze or feed forage.
Chloramben (Amiben)	2 to 3 (several formulations)	Preplant incorporated or preemergence	Inconsistent wild mustard control. Do not graze or feed treated forage.
Ethalfluralin (Sonalan)	0.57 = 1.12 (1-1/2 - 3 pts/A)	Preplant incorporated	Do not graze or feed forage. No wild mustard control. May carryover to next year's crop. See label for re-cropping restrictions.

Table 1. (continued)

Herbicide	Active ingredient(lb/A) or (formulation/A)[1]	Time of application	Remarks
Chloramben (Amiben) + other herbicides	2 + appropriate rate of other herbicide	Preplant incorporated or preemergence	Other herbicides include EPTC, pendimethalin, trifluralin, alachlor, and ethalfluralin. Do not feed treated forage to livestock.
Barban (Carbyne)	0.375 (1.5 pt of 2 EC)	When wild oat is in the two-leaf stage but within 30 days after sunflower emergence.	Apply in 5-10 gallons of water/A using sufficient pressure (min. 45 psi) to break spray to small droplets. Do not let livestock graze treated fields until after harvest.
Sethoxydim (Poast)	0.1 - 0.4 (0.5 - 2.0 pt)	Postemergence	Clearance expected but not received as of October 1985. Always apply with oil concentrate at 1 qt/A.
Paraquat (Ortho Paraquat + Plus/ Gramoxone)	0.25 to 0.5 (0.5 to 1 qt)	For use as a desiccant. Apply when back side of sunflower heads are yellow and bracts turning brown.	Use on oilseeds only. Apply with X-77 at 0.25% v/v. Restricted use herbicide.
Sodium Chlorate (Several suppliers)	4.5 to 6 (1.5 to 2 gal)	For use as a desiccant. Apply when back side of sunflower heads are yellow and bracts are turning brown.	For use on confectionary and oilseed varieties. Thorough coverage of plant is essential.

[1] Use the low rate for coarse textured soils, intermediate rate for medium textured soils, and high rate for fine textured soils.

Table 3. Herbicide names and formulations used in sunflowers.

Common Name	Trade Name	Concentration and Commercial Formulations[1]
Alachlor	Lasso	4 lb/gal L, 15% G
Barban	Carbyne	1 or 2 lb/gal L
Chloramben	Amiben	1.8 lb/gal L, 10% G, 75% DS
EPTC	Eptam/Genep	7 lb/gal L, 10% G
Ethalfluralin	Sonalan	3 lb/gal L
Fluchloralin	Basalin	4 lb/gal L
Paraquat	Ortho Paraquat+Plus/Gramoxone	2 lb/gal L
Pendimethalin	Prowl	4 lb/gal L
Sethoxydim	Poast	1.5 lb/gal L
Sodium Chlorate	Several	3 lb/gal L
Trifluralin	Treflan	4 lb/gal L, 10% G

[1] L = Liquid, G = Granular, DS = Dry Soluble

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

The information given in this publication is for educational purposes only. Reference to commercial products or trade names is made with the understanding that no discrimination is intended and no endorsement by the Minnesota Agricultural Extension service is implied.

Table 2. Effectiveness of herbicides for weed control in sunflowers.[1]

	Alachlor (Lasso)	Barban (Carbyne)	Chloramben (Amiben)	EPTC (Eptam/Genep)	Ethalfluralin (Sonalan)	Fluchloralin (Basalin)	Pendimethalin (Prowl)	Sethoxydim (Poast)	Trifluralin (Treflan)
Type of Application[2]:	PRE/PPI	POST	PRE/PPI	PPI	PPI	PPI	PPI	POST	PPI
Sunflower tolerance	G	G	G	G	G	G	G	G	G
Grasses									
Giant foxtail	G	N	G	G	G	G	G	G	G
Green and yellow foxtail	G	N	G	G	G	G	G	G	G
Wild oats	P	G	P	F	F	P	P	G	P
Broadleaves									
Cocklebur	N	N	P	P	N	N	N	N	N
Common lambsquarters	F	N	G	F	G	G	G	N	G
Common ragweed	P	N	G	F	N	N	P	N	N
Kochia	P	N	G	F	G	G	G	N	G
Pigweed sp.	G	N	G	F	G	G	G	N	G
Smartweed sp.	P	N	G	P	P	P	F	N	P
Wild mustard	P	N	F	P	N	N	P	N	N

1 G = Good, F = Fair, P = Poor, N = No control.

2 PRE = Preemergence, PPI = Preplant incorporated, POST = Postemergence.

WEED CONTROL PROGRESS IN CORN

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A copy of "Weed Control in Corn" AG-FO-0892, 1986 revision, is included herein immediately behind this abstract. Changes in the 1986 revision are minor. Because of the corn injury reports from Bladex used early postemergence on corn, the discussion in the text was rewritten to place increased emphasis on the possibility of such injury occurring and to more clearly define the conditions giving rise to the corn injury. There were no EPA registrations of new herbicides for inclusion in the 1986 revision but registration of tridiphane (Tandem) seems probable. A brief paragraph describing Tandem usage as an early postemergence treatment in tank mixes with Bladex or atrazine plus oil for annual grass control has been added to the text of "Weed Control in Corn."

EPA has initiated a special review of cyanazine (Bladex) because there is evidence that it has caused birth defects in laboratory animals. There is concern also that Bladex can move through soil and contaminate groundwater. New Bladex label precautions require that applicators wear a face shields and protective clothing while handling Bladex to reduce exposure. There will be additional precautionary statements on the label advising against applying Bladex to soils that are very permeable or where the water table is close to the surface. After the 1986 season on September 1, 1986, Bladex will be reclassified as a "Restricted Use Pesticide" and, thereafter, those who apply it will have to be certified applicators.

Research was continued at four locations in 1985 to further evaluate the safety of early postemergence applications of 0.5 lb/A of dicamba (Banvel) to corn and to evaluate its effectiveness in velvetleaf control at one location. At Morris, MN, dicamba caused a leaf roll response that was very evident in late June and early July. However, this symptom disappeared later in the season and no yield effects were apparent. At the St. Paul location, dicamba applications of 0.5 and 1.0 lb/A made on 5 days over a 10-day period to corn from 2 inches to 6 inches tall caused no apparent injury to the corn. These treatments did not result in complete eliminiation of velvetleaf but suppressed growth so that surviving velvetleaf plants were less than 4 inches tall in late September. This indicates that it is possible to obtain satisfactory, season long, velvetleaf control in corn with the early postemergence Banvel treatment using the 0.5 lb/A rate.

Research efforts were continued in an attempt to develop a treatment for postemergence control of larger annual grasses in corn. Drop nozzle applications of sethoxydim (Poast) to corn 24 inches tall gave fair to good grass control but resulted in corn stand reductions due to deterioration of the lower internodes in some experiments. Applications made with more precision and to taller corn may be required to avoid corn injury from Poast.

Alachlor (Lasso) and linuron (Lorox) continue to be under Special Review by the U.S. Environmental Protection Agency. However, no changes in usage are expected for 1986. These Special Reviews should be completed and final rulings made on the future use of these herbicides before the 1987 growing season.

WEED CONTROL IN CORN

Richard Behrens, Extension Agronomist--Weeds

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. There are many opportunities for reducing the costs of weed control in corn. Knowing the weed species that are present and selecting herbicide(s) with a high level of effectiveness on those weeds at the lowest cost per acre can result in substantial savings. Using band applications supplemented with cultivation is also a money-saving option to consider. Reducing herbicide rates below those recommended increases the possibility of costly failures in weed control. However, applying herbicides at rates higher than those suggested adds unnecessarily to your weed control costs, and may result in corn injury. Applying herbicides at the prescribed time and rate with a carefully calibrated applicator provides the best return on your herbicide investment.

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

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

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

Acetamides--alachlor, metolachlor, propachlor
Benzoic acids--dicamba
Dinitroaniline--pendimethalin
Others--bentazon, bromoxynil
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.

No-Till or Minimum Till

With no-till or minimum till, weed problems may become worse. Winter annual, biennial, and perennial weeds that are destroyed or greatly weakened by conventional tillage survive and grow vigorously early in the spring, long before the corn is planted. Special herbicide treatments may be necessary to control or suppress these weeds. Glyphosate (Roundup) and paraquat (Paraquat Plus, Gramoxone) are very active, non-selective herbicides that will control all emerged weeds. These herbicides have no residual soil activity but can be tank-mixed with a number of herbicides that will provide residual weed control (see table 2). Atrazine and cyanazine (Bladex) may be used early preplant to control weed seedlings, but are relatively ineffective on larger annual, biennial, and perennial weeds. The use of liquid nitrogen or fertilizer as carrier in preplant or preemergence applications of cyanazine improves its burndown effectiveness on larger emerged weeds. If herbicides are applied several weeks or more before corn planting, a postplanting herbicide treatment may be required to provide adequate residual weed control.

Preplanting Applications

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

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

EPTC (Eradicane, Eradicane Extra) and butylate (Sutan +, Genate Plus) applied preplant incorporated give excellent control of annual grasses and some annual broadleaf weeds, but do not control other broadleafs or most biennials and perennials (see table 1). Both chemicals are effective on nutsedge. EPTC may be used for quackgrass control but trial results have been inconsistent. EPTC is the most effective soil-applied herbicide for wild proso millet and woolly cupgrass control. Following repeated annual use for several years, the weed control effectiveness of EPTC may decline due to an increased rate of EPTC breakdown in the soil.

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

Mixtures of butylate or EPTC (Eradicane) and atrazine or cyanazine (Bladex) applied preplanting and incorporated have controlled both annual grasses and broadleafs. These mixtures improve broadleaf control compared to butylate or EPTC alone. Cyanazine does not carry over to the following year, and the lower rate of atrazine used in the mixtures reduces carryover problems from atrazine compared to those caused by the higher rates when atrazine is applied alone.

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-pounds-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 that 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. Weed control is not as good under dry conditions as under moderate to heavy rainfall. Within the suggested rates of 1.2 to 4.75 pounds per acre, the high rates are required on soils higher in organic matter and finer-textured soils. Corn injury may occur on sandy soils or when maximum rates are used on heavier soils.

> NOTICE: Cyanazine (Bladex) is now undergoing a special review by the U.S. Environmental Protection Agency (EPA) because of concern over the results of a laboratory study on animal birth defects that was inconclusive plus evidence suggesting cyanazine contamination of ground water. In this special review, the EPA is re-examining the health and safety risks and benefits of cyanazine use and will eventually develop recommendations for its future use. As of November, 1985, it seems probable that cyanazine will continue to be available for use by Minnesota farmers during 1986 without label changes. However, it is probable that cyanazine will be labeled as a "Restricted use Pesticide" before the 1987 season.

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

Alachlor (Lasso) and metolachlor (Dual) control annual grasses in corn. Both chemicals also have given good control of redroot pigweed, but control of other broadleafs has been erratic. Preemergence applications have controlled nutsedge on coarse soils that are low in organic matter, but on finer-textured, dark soils, preplanting incorporated applications have controlled nutsedge better than preemergence treatments. Corn has good tolerance to alachlor and metolachlor. Suggested rates for alachlor are 2 to 4 pounds per acre in the liquid formulation and 2.45 to 3.9 pounds per acre in the granular formuation (Lasso II). Metolachlor is labeled for preemergence application at 1.5 to 3 pounds per acre in the liquid and granular formulations. Corn, soybeans, sorghum, root crops, potatoes, pod crops, buckwheat, or small grains may be grown the year after using metolachlor. Any crop may be grown the year following alachlor use.

> NOTICE: Alachlor (Lasso) is now undergoing a special review by the U.S. Environmental Protection Agency (EPA) because tests show that tumors are caused when high levels of alachlor are fed daily to laboratory animals over long periods of time. In this special review, the EPA is re-examining all health and safety tests and product benefits from alachlor usage. Recommendations from the EPA on future uses of alachlor will be developed based on their estimates of these risks and benefits. As of November, 1985, it seems probable that alachlor will continue to be available during 1986 for use by Minnesota farmers.

Pendimethalin (Prowl) may be used alone at 3/4 to 2 pounds per acre or in mixtures at 3/4 to 1 1/2 pounds per acre for preemergence control of most annual grassy weeds and some broadleafs 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 applications of pendimethalin, especially on sandy soils. In tank mixes with dicamba, do not use 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.

> NOTICE: Linuron (Lorox) is now undergoing a special review by the U.S. Environmental Protection Agency (EPA) because tests show that tumors may occur when high levels of linuron are fed daily to laboratory animals over long periods of time. In this special review, the EPA is re-examining all health and safety tests and product benefits from linuron usage. Recommendations from the EPA on future uses of linuron will be developed based on their estimates of these risks and benefits. As of November, 1985, it seems probable that linuron will continue to be available during 1986 for use by Minnesota farmers.

At 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 1/2 to 1 1/2 pounds per acre of each chemical according to soil type. Corn tolerance to this mixture is not as great as to atrazine alone. Corn injury may occur on coarse-textured soils that have low organic matter content.

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

Using mixtures of linuron and propachlor or alachlor reduces the potential for corn injury compared to using linuron alone since lower rates of linuron are used. These mixtures control broadleafs better than propachlor or alachlor alone. Suggested rates are 1 to 1 1/2 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

Postemergence sprays of atrazine effectively control most annual weeds in corn. Broad-leaved weed control is especially good. Grass control is less consistent. It is important to apply early post-emergence treatments at the proper time or results may be poor. Apply atrazine while the weeds are less than 1 1/2 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 1/4 to 1/2 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 applications with oil are 1.2 pounds per acre for broadleafs and 2 pounds per care 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 and 90DF) is effective on annual grasses and broadleafs as an early post-emergence herbicide. The 4L formulation is not cleared postemergence because corn leaf burn is more likely to occur. Cyanazine is cleared for use through the 4-leaf stage of corn and before weeds are more than 1 1/2 inches tall. Pigweed and lambsquarters have shown some tolerance. Vegetable oils or surfactants added to improve weed control effectiveness under dry conditions increase the potential for corn injury and have resulted in severe corn leaf kill and stand reduction if heavy rains or dews and cool temperature occur soon after application. Smaller corn, spike to 2-leaf stage, is less likely to be injured than larger corn, 3- to 4-leaf stage.

Under dry weather conditions add an emulsible vegetable oil or a at their recommended rates. Do not use petroleum-based crop oils because corn leaf kill and stand reductions may occur. Do not add vegetable oils or surfactants under moist, rainy conditions because corn injury may occur. Do not apply this treatment under cold, wet conditions or to weather-stressed corn. Corn yellowing, leaf kill and stunting may result from this treatment, particularly if cold, adverse growing conditions occur after application. Extreme or extended cold and wet conditions following treatment may result in reduced corn stands. Do not use cyanazine on corn grown for seed. Any rotational crop may be planted in the fall or spring following the cyanazine treatment.

Tridiphane (Tandem), when added to postemergence applications of atrazine plus oil or cyanazine (Bladex) has frequently improved the control of small annual grasses in trials at several locations over several years. Caution: EPA clearance is expected before the 1986 growing season but has not been received as of November, 1985.

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

Alachlor (Lasso) may be applied postemergence in a mixture with dicamba (Banvel) to corn less than 3 inches tall. Alachlor or metolachlor (Dual) may be applied with atrazine on corn that is no more than 5 inches tall to control weeds in the 2-leaf stage or smaller. Propachlor (Ramrod) alone or mixed with atrazine may be applied after corn has emerged to control grasses up to the 2-leaf stage. Annual grass control may be less consistent in these postemergence applications than that from preemergence applications.

Pendimethalin (Prowl) in mixtures with atrazine or cyanazine (wettable powder or dispersible granule) may be applied after corn emergence, but not later than when corn is in the 4-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 greatly improves the control of proso millet and woolly cupgrass. However, corn leaf burn and stand reductions are possible if cool, wet weather occurs soon after treatment. Applications to corn in the spike to 2-leaf stage are safer but weed control effectiveness is best if the weeds have emerged.

Bromoxynil (Brominal, Buctril) applied at 1/4 pound per acre as an early postemergence spray controls some annual broadleaved weeds, including annual smartweeds, wild buckwheat, cocklebur, kochia, common lambsquarters, pigweed, common ragweed, Russian thistle, wild sunflower, and wild mustard. Bromoxynil does not control grasses or perennial weeds. To be most effective, bromoxynil must be applied when weeds have 2 to 4 leaves and corn is less than 6 inches tall. Corn leaf burn may occur, especially under conditions of high temperature or high humidity. Follow specific label information for bromoxynil use in tank mixes with 2,4-D or atrazine.

Postemergence Applications

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

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

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

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 1/2 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 1/2 to 1 pound per acre after the dough stage if necessary, but it is more beneficial to control weeds earlier.

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

Dicamba may be used in corn at 1/8 to 1/2 pound per acre, either alone or in mixtures with 2,4-D amine at 1/4 to 1/2 pound per acre. Do not use dicamba at 1/2 pound per acre after the corn is 5 inches tall. The lower rate of dicamba has given satisfactory weed control with less crop effect than the higher rate. Applications can be made until corn is 2 feet tall or until 15 days before tassel emergence, whichever occurs first. Do not use on corn grown for seed. Later applications, especially when corn is tasseling, may result in poor kernel set. Use drops after corn is 8 inches tall. Do not use additives with dicamba.

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

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

Applications are not recommended at temperatures above 85° F. Reduce spray and vapor drift effects on soybeans 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 made 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 1 1/2 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.

The information given in this publication is for educational purposes only. Reference to commercial products or trade names is made with the understanding that no discrimination is intended and no endorsement by the Minnesota Agricultural Extension Service is implied.

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

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

	PREPLANTING							PREEMERGENCE								POSTEMERGENCE								
	alachlor (Lasso)	metolachlor (Dual)	atrazine + metolachlor (Bicep)	butylate (Sutan +)	EPTC (Eradicane, Eradicane Extra)	cyanazine (Bladex)	atrazine (AAtrex, others)	alachlor (Lasso)	atrazine (AAtrex, others)	atrazine + metolachlor (Bicep)	dicamba (Banvel)	metolachlor (Dual)	propachlor (Ramrod)	linuron (Lorox)	cyanazine (Bladex)	2-4-D	dicamba (Banvel)	atrazine and oil	cyanazine (Bladex)	bentazon (Basagran)	bromoxynil (Buctril, Brominal)	bentazon + atrazine (Laddok)	pendimethalin + atrazine (Prowl + atrazine)	pendimethalin + cyanazine (Prowl + Bladex 80W)
CORN TOLERANCE	G	G	G	G	G	F	G	G	G	G	F	G	G	F	F	F	G	G	F	G	G	G	F/G	F
GRASSES																								
Giant & robust foxtail	G	G	G	G	G	F/G	F	G	F	G	P	G	G	F	F/G	N	N	F	F	N	N	F	G	G
Green foxtail	G	G	G	G	G	G	G	G	G	G	P	G	G	F	G	N	N	G	G	N	N	F	G	G
Yellow foxtail	G	G	G	G	G	G	G	G	G	G	P	G	G	F	G	N	N	G	G	N	N	F	G	G
Barnyardgrass	G	G	G	G	G	F	F	G	F	G	P	G	F	F	F	N	N	F	F	N	N	F	G	G
Crabgrass	G	G	G	G	G	F/G	P	G	P	G	P	G	G	F	F/G	N	N	P	F	N	N	P	F/G	G
Panicum	G	G	G	G	G	F	P	G	P	G	P	G	F	F	F	N	N	P	F	N	N	P	F/G	G
Nutsedge	G	G	G	G	G	P	P	F	P	F	N	F	F	P	P	N	N	F	P	G	N	G	P	P
Sandbur	F	F	F	G	G	F	F	F	F	G	P	F	P	–	F	P	P	F/G	F	P	N	P	F	F/G
Quackgrass	N	N	P	N	F	P	G	N	G	P	N	N	N	N	P	N	N	G	P	N	N	P	P	P
Woolly cupgrass	G	G	G	F	G	P	P	G	P	G	P	G	F	P	P	N	N	F	F	N	N	P	F	G
Proso millet	F	F	F	F	F/G	P/F	P	F	P	F	P	F	F	P	P/F	N	N	P	P/F	N	N	P	F	G
Wild oats	P	P	G	F	F	F	G	P	G	G	N	P	P	P	F	N	N	G	F	N	N	G	G	G
BROADLEAFS																								
Buffalobur	P	P	P	F	G	P	P	P	P	P	P	P	P	P	P	P	P	G	F	P	G	G	G	F
Cocklebur	N	N	F	P	P	F	F	N	F	F	F	N	P	F	F	G	G	G	F	G	G	G	G	F
Kochia	P	P	G	P	F	G	G	P	G	G	F	P	P	F	G	F	G	G	G	–	G	G	G	G
Lambsquarters	F/P	F/P	G	P	F/G	G	G	F/P	G	G	G	F/P	P	G	G	G	G	G	G	F	G	G	G	G
Mustard	P	P	G	P	P	G	G	P	G	G	G	P	P	G	G	G	F	G	G	G	G	G	G	G
Eastern black nightshade	F	F	G	F	F	G	G	G	G	G	F	G	P	P	G	F	F	G	G	P	G	G	G	G
Pigweed	G	G	G	F	F	F	G	G	G	G	G	G	F	G	F	G	G	G	F	P	G	G	G	F
Ragweed	P	P	G	P	F	G	G	P	G	G	G	P	P	G	G	G	G	G	G	G	G	G	G	G
Smartweed	P	P	G	P	P	G	G	P	G	G	G	P	P	G	G	P	G	G	G	G	G	G	G	G
Velvetleaf	P	P	F	F	F	F	F	P	F	F	F	P	P	F	F	G	G	F	F	G	G	G	G	G
Wild sunflower	P	P	F	P	P	F	F	P	F	F	F	P	P	F	F	F	G	G	F	G	G	G	G	G
Canada thistle	N	N	P	N	N	P	P	N	P	P	N	N	N	N	P	F	G	F	P	F	F	F	P	P
Jerusalem artichoke	N	N	P	N	N	P	P	N	P	P	P	N	N	P	P	G	G	P	P	P	N	P	P	P
American germander	N	N	P	P	F	P	P	N	P	P	P	N	N	P	P	P	P	G	F	P	N	F	F	F

[1] G = good, F = fair, P = poor, N = none, – = insufficient information.

Table 2. Herbicide choices for use in corn.

Herbicide	Active ingredient, lb/A or (formulation/A)	Remarks
NO TILL or MINIMUM TILL		
glyphosate	.75 to 3	Kills emerged weeds. Has no soil activity so usually combined with residual herbicides.
(Roundup)	(1 to 4 qt)	Apply prior to corn emergence to prevent corn kill.
Labeled mixtures*		
alachlor (Lasso, Bronco)	2.5 to 4	Adds preemergence control of most annual grasses and some broadleafs.
alachlor + atrazine	2 to 3 + 1 to 2	Adds preemergence control of most annual grasses and broadleafs.
alachlor + cyanazine (Bladex)	2 to 3 + 1 to 2.2	Adds preemergence control of most annual grasses and broadleafs.
atrazine	2 to 3	Adds preemergence control of most annual broadleafs and some grasses.
atrazine + metolachlor (Dual)	1.2 to 2 + 1.5 to 2.5	Adds preemergence control of most annual broadleafs and grasses.
metolachlor (Dual)	1.5 to 2.5	Adds preemergence control of most annual grasses and some broadleafs.
paraquat	.25 to 1	Kills emerged weeds. Has no soil activity so usually combined with residual herbicides.
(Paraquat Plus or Gramoxone)	(1 to 4 pt)	Apply prior to corn emergence to avoid corn kill. A restricted use herbicide.
Labeled mixtures*		
atrazine	2 to 3	Adds preemergence control of most annual broadleafs and some grasses.
cyanazine (Bladex)	1.2 to 4	Adds preemergence control of most annual broadleafs and many grasses.
alachlor + atrazine	2 to 2.5 + 1 to 2	Adds preemergence control of most annual broadleafs and grasses.
metolachlor (Dual)	1.5 to 2.5	Adds preemergence control of most annual grasses and some broadleafs.
metolachlor + atrazine	1.2 to 2 + 1.5 to 2.5	Adds preemergence control of most annual grasses and broadleafs.
cyanazine	1.25 to 4.75	Kills small weeds and gives preemergence control of annual broadleafs and some grasses.
(Bladex 80W)	(1.5 to 6 lb)	Nitrogen or fertilizer solutions as carriers improve burndown. If applied more
(Bladex 4L)	(1.25 to 4.75 qt)	than 15 days before planting a preemergence herbicide will be needed.
(Bladex DF)	(1.35 to 5.3 lb)	
Labeled mixtures*		
alachlor (Lasso)	2 to 2.5	Improves preemergence control of annual grasses and pigweeds.
atrazine	.4 to 1.6	Improves preemergence control of some broadleafs. Use reduced rates of cyanazine.
metolachlor (Dual)	1.25 to 2.5	Improves preemergence control of annual grasses and pigweeds.
pendimethalin (Prowl)	.75 to 1.5	Improves preemergence annual grass control. Apply after planting. Do not incorporate.
atrazine + alachlor	.4 to 1.6 + 2 to 2.5	Improves preemergence control of most annual broadleafs and grasses.
atrazine + metolachlor	.4 to 1.6 + 1.25 to 2.5	Improves preemergence control of most annual broadleafs and grasses.
2,4-D	.38 to .75	Improves control of emerged broadleaf perennials and pigweeds.

atrazine	2 to 3	Kills emerged weed seedlings and provides preemergence control of most annual broadleafs and some grasses. Use of liquid fertilizer or nitrogen solutions as carrier improves weed burndown.
(Atrazine 80W)	(2.5 to 3.75 lb)	
(Atrazine 4L)	(2 to 3 qt)	
(Atrazine DF)	(2.2 to 3.3 lb)	
Labeled mixtures*		
alachlor (Lasso)	2 to 2.5	Improves preemergence annual grass control.
glyphosate (Roundup)	.75 to 3	Improves burndown of emerged weeds.
metolachlor (Dual or Bicep)	1.5 to 2.5	Improves preemergence annual grass control.
paraquat (Gramoxone)	.25 to 1	Improves burndown of emerged weeds.
pendimethalin (Prowl)	.75 to 1.5	Improves preemergence annual grass control. Apply after planting. Do not incorporate.
PREPLANT INCORPORATED		
butylate	4 to 6	Controls most grasses and some broadleafs. Incorporate immediately. Safeners have been added to protect corn from injury.
(Sutan +, Genate Plus)	(3.75 to 7.33 pt)	
Labeled mixtures*		
atrazine	.75 to 1.5	Improves broadleaf weed control.
cyanazine (Bladex)	1.5 to 2	Improves broadleaf weed control.
atrazine + cyanazine	.5 to 1 + 1 to 2	Improves broadleaf weed control.
EPTC	3 to 6	Controls most grasses and some broadleafs. Incorporate immediately.
(Eradicane)	(3.75 to 7.33 pt)	Eradicane contains a safener to protect corn from EPTC.
(Eradicane Extra)	(4 to 8 pt)	Eradicane Extra contains a safener plus an extender which increases EPTC soil life.
Labeled mixtures*		
atrazine	1 to 1.5	Improves broadleaf weed control.
cyanazine	1.5 to 2	Improves broadleaf weed control.
PREPLANT INCORPORATED or PREEMERGENCE		
alachlor	1.5 to 4	Controls many annual grasses and some broadleaf weeds. Use high rate and incorporate for nutsedge.
(Lasso)	(1.5 to 4 qt)	
(Lasso II)	(16 to 26 lb)	
Labeled mixtures*		
atrazine	1 to 1.85	Improves broadleaf weed control.
cyanazine (Bladex)	1 to 2.4	Improves broadleaf weed control.
dicamba (Banvel)	.5	Preemergence onlyon medium or fine soils above 2.5% O.M. Improves broadleaf control.
atrazine + cyanazine	.75 to 1.25 + 2	Improves broadleaf weed control.
linuron (Lorox)	.67 to 3	Do not incorporate. Improves broadleaf control.

atrazine	2 to 4	Controls many broadleaf weeds and grasses. Use split application for quackgrass. May carry over and injure sensitive crops. See label restrictions on rotational crops.
(Atrazine 80W)	(2.5 to 5 lb)	
(Atrazine 4L)	(2 to 4 qt)	
(Atrazine DF)	(2.2 to 4.4 lb)	
<u>Labeled mixtures*</u>		
alachlor (Lasso)	2 to 3	Improves annual grass control.
butylate (Sutan +)	4 to 6	Improves annual grass control. Prepaint incorporated only.
cyanazine (Bladex)	.75 to 3.75	Reduces atrazine carryover. Improves annual grass control.
EPTC (Eradicane)	3 to 6	Improves annual grass control. Preplant incorporated only.
linuron (Lorox)	.67 to 3	Do not incorporate. Reduces atrazine carryover.
metolachlor (Dual or Bicep)	1.5 to 2.5	Improves annual grass control.
pendimethalin (Prowl)	.75 to 1.5	Improves annual grass control. Do not incorporate.
propachlor (Ramrod)	4 to 6	Improves annual grass control.
simazine (Princep)	1 to 2	Improves crabgrass and fall panicum control. Increased carryover.
metolachlor + simazine	1.5 to 2.5 + 1 to 2	Improves annual grass control. Increased carryover.
butylate + safener	4 to 6	Use preplant and incorporate immediately. Controls many annual grasses, some broadleaf weeds and nutsedge.
(Sutan +, Genate Plus)	(3.75 to 7.33 pt)	
<u>Labeled mixtures*</u>		
atrazine	.75 to 1.5	Improves broadleaf weed control.
cyanazine	1.5 to 2	Improves broadleaf weed control.
atrazine + cyanazine	.5 to 1 + 1 to 2	Improves broadleaf control.
cyanazine	.6 to 4.75	Controls many broadleaf weeds and grasses. Weak on pigweeds.
(Bladex 80W)	(.75 to 5.9 lb)	
(Bladex 4L)	(.6 to 4.75 qt)	
(Bladex DF)	(.67 to 5.3 lb)	
<u>Labeled mixtures*</u>		
alachlor (Lasso)	2 to 2.5	Improves annual grass control.
atrazine	.5 to 1.5	Improves pigweed control.
butylate (Sutan +, Genate Plus)	1.5 to 2	Improves annual grass control. Use prepaint incorporated only.
EPTC (Eradicane)	1.5 to 2	Improves annual grass control. Use preplant incorporated only.
metolachlor (Dual)	1.25 to 2.5	Improves annual grass control.
pendimethalin (Prowl)	.75 to 1.5	Improves annual grass control. Do not incorporate.
EPTC + safener	3 to 6	Use preplant and incorporate immediately. Controls many grasses, some broadleaf weeds and nutsedge. Eradicane Extra has longer soil activity. Repeated annual use reduces weed control effectiveness.
(Eradicane)	(3.75 to 7.33 pt)	
(Eradicane Extra)	(4 to 8 pt)	
<u>Labeled mixtures*</u>		
atrazine	1 to 1.5	Improves broadleaf weed control.
cyanazine	1.5 to 2	Improves broadleaf weed control.

metolachlor	1.5 to 3	Contorl many annual grasses and some broadleafs. Can be applied early preplant, either alone or in tank mixtures for weed control in minimum- or no-till corn. Use high reate and incorporate for nutsedge.
(Dual 8E)	(1.5 to 3 pt)	
(Dual 25G)	(6 to 12 lb)	
Labeled mixtures*		
atrazine	1 to 2	Improves broadleaf weed control.
cyanazine	.8 to 2.5	Improves broadleaf weed control.
dicamba (Banvel)	.5	Improves broadleaf control. Preemergence only on medium or fine soils above 2.5% O.M.
propachlor	4 to 6	Preemergence only. Controls many grasses and some broadleaf weeds.
Ramrod 4L)	(4 to 6 qt)	
(Ramrod 20G)	(20 to 30 lb)	
Labeled mixtures*		
atrazine	1 to 1.6	Improves broadleaf weed control.
linuron (Lorox)	.67 to 3	Improves broadleaf weed control.
POSTEMERGENCE		
ametryne	1.6 to 2	Directed spray to corn over 12 inches tall for weeds no more than 4 inches tall. To avoid serious corn injury do not spray the upper leaves or whorl.
(Evik)	(2 to 2.5 lb)	
atrazine with oil	1.2 to 2	Controls small grasses up to 1.5 inches tall and broadleafs to 4 inches tall but pigweed and lambsquarters to 6 inches tall. See label for oil rates and specifications. If weed control is poor, cultivation will be required.
(Atrazine 80W)	(1.25 to 2.5 lb)	
(Atrazine 4L)	(1 to 2 qt)	
(Atrazine DF)	(1.1 to 2.2 lb)	
Labeled mixture*		
pendimethalin (Prowl)	.75 to 1.5	Apply to corn in the spike to 4-leaf stage. Do not add oil. Improves grass control.
tridiphane (Tandem)	.5	Improves annual grass control. Clearance expected for 1986 but not yet received.
bentazon	.5 to .75	Controls small annual broadleafs, Canada thistle and yellow nutsedge. Second application may be required for Canada thistle and nutsedge.
(Basagran)	(1 to 1.5 pt)	
Labeled mixture*		
Atrazine (Laddox)	(2.4 to 3.6 pt)	Improves broadleaf weed control. Always add oil concentrate.
bromoxynil	.25 to .5	Controls small broadleaf weeds in corn up to 14 inches tall. Corn foliage burn may occur.
(Brominal ME4)	(.5 to 1 pt)	
(Buctril)	(1 to 1.5 pt)	
Labeled mixtures*		
atrazine	.5 to 1.2	Improves pigweed control. Rate too low for grass control. Do not use oil.
2,4-D	.25	Improves pigweed and perennial broadleaf control.

cyanazine	1.2 to 2	Controls small broadleafs and grasses. Weak on pigweed. Do not spray corn if the 5th leaf is visible. Do not use Bladex 4L. Under dry conditions add surfactant or vegetable oil.
(Bladex 80W)	(1.5 to 2.5 lb)	
(Bladex DF)	(1.35 to 2.2 lb)	
Labeled mixtures*		
atrazine	.4 to .6	Improves pigweed control.
dicamba (Banvel)	.25 to .33	Improves pigweed control. Avoid drift to sensitive crops.
pendimethalin (Prowl)	.75 to 1.5	Safer on smaller corn. Best for small proso millet and woolly cupgrass.
tridiphane (Tandem)	.5	Improves annual grass control. Clearance expected for 1986 but not yet received.
dicamba	.25 to .5	Controls many annual and perennial broadleaf weeds. Corn up to 36 inches tall. Use drop nozzles in corn over 10 inches tall. May be used as an overlay following soil-applied herbicides. Avoid spray or vapor drift to soybeans or other sensitive crops.
(Banvel)	(.5 to 1 pt)	
(Banvel II)	(1 to 2 pt)	
Labeled mixtures*		
alachlor (Lasso)	1.5 to 4	Before corn is 3 inches tall. Provides annual grass control.
atrazine	1.25 to 4	Before grasses are 1.5 inches tall. Provides grass control.
cyanazine (Bladex 80W)	1.5 to 2	Corn not beyond four leaves and grass up to 1.5 inches tall. Provides grass control.
2,4-D	.12 to .25	Use drop nozzle after corn is 8 inches tall. Improves mustard control.
linuron + surfactant	.62 to 1.5	Directed spray to corn over 15 inches tall for weeds up to 5 inches tall. To avoid serious corn injury do not spray the upper leaves or whorl. Controls broadleafs and grasses.
(Lorox WP)	(1.25 to 3 lb)	
(Lorox L)	(.62 to 1.5 qt)	
2,4-D	.25 to .5	Controls emerged annual and perennial broadleaf weeds. Use drop nozzles after corn is 10 inches tall. Do not spray from before tasseling until the silks are brown. Corn stalk brittleness commonly occurs when the corn stalk is elongating. Higher 2,4-D rates, 1 to lb/A, may be used after the hard dough stage to control perennials and large annuals. Avoid spray drift to soybeans or other sensitive crops.
amine (4 lb/gal)	(.5 to 1 pt)	
ester (4 lb/gal)	(.5 to .75 pt)	

* Follow label directions and precautions of all products in a mixture.

Table 3. Herbicide names and formulations

Common name	Trade name	Concentration and commercial formulation[1]
alachlor	Lasso	4 lb/gal L
	Lasso II	15% G
alachlor-atrazine	Lasso-Atrazine	2.5 + 1.5 lb/gal F
ametryne	Evik	80% WP
atrazine	AAtrex, others	80% WP, 90% WDG, 4 lb/gal F
atrazine-metolachlor	Bicep	2 + 2.5 lb/gal F
bentazon	Basagran	4 lb/gal L
bentazon-atrazine	Laddok	1.66 + 1.66 lb/gal F
bromoxynil	Brominal	4 lb/gal L
	Buctril	2 lb/gal L
butylate-protectant	Sutan +	10% G, 6.7 lb/gal L
butylate-protectant-atrazine	Sutazine	4.8 + 1.2 lb/gal L
cyanazine	Bladex	80% WP, 90% WDG, 4 lb/gal F
dicamba	Banvel	4 lb/gal L
	Banvel II	2 lb/gal L
EPTC-protectant	Eradicane	6.7 lb/gal L
EPTC-protectant-extender	Eradicane Extra	6 lb/gal L
linuron	Lorox	50% WP, 4 lb/gal F
metolachlor	Dual	25% G, 8 lb/gal L
pendimethalin	Prowl	4 lb/gal L
propachlor	Ramrod	20% G, 65% WP, 4 lb/gal F
propachlor-atrazine	Ramrod and Atrazine	3 lb + 1 lb/gal F
2,4-D	several	various

[1] G=granular, L=liquid, WP=wettable powder, WDG=water dispersible granule, F=flowable.

BASIC RESEARCH TO IMPROVE WEED CONTROL

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The objective of basic research is to generate fundamental knowledge that will provide a background base of information to aid in solving particular problems. In the area of weed science, basic research provides information needed to: 1) increase the effectiveness and selectivity of existing herbicides; 2) develop safer more effective herbicides; and 3) develop crop cultivars resistant to herbicides. Several basic research projects are being conducted by the Weed Research Unit at the University of Minnesota and these are described below.

Influence of the Environment on Herbicide Efficacy

The effectiveness of the new postemergence grass herbicides, sethoxydim (Poast), fluazifop (Fusilade), haloxyfop (Verdict), is greatly reduced when they are applied under conditions of soil moisture stress. Research is being conducted to determine whether this is due to the effects of water stress on: 1) herbicide retention and absorption; 2) the conversion of the herbicide to its active form; or 3) the movement of the herbicide to the growing points of grass weeds.

Perennial Weed Control - Bud Dormancy

Glyphosate (Round-up) is a systemic herbicide which is effective in controlling perennial weeds, such as quackgrass and milkweed. However, complete control is usually not obtained. To a large extent this is due to incomplete kill of the buds of the underground root system of these weeds. Incomplete control appears to be due to restricted movement of glyphosate into root buds that are dormant (inactive). These dormant buds survive the herbicide treatment and later become non-dormant (active) and form new plants. Research is being conducted to understand the mechanisms controlling dormancy in these root buds. Current work is focusing on determing the levels of compounds (hormones) thought to be involved in regulating dormancy. Anatomical differences which distinguish dormant and non-dormant buds are also being studied.

Herbicide Selectivity

Two areas of research are being pursued under this heading. One of these involves examining the basis for the resistance of a particular velvetleaf biotype to atrazine. Heretofore, most cases of atrazine resistance in weeds have been reported to be due to a modification at the site of herbicide action. However, the resistance that is found in this particular velvetleaf biotype is not due to this type of modification.

The second area of basic research under this heading involves investigating the susceptibility of corn lines to injury by the chloroacetanilide herbicides alachlor (Lasso) and metolachlor (Dual). A project is being initiated to measure the levels of a certain compound (glutathione) and enzyme (glutathione S-transferase) in corn lines which vary in susceptibility to the chloroacetanilide herbicides. It is hypothesized that the levels of glutathione or glutathione S-transferase may regulate susceptibility to injury by these herbicides.

Herbicide Mode-of-Action

The mode-of-action of the new postemergence grass herbicides (Poast, Fusilade, Verdict) is not known and is being investigated. These herbicides exert their phytotoxic effect on the growing points of grasses. Current research involves examining the effect of these herbicides on the production of energy and the synthesis of lipid in these growing points.

Herbicide - Resistant Crops

A research project has been initiated to utilize tissue culture techniques to select for resistance to glyphosate (Round-up) in birdsfoot trefoil. Using tissue culture techniques, cells of birdsfoot trefoil are grown on a nutrient medium. Cells grown under such conditions will exhibit random and spontaneous "changes" in their genetic content. Some of these "changes" may result in the cell becoming resistant to glyphosate. When glyphosate is added to the culture medium, the only cells that will survive are those that "changed" so that they are now resistant to glyphosate. The individual cells of birdsfoot treioil that are glyphosate resistant can then be regenerated into a whole plant.

WEED CONTROL PROGRESS IN SOYBEANS

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University of Minnesota

The 1985 revision of "Weed Control in Soybeans" AG-FO-0841 has been completed and a copy is included in this publication immediately following this report. There are four possible new herbicide registrations for the 1986 growing season from among the fourteen herbicides that were evaluated in 1985 for use in soybeans. However, none have received clearance from EPA as of November, 1985. Two herbicide candidates, dimethazone (Command) and imazaquin (Scepter) control both broadleaf and grassy weeds. Clearance of Scepter for use in Minnesota is unlikely because of its persistence in the soil which is greater in the shorter, colder Minnesota growing season and could affect corn or other crops planted the next year.

Command, applied to the soil in preplanting incorporation or preemergence treatments, controls or suppresses many annual grass and broadleaf weeds. The application rate ranges from 0.75 to 1.25 lb/A with the higher rates used on heavier soils with higher organic matter. Cocklebur, pigweed and eastern black nightshade require higher application rates while giant ragweed, wild mustard and wild sunflower are not effectively controlled by Command. Weed control effectiveness is reduced if rainfall does not occur after preemergence applicaions. Shallow incorporation improves weed control when rainfall is lacking. Command causes bleaching of plant shoots so drift and carryover are very obvious when they occur. Serious drift injury from spray or vapor drift is unlikely to occur. There is a possibility of carryover in Minnesota. Corn is less sensitive to carryover than are small grains. Carryover of Command is likely to be worse in northern Minnesota but data to determine relative carryover of Command at various geographical locations is not available at this time. Clearance is expected on mixtures with metribuzin (Sencor or Lexone) or linuron (Lorox). If registered by EPA for the 1986 season, supplies will be limited.

DPX-Y6202 (Assure) is a postemergence grass herbicide for use in soybeans which will provide excellent annual grass control and perennial grass suppression but has no apparent effect on sedges or broadleaf plants. The application rates range from 1/2 to 2 oz/A with the higher rates used for larger weeds and perennials. Crop oil or a nonionic surfactant must be used to obtain maximum effectiveness. Herbicidal effectiveness is reduced on the grassy weeds under dry conditions. Injury from spray drift onto nearby sensitive grasses is a possibility.

DPX-F6025 (Classic) is a post emergence broadleaf herbicide for use in soybeans but has little apparent effect on perennial broadleafs or grassy weeds. Application rates are very low ranging from 1/6 to 1/3 oz/A. The addition of a surfactant, but not a crop oil, is recommended. Classic may carry over in the soil in Minnesota and affect sensitive rotational crops grown the next year. Conditions making carryover greater are higher application rates, high pH, low temperature and low rainfall. Susceptible weeds include wild mustard, cocklebur, ragweeds, pigweed, smartweed, velvetleaf, sunflower and nutsedge. Postemergence control of lambsquarters and eastern black nightshade is poor.

Some other new herbicides that may be cleared in 1987 are Cinch, Cobra and Verdict. Clearance schedules for Reflex, Trophy and Whip are uncertain.

Studies on the tolerance of soybean varieties to Sonalan indicate that there may be substantial differences in tolerance. These studies will be continued in 1986 in order to obtain a more reliable data base.

Alachlor (Lasso) and linuron (Lorox) remain under Special Review by the U.S. Environmental Protection Agency. However, no changes in usage are expected in 1986. These Special Reviews should be completed and final rulings made on the future use of these herbicides before the 1987 growing season.

AG-FO-0841--REVISED FOR 1986

AGRICULTURAL EXTENSION SERVICE
UNIVERSITY OF MINNESOTA

WEED CONTROL IN SOYBEANS

Richard Behrens, Extension Agronomist

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

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

There are opportunities for reducing the costs of weed control in soybeans. Knowing the specific weed species present and selecting the appropriate herbicide or herbicides that have a high level of effectiveness and the lowest per acre cost may allow substantial savings. Using band applications can cut the cash outlay for herbicides by one-half to two-thirds. Lower cost cultivation can provide between-the-row weed control in band application and may in some instances be used in place of high-cost herbicides. Reducing herbicide rates below label recommendations increases the possibility of costly failures in weed control. On the other hand, applying herbicides at rates higher than label recommendations to assure weed control success adds unnecessarily to herbicide costs and may result in crop injury. Applying herbicides at the proper time and rate with a carefully calibrated applicator provides the best return on your herbicide investment.

Cultural Practices

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

Herbicides

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

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

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

No-Till or Minimum Till

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

Preplant Incorporated Applications

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

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

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

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

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

Preplant Incorporated or Preemergence Applications

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

NOTICE: Alachlor (Lasso) is now undergoing a Special Review by the U.S. Environmental Protection Agency (EPA) because tests show that tumors are caused when high levels of alachlor are fed daily to laboratory animals over long periods of time. In this Special Review, EPA is re-examining all health and safety tests and product benefits from alachlor usage. Recommendations from EPA on future uses of alachlor will be developed based on their estimate of these risks and benefits. As of November, 1985, it seems probable that alachlor will continue to be available during 1986 for use by Minnesota farmers.

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

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

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

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

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

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

NOTICE: Linuron (Lorox) in now undergoing a Special Review by the U.S. Environmental Protection Agency (EPA) because tests show that non-cancerous tumors are caused when high levels of linuron are fed daily to laboratory animals over long periods of time. In this Special Review, EPA is re-examining all health and safety tests and product benefits from linuron usage. Recommendations from EPA on future uses of linuron will be developed based on their estimates of these risks and benefits. As of November, 1985, it seems probable that linuron will continue to be available during 1986 for use by Minnesota farmers.

Dimethazone (Command) is a new herbicide which controls many grass and broadleaf weeds in soybeans when applied preplanting incorporated or preemergence. It is generally more toxic to grasses but is also highly toxic to velvetleaf. It gives effective control of common lambsquarters, Pennsylvania smartweed, common ragweed and suppresses common cocklebur. Caution: A request for registration has been submitted to the U.S. Environmental Protection Agency and clearance is expected prior to the 1986 growing season, but as of November, 1985, dimethazone has not been cleared for use on soybeans.

Postemergence

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

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

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

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

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

Fluazifop (Fusilade) and sethoxydim (Poast) are postemergence chemicals for annual and perennial grass control in soybeans. Soybeans have good tolerance. Neither chemical control broad-leaved weeds. An oil concentrate is used with the spray to improve performance. Tank mixtures with bentazon and acifluorfen provide control of many broadleaf weeds also, but effectiveness of sethoxydim and fluazifop on grasses may be reduced. See the appropriate labels for further information on these tank mixes.

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

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

2,4-DB amine (Butoxone, Butyrac 200) is labeled for postemergence control of common cocklebur in soybeans. Weed control is less satisfactory and the potential for crop injury greater when 2,4-DB is used than when other postemergence broadleaf herbicides are used. A combination of 2,4-DB with naptalam (Rescue) can be applied to larger soybeans in bloom when competition from cocklebur, giant ragweed and sunflower is severe to reduce competition. Some soybean leaf injury and stunting should be expected.

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

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Notes:

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

	PREPLANT INCORPORATED								PREEMERGENCE						POSTEMERGENCE								
	alachlor (Lasso)	chloramben (Amiben)	metolachlor (Dual)	metribuzin (Sencor or Lexone)	pendimethalin (Prowl)	ethalfluralin (Sonalan)	trifluralin (Treflan)	vernolate (Vernam, Reward)	alachlor (Lasso)	chloramben (Amiben)	naptalam + dinoseb (Dyanap)	linuron (Lorox)	metolachlor (Dual)	metribuzin (Sencor or Lexone)	acifluorfen (Blazer)	bentazon (Basagran)	2,4-DB (Butoxone or Butyrac 200)	diclofop (Hoelon)	dinoseb (Premerge)	naptalam + 2,4-DB (Rescue)	naptalam + dinoseb (Dyanap)	fluazifop (Fusilade)	sethoxydim (Poast)
SOYBEAN TOLERANCE	G	G	G	F	F/G	F/G	F/G	F	G	G	P	F	G	F	F	G	P	G	P	F/P	F/P	G	G
GRASSES																							
Barnyardgrass	G	G	G	F	G	G	G	G	G	F/G	P	F	G	F	P	N	N	G	P	P	P	G	G
Woolly cupgrass	G	G	G	P	G	G	G	F/G	G	G	P	P	G	P	P	N	N	P	P	P	P	G	G
Giant foxtail	G	G	G	F	G	G	G	G	G	F/G	P	F	G	F	P	N	N	G	P	P	P	G	G
Green foxtail	G	G	G	F	G	G	G	G	G	F/G	P	F	G	F	P	N	N	G	P	P	P	G	G
Yellow foxtail	G	G	G	F	G	G	G	G	G	F/G	P	F	G	F	P	N	N	F	P	P	P	G	G
Proso millet	F	F	F	P	F	F	F	F	F	F	P	P	F	P	P	N	N	P	P	P	P	G	G
Nutsedge	G	P	G	P	N	N	N	G	F	P	P	P	F	P	P	G	N	P	P	P	P	N	N
Quackgrass	N	N	N	P	P	P	P	F	N	N	P	P	N	P	N	N	N	N	P	N	P	G	F
Sandbur	F	P	F	P	G	G	G	G	F	P	P	P	F	P	P	P	P	P	P	P	P	G	G
BROADLEAFS																							
Canada thistle	N	N	N	P	N	N	N	N	N	N	P	P	N	P	P	G	P	N	P	P	F/P	N	N
Cocklebur	P	P	N	F	N	N	N	P	N	P	F	P	N	F	F	G	F	N	F	F	F	N	N
Kochia	P	G	P	G	G	G	G	-	P	G	F	F	P	G	-	F	-	N	-	F	F	N	N
Lambsquarters	F/P	G	F/P	G	F/G	F/G	F/G	F	F/P	G	F	G	F/P	G	P	F	P	N	P	-	P	N	N
Venice mallow	P	G	P	G	P	P	P	G	P	G	-	G	P	G	F	G	P	N	-	-	F	N	N
Mustard	P	F	P	G	N	N	N	F	P	F	G	G	P	G	G	G	P	N	G	-	G	N	N
Eastern black nightshade	F	F	F	P	P	F	P	P	G	G	-	P	G	P	G	F	P	N	G	-	F/P	N	N
Hairy nightshade	F	F	F	P	P	P	P	P	G	G	-	-	F	P	F	F	-	N	-	-	-	N	N
Pigweed	G	G	G	G	G	G	G	G	G	G	F	G	G	G	G	P	P	N	P	-	P	N	N
Common ragweed	P	G	P	G	N	N	N	P	P	G	F	G	P	G	G	G	P	N	F	F	F	N	N
Giant ragweed	P	F	P	P	N	N	N	P	P	F	F	F	P	F	G	F	F	N	-	-	F	N	N
Smartweed	P	G	P	G	F	P	P	P	P	G	F	F	P	G	G	G	P	N	G	-	F	N	N
Wild sunflower	P	P	P	F	N	N	N	P	P	P	F	P	P	F	F/G	G	P	N	F	F	F	N	N
Velvetleaf	P	F	P	G	F	N	N	F	P	F	P	F	P	F	P	G	P	N	P	-	P	N	N

[1] G = good; F = fair; P = poor; n = no control; - = insufficient information.

Table 2. **Herbicide choices for soybeans.**

Herbicide	Active ingredient, lb/A or (formulation/A)	Remarks
NO-TILL or MINIMUM TILL		
glyphosate (Roundup)	.75 to 3 (1 to 4 qts)	Kills emerged weeds. Has no soil activity so commonly combined with residual herbicides. Apply prior to soybean emergence to prevent soybean kill.
Mixtures listed on the label		
alachlor (Lasso or Bronco)	2.5 to 4	Adds preemergence control of annual grasses and a few broadleaf weeds.
alachlor + linuron (Lorox)	2.5 to 4 + .5 to 1.5	Adds preemergence control of annual grasses and broadleaf weeds.
alachlor + metribuzin	2.5 to 4 + .25 to .75	Adds preemergence control of annual grasses and broadleaf weeds.
Mixtures listed on other labels		
chloramben (Amiben)	2 to 3	Adds preemergence weed control. Use any labeled preemergence chloramben tank mix.
metolachlor + linuron	1.5 to 2.5 + .5 to 1.5	Adds preemergence weed control of annual grasses and broadleaf weeds.
metolachlor + metribuzin	1.5 to 2.5 + .25 to .5	Adds preemergence weed control of annual grasses and broadleaf weeds.
chloramben + metolachlor	2 to 3 + 1.5 to 2.5	Adds preemergence weed control of annual grasses and broadleaf weeds.
chloramben + alachlor	2 to 3 + 1.5 to 3	Adds preemergence weed control of annual grasses and broadleaf weeds.
paraquat (Paraquat Plus or Gramoxone)	.25 to 1 (1 to 4 pts)	Kills emerged weeds. Has no soil activity so commonly combined with residual herbicides. Apply prior to soybean emergence to prevent soybean kill. A restricted use herbicide.
Mixtures listed on the label		
linuron (Lorox)	.5 to 1.5	Adds preemergence weed control.
metribuzin (Sencor or Lexone)	.38 to 1	Adds preemergence control of broadleaf weeds.
alachlor (Lasso) + linuron	2 to 3 + .5 to 1.5	Adds preemergence weed control.
alachlor + metribuzin	2 to 3 + .25 to .5	Adds preemergence weed control.
Mixtures listed on other labels		
chloramben	2 to 3	Adds preemergence weed control. Use any labeled preemergence chloramben tank mix.
metolachlor (Dual) + linuron	1.5 to 2.5 + .5 to 1.5	Adds preemergence control of annual grasses and broadleaf weeds.
metolachlor + metribuzin	1.5 to 2.5 + .25 to .5	Adds preemergence control of annual grasses and broadleaf weeds.
chloramben + metolachlor	2 to 3 + 1.5 to 2.5	Adds preemergence control of annual grasses and broadleaf weeds.
chloramben + alachlor	2 to 3 + 1.5 to 3	Adds preemergence control of annual grasses and broadleaf weeds.

PREPLANT INCORPORATED

ethalfluralin	.56 to 1.12	Controls annual grasses and some broadleaf weeds. Use preplant incorporated.
(Sonalan)	(1.5 to 3 pts)	At maximum rate gives partial control of eastern black nightshade.
Mixtures listed on the label		
alachlor (Lasso)	2 to 4	Adds control of nightshades, witchgrass and yellow nutsedge.
chloramben (Amiben)	2 to 3	Adds control of broadleaf weeds.
metolachlor (Dual)	1.5 to 3	Adds control of black nightshade and yellow nutsedge.
metribuzin (Lexone, Sencor)	.25 to .5	Adds control of broadleaf weeds.
pendimethalin	.5 to 1.5	Controls annual grasses and some broadleafs. Preplant incorporated.
(Prowl)	(1 to 3 pts)	
Mixtures listed on the label		
alachlor (Lasso)	2.5 to 4	Improves grass control and adds control of nightshades and yellow nutsedge.
chloramben (Amiben)	2	Adds control of smartweeds, velvetleaf and common ragweed.
metolachlor (Dual)	1.5 to 3	Improves control of grasses and adds control of nightshades and yellow nutsedge.
metribuzin (Lexone, Sencor)	.5 to .75	Controls additional broadleaf weeds.
chloramben + metribuzin	1.5 to 2 + .37 to .55	Controls additional broadleaf weeds.
trifluralin	.5 to 1	Controls annual grasses and some broadleafs. Use preplant incorporated in the fall
(Treflan 4E)	(1 to 2 pts)	or spring. Do not exceed recommended rates for the soil type or carryover may
(Treflan 10G)	(5 to 10 lbs)	injure sensitive crops the following year.
Mixtures listed on the label		
alachlor (Lasso)	2.5 to 4	Adds control of nightshades and yellow nutsedge. Preemergence overlay cleared.
chloramben (Amiben)	2 to 3	Controls additional broadleafs. Preemergence overlay cleared.
metolachlor	1.5 to 3	Adds control of nightshades and yellow nutsedge. Preemergence overlay cleared.
metribuzin	.25 to .5	Adds control of yellow nutsedge, velvetleaf and wild mustard.
chloramben + metribuzin	1.5 to 2.5 + .25 to .38	Controls additional broadleafs. Preemergence overlay cleared.
vernolate	2 to 3	Controls annual grasses, some broadleafs plus yellow nutsedge. Use preplant
(Vernam 7E)	(2.3 to 3.5 pts)	and incorporate immediately. Extender in Reward increases vernolate soil
(Vernam 10-G)	(20 to 30 lbs)	persistence. Reward or Vernam 10-G may be applied and incorporated after
(Reward)	(2.7 to 4 pts)	planting.
Mixtures listed on the label		
alachlor (Lasso)	1 to 2	Adds control of nightshades.
chloramben (Amiben)	1.5	Adds control of many broadleafs.
pendimethalin (Prowl)	.38 to .75	Adds control of velvetleaf, kochia and smartweeds.
trifluralin (Treflan)	.5 to 1	Adds control of kochia and improves annual grass control.
trifluralin + metribuzin	.5 + .25 to .38	Adds control of many broadleaf weeds and improves annual grass control.

PREPLANT or PREEMERGENCE

alachlor	1.5 to 4	Controls annual grasses and some broadleafs including nightshade.
(Lasso)	(1.5 to 4 qts)	Cleared postemergence but less effective on emerged weeds.
(Lasso II)	(16 to 26 lbs)	
<u>Mixtures listed on the label</u>		
chloramben (Amiben)	2	Adds control of many broadleaf weeds.
dinoseb (Premerge)	3 to 4.5	Preemergence or before soybean leaves unfold. Use low rate for emerged broadleafs. If terminal bud is exposed soybean injury can be serious.
linuron (Lorox)	.5 to 1.5	Do not incorporate. Added broadleaf control.
metribuzin (Sencor or Lexone)	.25 to .5	Adds control of many broadleaf weeds.
chloramben + metribuzin	.75 to 3 + .25 to .5	Adds control of many broadleaf weeds.
linuron + metribuzin	.17 to 1 + .13 to .5	Adds control of most broadleaf weeds.
chloramben	1.8 to 3	Controls broadleafs and grasses, but more effective on broadleafs.
(Amiben)	(4 to 6 qts)	Cleared postemergence but less effective on emerged weeds.
(Amiben DS)	(2.4 to 3.6 lbs)	Weak on wild mustard.
(Amiben Granular)	(20 to 30 lbs)	
<u>Mixtures listed on the label</u>		
alachlor (Lasso)	1.5 to 3	Improves grass, nutsedge and nightshade control.
dinoseb (Premerge)	1.5 to 4.5	Preemergence or before first soybean leaves open. Use low rate for emerged broadleafs at cracking stage. If terminal bud is exposed soybean injury can be serious.
linuron (Lorox)	.33 to 1.5	Preemergence only. Improves grass and broadleaf control.
metolachlor (Dual)	1.5 to 2.5	Improves grass, nutsedge and nightshade control.
metribuzin (Sencor, Lexone)	.25 to .5	Improves broadleaf control, especially wild mustard.
pendimethalin (Prowl)	.75 to 1.25	Preplant incorporated. Improves grass control.
trifluralin (Treflan)	.5 to 1	Preplant incorporated only. Improves grass control.
vernolate (Vernam, Reward)	2.7 to 4	Preplant incorporated. Improves grass and velvetleaf control.
alachlor + metribuzin	1.5 to 3 + .25 to .5	Improves grass, nutsedge, nightshade and mustard control.
metolachlor + metribuzin	.75 to 1.5 + .25 to .5	Improves grass, nutsedge, nightshade and mustard control.
pendimethalin + metribuzin	.75 to 1.5 + .25 to .5	Preplant incorporated. Improves grass and mustard control.
trifluralin + metribuzin	.5 to 1 + .25 to .5	Preplant incorporated. Improves grass and mustard control.
diallate	1.5 to 2	Controls wild oats only. Apply preplant or preemergence incorporated.
(Avadex)	(1.5 to 2 qts)	<u>A restricted use herbicide.</u>

linuron	.5 to 2.5	Use in preemergence mixtures to improve broadleaf weed control. Ineffective if incorporated. If emerged, soybeans will be severely injured. Do not use on sandy soils with less than 0.5 % organic matter. Directed postemergence for small broadleafs.
(Lorox WP)	(1 to 5 lbs)	
(Lorox 4L)	(.5 to 2.5 qts)	
<u>Mixtures listed on the label</u>		
alachlor (Lasso)	.5 to 3	Improves grass control and adds nutsedge and nightshade control.
chloramben (Amiben)	1.5 to 2.5	Improves overall grass and broadleaf control.
metolachlor (Dual)	1 to 2.5	Improves grass control and adds nutsedge and nightshade control.
pendimethalin (Prowl)	.5 to 1.3	Improves grass control. Apply pendimethalin preplant and linuron preemergence.
propachlor (Ramrod)	.65 to 3	Improves grass control. Seed crop only.
dinoseb (Premerge)	1.5 to 4.5	Directed spray to soybeans over 8 inches tall to control weeds up to 3 inches tall.
2,4-DB (Butyrac)	.2	Directed spray to soybeans over 8 inches tall to control 1- to 3-inch weeds.
metolachlor	2 to 3	Controls annual grasses and some broadleafs. Apply preplant incorporated or preemergence. Cleared early preplant for no-till and minimum till.
(Dual)	(2 to 3 pts)	
<u>Mixtures listed on the label</u>		
chloramben (Amiben)	1.8 to 2.7	Adds control of many broadleaf weeds.
dinoseb (Premerge)	1.5 to 4.5	Preemergence or before soybean leaves unfold. Use low rate for emerged broadleafs. If terminal bud is exposed soybean injury can be serious.
linuron (Lorox)	.5 to 1.5	Preemergence only. Adds control of broadleaf weeds.
metribuzin (Sencor, Lexone)	.25 to .5	Adds control of many broadleaf weeds.
dinoseb + naptalam (Dyanap)	1.1 to 1.5 + 2.3 to 3	Use preemergence or before soybean leaves unfold. If terminal bud is exposed soybean injury may occur.
metribuzin	.25 to .87	Controls many broadleaf weeds including wild mustard. Apply early preplant, preplant incorporated or preemergence. Use in mixtures with grass herbicides. Soybean tolerance only fair. In early preplant application, a second preemergence application can be used to extend weed control.
(Sencor or Lexone 4L)	(.5 to 1.7 pts)	
(Sencor or Lexone DF)	(.3 to 1.2 lbs)	
<u>Mixtures listed on the label</u>		
alachlor (Lasso)	2 to 3	Adds grass, nutsedge and nightshade control.
chloramben (Amiben)	1.5 to 2.5	Adds some grass and nightshade control.
ethalfluralin (Sonalan)	.56 to 1.12	Preplant incorporated only. Adds grass control.
metolachlor (Dual)	1.25 to 2.5	Adds grass, nutsedge and nightshade control.
pendimethalin (Prowl)	.75 to 1	Preplant incorporate to minimize soybean injury. Adds grass control.
trifluralin (Treflan)	.5 to 1	Preplant incorporated only. Adds grass control.
dinoseb + naptalam (Dyanap or Premerge Plus)	1.1 to 1.5 + 2.3 to 3	Improves control of cocklebur. Preemergence or before soybean leaves unfold. If terminal bud is exposed soybean injury can be serious.
alachlor + dinoseb + naptalam	2 to 3 + 1.12 to 1.5 + 2.3 to 3	Adds control of grasses and cocklebur. Preemergence but before soybean leaves unfold. If terminal bud is exposed soybean injury can be serious.
alachlor + linuron	.75 to 2 + .17 to 1	Adds grass and some broadleaf control.
metolachlor + linuron	1.25 to 2.5 + .17 to 1	Adds grass and some broadleaf control.

POSTEMERGENCE

acifluorfen	.37 to .75	Controls small broadleaf weeds. Apply postemergence. Apply again if necessary for
(Blazer)	(1.5 to 3 pts)	late emerging weeds. Burn of soybean leaves is common but recovery is usually
		complete. Surfactant is needed for maximum effectiveness.
Mixtures listed on the label		
bentazon (Basagran)	.5 to .75	Improves broadleaf control. Adding liquid fertilizer (10-34-0) improves velvetleaf control.
chloramben (Amiben)	2.5 to 3	Provides residual activity for later germinating weeds.
fluazifop (Fusilade)	.13 to .25	Adds grass and corn control. Some antagonism in tank mixes.
sethoxydim (Poast)	.23 to .38	Adds annual grass and corn control. Use 50% greater rates of sethoxydim in tank mixes.
bentazon + sethoxydim	.5 to .75 + .23 to .38	Adds annual grass and corn control. Use 50% greater rates of sethoxydim in tank mixes.
2,4-DB (Butyrac 200)	.03	Improves control of larger cocklebur, pigweed and ragweed.
barban	.38	Controls wild oats only. Apply when wild oats is in the 2-leaf stage.
(Carbyne 2EC)	(3 pts)	
bentazon	.75 to 1	Controls many annual broadleafs, nutsedge and Canada thistle. Apply when weeds
(Basagran)	(1.5 to 2 pts)	are small. Add oil concentrate under adverse conditions.
Mixtures listed on the label		
acifluorfen (Blazer)	.25 to .5	Improves control of nightshade, pigweeds and common ragweed. Soybean leaf burn occurs.
sethoxydim (Poast)	.3 to .4	Adds annual grass and corn control. Use 50% higher sethoxydim rate in tank mix.
acifluorfen + sethoxydim	.25 + .3	Improves control of broadleafs. Adds control of annual grasses and corn.
chloramben	3	Must add crop oil. Use after a soil-applied grass herbicide. Post emergence suppression
(Amiben)	(6 qts)	or control of pigweed, common ragweed and Pennsylvania smartweed plus residual
(Amiben DS)	(3.6 lbs)	preemergence activity.
diclofop	.75 to 1.25	Controls many annual grasses and volunteer corn. A restricted use herbicide.
(Hoelon)	(2 to 3.3 pts)	
dinoseb	.38 to 2.25	Apply high rates to soybeans in the cotyledonary stage. For emerged weeds only.
(Premerge)	(1 to 6 pts)	Apply lower rates from 1st trifoliate to bloom stage or soybeans for cocklebur.
		Soybean leaf burn likely.
Mixtures listed on the label		
naptalam (Dyanap or Premerge Plus)	.75 to 2	Soybeans from 1st trifoliate to bloom only. Expect soybean leaf burn and stunting.
		Only fair control of many broadleaf weeds. Variable weed control and soybean injury
		due to temperature. Split applications are possible.

fluazifop (Fusilade 2000)	.09 to .19 (.75 to 1.5 pts)	Controls annual grasses, corn and quackgrass. Quackgrass may require a second application. Always add a surfactant or crop oil concentrate.
Mixtures listed on the label		
acifluorfen (Blazer)	.38 to .75	Adds broadleaf weed control. Add a surfactant. Sequential or tank mix.
sethoxydim (Poast)	.1 to .5 (.5 to 2.5 pts)	Controls grasses plus corn and suppresses quackgrass. Quackgrass may require a second application. Add a crop oil concentrate.
Mixtures listed on the label		
bentazon (Basagran)	.75 to 1	Adds broadleaf weed control. Reduced grass control requires a 50% sethoxydim rate increase. Avoid antagonism by using sequential applications.
bentazon + acifluorfen (Blazer)	.75 to 1 + .25 to .5	Adds broadleaf weed control. Reduced grass control requires a 50% sethoxydim rate increase. Avoid antagonism by using sequential applications.
2,4-DB (Butyrac 200)	.18 to .4 (.7 to 1.6 pts)	Mainly for common cocklebur. Apply as a directed spray to soybeans at least 8 inches tall and cocklebur to 3 inches tall or other weeds 2 inches tall.
Mixtures listed on the label		
naptalam (Alanap or Rescue-pre mix)	1 to 1.5	Tank mix rate .03 to .045 lb/A of 2,4-DB. Apply broadcast to soybeans after first blooms appear to suppress cocklebur, giant ragweed, sunflower and wild mustard. Some soybean injury should be expected. A non-ionic surfactant or crop oil concentrate is required.