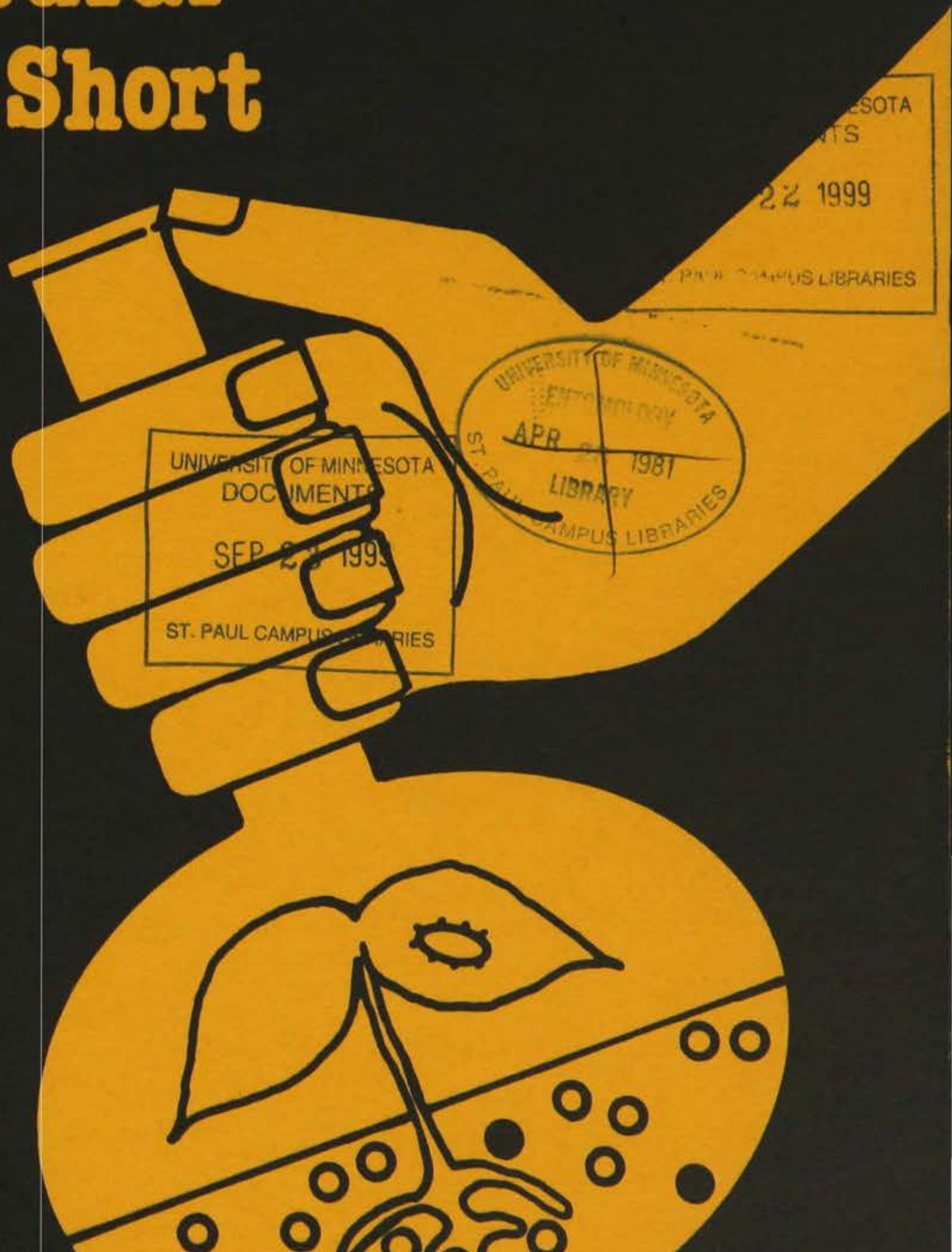
Soils, Fertilizer & Agricultural Pesticides Short Course



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PROCEEDINGS

SOILS, FERTILIZER AND AGRICULTURAL PESTICIDES

SHORT COURSE

December 10, 1980
Minneapolis Auditorium

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FERTILIZING FOR HIGH YIELDING CORN AND SOYBEANS IN WESTERN MINNESOTA

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Fertilizing for high yields means building soil fertility to a level that does not restrict yields and this is part of the total system of production that is interacting.

To build to a higher level than will give a yield response using all available production inputs under favorable climatic conditions is not desirable, however, it is important to be at this high level. It takes a period of time to build to this level and cannot be achieved in a year or two.

To start with, a background of Western Minnesota soils and climate is essential. The soils are developed primarily on calcareous glacial material of recent origin, the exception is windblown loess in the Southwest corner. They developed under limited rainfall which means they are not deeply leached and the native vegetation was prairie. This gives us a dark colored high organic matter soil that is not very acid and has a high nutrient holding capacity. This combination also has a good water holding capacity available for plant use of approximately 2 inches per foot.

The native fertility of these soils was very low in phosphorus and was the limiting factor in early agriculture. It was in this area that 50 years ago pictures were taken of phosphorus deficient cattle due to the vegetation they were eating. Potassium levels were medium to high. This is reflected in very limited response to potassium fertility except where the pH is high and a deficiency is induced by the Ca and Mg content.

Nitrogen content is determined by the organic matter and is relatively high due to the native prairie grasses that were here for the last 10,000 years. If there is 5% organic matter then there is about 10,000 pounds of nitrogen tied up in it. This is slowly released by mineralization and after farming for 100 years is now releasing enough nitrogen to average 68.2 bushels of corn over the last 20 years. This is the yield obtained in a continuous corn study where all other inputs are not limiting and a starter with 18 pounds of nitrogen is applied per year.

Climatic effects tend to be the limiting factor in crop production in Western Minnesota. It is on the western edge of the corn belt because of moisture and the northern edge because of temperature. With a continental climate the ranges of these is very wide and to have a normal year is very abnormal. Thus fertilizing to take advantage of all the moisture and length of growing season is essential. Precipitation on the average ranges from 20 to 27 inches over Western Minnesota with extremes from 10 inches to 40+. The growing season for corn and soybeans averages 2,450 growing degree days and ends about October 1st.

PHOSPHORUS:

Phosphorus was the shortest of the fertilizer nutrients when we started fertilizing. It is also practically immobile in the soil so it must be tilled into the depth that it will be. Thus it is important to build a fairly high level into a deep till layer. This is perhaps more important in Western Minnesota because the surface area often dries out below the wilting point and can limit root activity in this area. A phosphorus-potassium study was started in the fall of 1973 that had a soil test level of 55 on phosphorus and 290 on potassium. The test results as shown in Table 1 indicates that in 6 years of continuous corn the no phosphorus addition had dropped the test to the high 30's. However, where 100 pounds per year had been used the test level had gone up to the 60's and 70's. All this occured without a significant increase in yield over the last 4 years.

> *Using this and 20 years of fertilizer work on corn and soybeans, it appears that a phosphorus level in the 40's should be the goal of a soil fertility program for corn and soybeans in Western Minnesota.*

A level higher than this will not pay immediate returns and if it gets too high we may have an imbalance causing Zn, Mo and possibly other deficiencies.

POTASSIUM:

Subsoils of Western Minnesota are normally medium to high in potassium. The long term fertility trial referred to in Table 1 shows no response to potassium fertilization at these levels. The K test dropped from 290 to 265 without fertilization and increased to approximately 325 with 6 years of 100 pounds K_2O per year.

TABLE 1: EFFECT OF PHOSPHORUS AND POTASSIUM FERTILIZATION TO A HIGH TESTING SOIL[1] ON SOIL TEST P & K AND CORN YIELD

Annual Fertilizer Treatments		SOIL TEST FALL 1979		AVERAGE CORN YIELD
P_2O_5	K_2O	P	K	
lb/A		lb/A		bu/A
0	0	40	266	110
0	100	37	332	109
100	100	62	316	114
100	0	76	265	111
		**	**	
LSD5%		14	39	

1/ Average P & K soil test when experiments started (1973) was 55 and 290 lb/A respectively.

Using this and 20 years of fertilizer work on corn and soybeans, a potassium test of over 250 should be the goal of a soil fertility program for corn and soybeans in Western Minnesota.

A level this high or higher should provide adequate potassium for maximum yields as well as other growth qualities. Soils testing over 7.4 on pH should have extra potassium applied to balance the excessive calcium and magnesium.

STARTER:

The use of starter fertilizer has been researched extensively over the last 50 years. In trying to summarize the effectiveness of starter on tile drained or well drained soils, the level of phosphorus is most important in Western Minnesota.

TABLE 2: RESPONSE TO STARTER FERTILIZATION - NELSON'S PROJECTION - 20 YEARS DATA DIGESTION

SOIL P TEST	STARTER RESPONSE YEARS OUT OF 5	
lb/A	CORN	SOYBEANS
10	5	4
10-20	3	2
20-30	2	1
over 40	1	0

Using Nelson's projection once phosphorus fertility levels have been built to the 40's, the timeliness of planting says no starter, but below 30 it pays to take the time.

NITROGEN:

TABLE 3: EFFECT OF NITROGEN RATES ON CONTINUOUS CORN

ANNUAL N RATES * lb/A	19 YEAR AVERAGE CORN YIELD bu/A
0	68.2
40	94.7
80	108.5
160	113.0

*18 lb N in Starter in addition.

Nitrogen, the last fertilizer elements that needs to be considered is also the most elusive one. It moves. This, however, is also very beneficial in Western Minnesota with its limited rainfall. Data shows that we do not lose nitrates rapidly from our profiles as we are normally moisture deficient. However, during peak nitrogen demand, from 3 weeks before until 3 weeks after tasseling,we often have moisture deficiency in the surface 1 or 2 feet of our soil. An accumulation in the 3rd or 4th foot is usually readily available.

Our continuous corn study Table 3 shows that with only minimum nitrogen, our soils release enough N for corn yields in the 60's. However, with increasing rates the yield increases diminish rapidly.

Using this and 20 years of fertility work on corn, it appears 1 lb of N should be applied for each bushel of corn up to 125 bu/A than can be averaged over 5 years and 2 lbs of N for each bushel over 125.

I believe from the deep nitrate work now being done, we are just about ready to recommend N based on a soil test to 4 or 5 feet! ! This, however, is a different story.

No nitrogen response has been observed on soybeans when other fertility levels are medium to high.

Summary of all the fertility factors for corn and soybeans indicate that this is only one part of the production system that may be limiting.

In order to prevent fertility from being a limiting factor, build up the fertility level of the soil to the 40's for phosphorus, over 250 for potassium, and apply nitrogen every year for corn at 1 lb per bushel up to 125 and 2 lbs per bushel over 125.

It will take some time to build these fertility levels and it probably requires at least 100 lbs of phosphate or potash to make it economical energy and goal wise. This is only the fertility part of a corn-plete program that needs to be followed to get the maximum response.

FERTILIZING FOR HIGH YIELDING CORN AND SOYBEANS IN EASTERN MINNESOTA

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High corn and soybean yields require intensive management on the part of the producer. The ability to obtain these high yields consistently takes more than luck and good weather. The farmer must first have fertile, highly productive soils. He must then be able to manage all of the controllable factors at his disposal into maximizing the productivity of that soil. Some of these controllable factors include:

- primary tillage
- secondary tillage
- fertilization
- liming
- crop rotation
- drainage
- erosion control
- machinery
- energy input
- seed selection
- plant population
- planting date
- planting depth
- row width
- weed control
- insect control
- disease control
- irrigation

Each farmer needs to integrate all of these controllable factors into a "best management system" for his operation. He must be aware that many of these factors interact with each other. For instance, the crop rotation that he chooses will affect his method of primary tillage which in turn may influence his decisions on secondary tillage and on methods and best herbicides for weed control. Let's discuss some of the fertilization factors which fit into this "best management system" for obtaining high corn and soybean yields in Eastern Minnesota.

CROP ROTATION AND N FERTILIZATION

The previous crop has been shown to have a marked effect on corn yields and the amount of N required for high corn yields in Minnesota, Wisconsin, Iowa, Illinois and other states over the last decade. To illustrate this we will examine the results of a crop rotation--N fertilization study initiated on a tile-drained Webster clay loam at Waseca in 1974. The crop sequences included: (1) continuous corn, (2) corn-soybeans, (3) corn-wheat and (4) corn-wheat + interseeded alfalfa plowed down as green manure. The rates of N (0, 40, 80, 120, 160 and 200 lb N/A) were spring-applied as anhydrous ammonia. Because of the extremely dry conditions and low yields in 1975 and 1976, the average corn yields shown in Table 1 are from 1977-1980.

Table 1. Influence of previous crop and N rate on corn yield at Waseca from 1977-1980.

N rate	Corn	Corn yield following Soybeans	Wheat	Wheat + Alfalfa
lb N/A	----------------bu/A----------------			
0	84	122	115	127
40	112	142	144	144
80	124	157	158	160
120	136	163	160	165
160	143	166	164	166
200	146	169	168	165
Avg.:	124	153	152	154

Continuous corn yields averaged 20-25 bu/A less than corn following soybeans, wheat or wheat + alfalfa even when N rates were more than adequate (Table 1). Corn yields following soybeans, wheat and wheat + alfalfa were not affected significantly by the previous crop. Within the statistical variations of the data, the N rate was optimized at between 160 and 200 lb following corn and between 120 and 160 lb following soybeans, wheat or wheat + alfalfa.

Another experiment was conducted on a Webster clay loam to evaluate the effect of application time (fall, spring and sidedress) of N on crop utilization and N movement into the tile lines. Nitrogen was applied as ammonium sulfate (21% N with an isotope tracer) in the late fall and plowed down,in the spring and field cultivated in,and sidedressed at approximately the 8-leaf stage. The average grain yields from 1978-1980 and the grain to stover (stalk + leaf) ratios from 1979-1980 are given in Table 2.

Table 2. Corn yield and grain:stover ratio as influenced by N rate and time of application at Waseca.

N rate	Time	Grain Yield 1978-1980	Grain:Stover ratio 1979-1980
lb N/A		bu/A	
0	--	60.6	0.82
120	Fall	116.6	0.90
120	Spring	141.6	1.07
120	Sidedress	151.0	1.38
180	Fall	144.5	1.06
180	Spring	157.3	1.10
180	Sidedress	166.4	1.30

Corn yield and grain to stover ratio were both influenced by N rate as well as time of application (Table 2). Yields were increased substantially by the higher N rate. In addition, the time of application on this tile drained, fine-textured soil resulted in a very noticeable and consistent advantage for the sidedress application. Late fall application (after November 1) resulted in the poorest yields and lowest grain: stover ratios, while highest yields and grain:stover ratios were obtained with the sidedress treatment.

These data indicate that significant losses of N are occurring with fall application of this ammonium-N fertilizer. Delaying N application to the spring or early summer was more efficient and economically profitable. However, even the spring applications appear to be susceptible to some loss; perhaps, thru denitrification during late May and early June. The sidedress treatment appeared to supply more N to the plant later in the season. This resulted in a plant that did not appear to be as vigorous (lower stover yield) but one which did produce a large grain yield. Economically produced high corn yields in the future may require that at least a part of the N be sidedress-applied, even on the fine-textured, well tiled soils.

P AND K FERTILIZATION

Phosphorus and K fertilization to meet high yields can be approached quite differently than N fertilization because of the residual or carryover of P and K. Oftentimes it is said "fertilizing with P and K is like putting money in the bank". However, there becomes a practical limit when additional P & K additions do not result in necessarily a good investment. When does this occur? After P and K soil test levels are built to high and very high levels, yield responses to fertilizer P & K more than likely will not be obtained for a number of years even if P & K are not applied.

Let's look at a simple response curve showing crop yield as influenced by fertilizer P and K additions over various soil test levels. This illustration (Fig. 1) represents a rather simple fertilization philosophy.

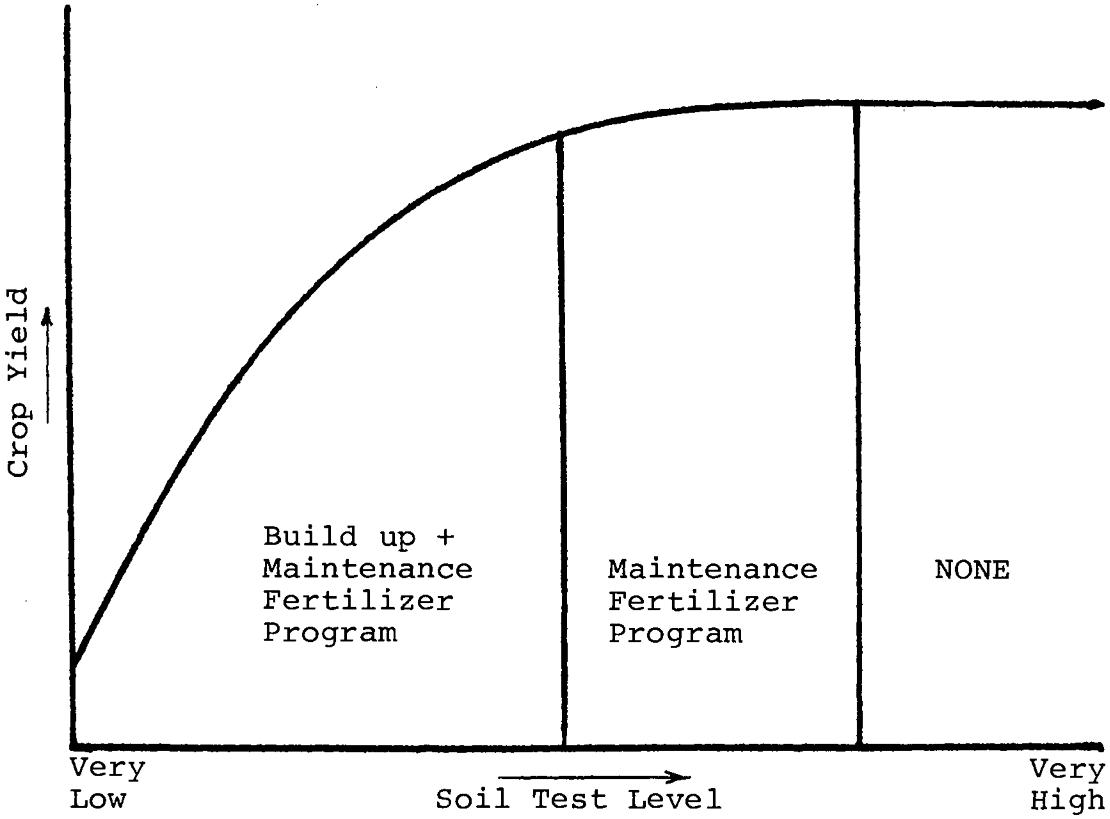

Fig. 1. Crop yield as influenced by P & K fertilization over various soil test levels.

When soil tests are low and medium the chance of obtaining higher yields (response) with P and K is improved. As soil test levels become high the chance of improving yield with extra P and K diminishes rapidly. At very high soil test levels there is almost no chance of boosting yields with extra P & K. Therefore, a farmer or dealer should strive to build up soil test levels to high levels and then maintain them at that level.

Continuous P and K applications to already very high testing soils would not be economical and may cause or induce micronutrient problems, i.e., zinc and perhaps iron deficiencies. Thus, we would not recommend P and K to these soils but would recommend periodic soil sampling to monitor soil test level. When the soil test begins to slip below 40 lb/A for P and 300 lb/A for K with corn, we would again recommend maintenance rates of each nutrient.

To look at an example illustrating this philosophy, let's look at the results from a residual P and K study being conducted at Waseca (this study is also being conducted at Lamberton and Morris). The experiment was begun in the fall of 1973 and the treatments shown in Table 3 have been applied annually.

Table 3. Influence of P and K additions to an initially high testing soil[1] on soil test P & K and corn yield.

Annual P and K Treatments	Soil Test 1977 P	1977 K	1980 P	1980 K	1977-80 Average Corn Yield
lb P_2O_5 + K_2O/A	---------	lb/A	--------		bu/A
0 + 0	20	210	24	205	152
0 + 100	22	225	22	240	154
50 + 100	32	230	40	235	162
100 + 100	39	245	59	265	164
(150)[2] + 100	32	225	42	235	163
100 + 0	34	200	59	220	159
100 + 50	37	215	52	205	163
100 + (150)[2]	37	215	48	210	163

1/ Average soil P and K test at initiation (1973) was 43 and 300 lb/A, respectively.

2/ Applied every three years which averages 50 lb/A/year.

Soil test results given in Table 3 show a gradual response to fertilizer P but little response to fertilizer K over this period. Fertilizer P applied for 7 years at the 50 lb P_2O_5 rate (either annually or at the 150 lb rate every 3 years) maintained soil test at about 40 while the 100 lb P_2O_5 rate increased the test to about 55. Soil test P dropped to less than 25 with no P application.

How were the yields affected? Corn yields over the last few years have been improved by the 50 lb P_2O_5/A/year application rate when the soil test ranged between 20 and 24 lb/A. Raising the soil test from 40 to 59 with the 100 lb rate did not improve the corn yields. Potassium additions had little effect on corn yield at these soil test K levels.

In summary, soil test P and K should be maintained at a high level to obtain high corn and soybean yields. These levels should not be "yield limiting" in a "non-limiting environment" necessary for consistent high yield production.

NON-LIMITING ENVIRONMENT RESULTS

In 1980, four non replicated demonstration plots were established at Waseca to determine the maximum corn and soybean yields that we could produce under a non-limiting environment. Supplemental water was applied from May 23 thru July 31 with trickle irrigation. The experimental procedures follow:

1) Crop system: Continuous corn
Corn following soybeans
Soybeans following corn
Continuous soybeans

2) Hybrid-varieties: Cargill 921
Pioneer 3732
Vickery

3) Row widths-population: Corn - 15"; 40,000 plants/A
Soybeans - 6 2/3"; 160,000 plants/A

4) Soil test levels: P = 265 lb/A VH
K = 940 lb/A VH

5) Fertility: Corn = 375 lb avail N/A as liquid dairy manure + 200 lb N/A as urea; No P or K
Soybeans: None

6) Pesticides: Corn = Lasso + Bladex and Counter
Soybeans = Treflan + Amiben

7) Planting date: Corn = April 21
Soybeans = May 1

8) Irrigation: Corn = 10.7 acre-inches
Soybeans = 6.2 acre-inches

9) Yield goal: Corn = 250 bu/A
Soybeans = 80 bu/A

The results from this demonstration show that we fell far below our yield goal (Table 4). The highest corn yield was 195 bu/A with one variety following corn with the second highest yield at 192 bu/A with the other variety following soybeans. Even though we added supplemental water the population was apparently too high for optimum corn production. Severe root lodging occurred with the 921 variety on June 27. By harvest most plants were lodged severely. Barren stalks were also common. These results indicate that final populations over 36000 are too high for maximizing yields with present-day varieties even in a "non-limiting environment".

Soybean yields following soybeans were substantially lower than when in a corn-soybean sequence. The plants on the continuous soybean plot reached maturity on September 11 which was 9 days earlier than after corn. This pre-mature ripening could have been due primarily to diseases.

Table 4. Corn and soybean production under a "non-limiting environment" at Waseca in 1980.

Crop System	Hybrid-Variety	Grain Yield	Barren Stalks	Root & Stalk Lodging	Final Popl'n
		bu/A	--------%	---------	x 10^{-3}
Cont. Corn	P 3732	195.0	12	44	39.0
" "	C 921	162.5	20	100	37.7
Corn after Sb	P 3732	175.2	ND[1/]	100	ND[1/]
" " "	C 921	192.0	24	100	38.8
Cont. Soybeans	Vickery	37.4			
Soybeans after Corn	Vickery	54.8			

[1/] ND = Not determined

SUMMARY

Obtaining consistently high corn and soybean yields takes careful planning and management. A farmer must implement all controllable factors into a "best management system" for his operation. He cannot concentrate only on high fertilization but must integrate fertilization with the other factors. He must use the utmost in N management such as sidedressing, crop rotations, nitrification inhibitors, drainage, etc. His P and K fertilization program must be adequate to maintain a high soil test level (not very high or super high levels as we sometimes see) which will provide a "non-limiting environment" with respect to P and K. Continued soil and plant analyses should be conducted to monitor both soil and plant nutrient conditions as farmers strive for higher yields.

FERTILIZATION FOR HIGH CORN AND SOYBEAN YIELDS UNDER IRRIGATION

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For a producer to obtain high corn and soybean yields numerous decisions must be made and implemented in a timely manner if he is to attain reasonable success. For all producers, fertilization is only one component of this management picture, and other decisions such as planting date, variety selection, tillage, seedbed preparation, weed control, insect control, plant population, as well as other decisions must be considered in the overall management programs. It should, however, be remembered that making all of these decisions do not guarantee high yields. The final yield attained is a reflection of not only management decisions but also how these decisions interacted with that particular growing season. Hopefully the management decisions made will enable us to attain those high yields in the good growing seasons.

FERTILIZATION UNDER IRRIGATION

The producer under irrigation must make many of the same production decisions as the producer under dry land. The fact that a producer has made a management decision to irrigate will in itself create new management decisions. The higher yield potential that may be made possible because of irrigation creates important fertilizer management questions that need to be evaluated.

The fertilizer management problems that may be encountered under irrigation are primarily a result of the difference which exists between soils. The following table lists some of the major soil characteristics and how they might differ between soils which are not or are commonly irrigated.

Soil Characteristic[1/]	Soil series			
	Webster	Barnes	Hubbard	Estherville
Crop equivalent Rating	90	65	36	42
Organic matter	High	High	Medium	Medium
Natural Drainage	Poor	Well	Excessive	Excessive
Available water in/5'	13.9	12.3	4.2	5.5
Common surface texture	clay loam	loam	loamy coarse sand	sandy loam

1/ Taken from Crop Equivalent Rating Guide for Soils of Minnesota. Misc. Report 132 by R.H. Rust and L.D. Hanson.

The Webster and Barnes soils are commonly non-irrigated productive soils of southern and western Minnesota while the Hubbard and Estherville soils are good examples of Minnesota soils which are commonly irrigated. The higher crop equivalent ratings for the Webster and Barnes series point out the highly productive nature of the soils in southern and western Minnesota. The lower ratings on the Hubbard and Estherville soils do not necessarily mean that these soils cannot attain high yield, but that a much higher level of management would be required to attain comparable yields. Irrigation is one management tool that is often used on these soils to help attain higher yields.

When you compare the typical irrigated and non-irrigated soils several different soil characteristics can be observed. The irrigated soils are characteristically coaser textured, leading to a much lower water holding capacity, and excessive drainage characteristics. This is often the most limiting production feature of these soils if they are not irrigated. These coarse textured, lower organic matter, low water holding capacity soils create many new fertilization problems that might not otherwise be present on the dry land soils of southern and western Minnesota. Because of the lower organic matter and clay content on these irrigated soils the reservior for holding onto many plant essential nutrients is reduced. For this reason certain micronutrients and also some of the secondary macronutrients (magnesium and sulfur) could become limiting for high corn and soybean production.

The coarse textured nature and low water holding capacity of these soils also creates a problem due to downward movement or leaching of any nutrient or substance that is free to move with soil water. This becomes of special consideration when evaluating options concerning nitrogen management, since the nitrate form of nitrogen can move very readily with soil water. The potential for nitrogen fertilizer loss on the coarse textured soils is much greater than what might be obtained on the finer textured soils in Minnesota.

The remainder of this paper will discuss some of these important considerations and will review some of the current research information dealing with: 1) nitrogen management; 2) secondary macronutrient and micronutrient fertilization; and 3) other management variables for high corn and soybean production under irrigation.

NITROGEN MANAGEMENT UNDER IRRIGATION

Since nitrate nitrogen losses by leaching can be a severe problem on coarse textured soils, nitrogen management options become much more limited for a producer under irrigation than for a producer in southern or western Minnesota. Fall applications of nitrogen should be avoided on these coarse textured soils, and in many cases, preplant applications or early spring applications are discouraged. Recommended options normally call for split applications during the growing season (through the irrigation system) and/or with sidedress applications. Both of these management decisions must be flexible enough to guarantee that sufficent amounts of nitrogen are applied to the crop in adequate time so yield reductions are not encountered. The introduction of nitrification inhibitors such as N-Serve (Dow Chemcial Co.) appears to allow considerable more flexibility in nitrogen management than was available in the past.

Table 1 presents 1980 data evaluating the importance of nitrogen management and use of nitrification inhibitors under irrigation. In 1980 yield responses of corn to the application of fertilizer nitrogen was as high as 128 bu/A demonstrating the importance of nitrogen management. Yield reductions due to loss of fertilizer nitrogen because of early application ranged from 30-40 bu/A. Sidedress applications reduced but did not eliminate in all cases the potential yield reductions that were observed between preplant applications and split applications during the growing season (split-4). In most cases except one, (75#N/A-preplant) the use of a nitrification inhibitor in situations where nitrogen loss appeared to be a major problem resulted in substantial yield increases (46 bu/A-150#N/A preplant). Single major applications as late as tasseling did give some yield response, but this appeared to be limited to the first 75#N/A with very little response to higher application rates. Other combinations of split nitrogen application (split-2) showed only limited success (split-2 2/3, 1/3, 225#N/A). In most cases the split-2 combinations were inferior to many of the single N application treatments especially the early application with an inhibitor.

Although results from sidedress applications of nitrogen appear to be quire favorable, in 1980 there appeared to be a quantity of nitrogen beyond which late applications reduced grain yields. A tendancy for reduced yields were found in 1980 (Table 1) when 225#N/A was applied (as urea) at the 12-leaf stage. A similar trend was also observed in another trial (Table 2) utilizing anhydrous ammonia. Sidedress applications tended to increase grain yield at the lower nitrogen rate (75#N/A) but decreased grain yields at the higher rate of anhydrous ammonia application (150#N/A). Possibly due to the caustic effect of the ammonia on the rooting system. This is another factor that must be considered in the overall nitrogen management program.

SECONDARY MACRONUTRIENTS AND MICRONUTRIENTS

In addition to nitrogen management, which is probably the single most important fertility consideration under irrigation, concern must also be expressed for other nutrients. To obtain high yields requires not only nitrogen fertilization but also any other nutrient which might be limiting the potential yield. This first of all must include phosphorous and potassium for which soil test are available, but also other nutrients which may become limiting because of the soil type and the irrigation environment.

Trials were established at the Sand Plains Research Farm three years ago to evaluate the importance of fertilization with various secondary macronutrients and micronutrients. The trials established in a corn-potato rotation have been conducted for three years and the results are contained in Table 3. The 1980 results suggested a response trend for applications of boron, and zinc. This was the first year for a boron response. The three year average would suggest that the only nutrient thus far, which has given a consistent response has been zinc (soil test was marginal). Although zinc and boron have been the only nutrients that we have given a yield response in this experiment it is not uncommon for coarse textured soils under irrigation to show response to sulfur application and in some cases magnesium fertilization. Yield levels from this experimental area have been excellent over the last three years.

As this experiment is continued in the future, and as high yields put pressure of the fertility of the soil, additional nutrients may show signs of becoming limiting for the production of high yields.

OTHER MANAGEMENT VARIABLES FOR HIGH PRODUCTION

As higher and higher yields are attained questions are often raised as to how we can continue to increase our production. Are our old ideas and concepts of crop production still valid at these high production levels? Should we adjust our recommendations to account for such variables as plant population, crop variety, tillage, or any other management input? The answers to these questions are not complete, but as research information is obtained we have a better knowledge in assessing these questions.

To examine some of these management questions, a trial was established to look at three management variables: plant population, fertilization and plant row spacing. The experiment established is in a corn-soybean rotation, the area has been limed, and base applications of potassium-magnesium sulfate made to the entire area. In 1980 corn (Pioneer 3901) was planted on April 29th at populations of 28, 35 and 42 thousand plants per acre. Fertility variables included a nitrogen only treatment plus treatments which might be considered "high" and "extra high". The results from this experiment in 1980 are included in Table 4. Because of the potential for eliminating water stress because of irrigation higher plant populations may be sustained with reasonable success. Large increases in yield were not obtained with any of the variables tested. The 35,000 ppa population had a slightly higher overall yield than 28,000 ppa. The first level of fertilization also tended to show higher average yields than the control, but most of this came at the higher populations. The data would suggest relatively little incentive for the high plant population or extra high fertilizer application rates. This is, however, relatively limited data and varying management practices and varieties may show different responses.

GENERAL CONCLUSIONS

Fertilization for high yields under irrigation:

1. Nitrogen fertilization and nitrogen management are key management decisions.
   a) management programs must be flexible enough to allow substantial nitrogen applications well in advance of tasseling.
   b) sidedress applications of N are superior to single applications at planting although multiple applications are often even better.
   c) if nitrogen is applied prior to the eight-leaf stage of growth the use of a nitrification inhibitor would be recommended to minimize nitrogen loss.

2. On coarse textured irrigated soils yields may be restricted because of a limited supply of certain secondary micronutrients. (Sulfur and magnesium) or micronutrients (zinc, boron?). Soil tests are available for many of these nutrients and should be utilized in assessing nutrient needs.

3. Other management inputs and its relationship to fertilization will be continually examined in the future.

Table 1 Corn Grain Yields as Influenced by Timing of Nitrogen Applications and Use of Nitrification Inhibitors - Becker, MN 1980

Time of Nitrogen Application[1/]	Grain Yield -15.5% M			
	Nitrogen rate - #/A			
	0	75	150	225
	bu/A			
preplant	81	141 (149)[2/]	153 (199)	189 (204)
8-leaf		150 (170)	188 (193)	201 (201)
12-leaf		164 (167)	193 (180)	184 (182)
Tassel		143	148	152
[3/]Split 4		172	190	191
[4/]Split-2 (1/3, 2/3)		165 (161)	172 (181)	196 (199)
Split-2 (2/3, 1/3)		132 (156)	157 (190)	209 (204)

1/ All nitrogen aplied as urea with the nitrification inhibitors applied as a coating onto the fertilizer.

2/ ( ) denote yield obtained with the use of a nitrification inhibitor (N-Serve 0.5# ai/A - Trademark of Dow Chemical Co.

3/ Split-4=1/6 applied at planting, 1/6 at 8 leaf stage, 1/2 at the 12-leaf stage and 1/6 at tassel.

4/ Split-2=First application at planting, second application at the 12-leaf stage - where applicable, nitrification inhibitors were applied only with the first application.

Table 2 Corn Grain Yields as Influenced by Timing of Nitrogen Application and Use of Nitrification Inhibitors - Becker - 1980

Nitrogen Form	Time of N Appl.	Grain Yield - 15.5% M Nitrogen Rate - #/A 0	 75	 150
		----------bu/A----------		
Anhydrous Ammonia	preplant	93	159 (175)*	186 (184)
	8-leaf		169	180
	12-leaf		172	168
28% N Soln	preplant	93	157 (164)	174 (179)
	8-leaf		158	182
	12-leaf		145	178

*(   ) denote yields obtained with the use of a nitrification inhibitor (N-Serve - 0.5#ai/A - Trademark of Dow Chemical Co.)

Table 3 Corn Grain Yields as Influenced by Secondary Macronutrient and Micronutrient Fertilization - Becker, MN 1980

Treatment	Yearly Appl. Rate	Grain Yield - 15.5% M	
		1980	1978-1980
	#/A	bu/A	
Control	-	194	187
Copper	5	197	186
Boron	2	206	188
Sulfur	25	196	186
Magnesium	75	195	186
Zinc	10	201	192
Manganese	3	197	185

Table 4 Corn Grain Yields as Influenced by Plant Population Fertility Level and Row Spacing - Becker, MN 1980

Fertility Treatment				Grain Yield - 15.5% M			
				Plant Population - Thousand/A			
			Row	28	35	42	
N[1/]	P_2O_5	K_2O	Spacing	30"	30"	15"	30"
	#/A			---------------bu/A-------------------			
220	0	0		195			
220	60	220		190	199	200	203
330	90	330		195	197	198	198

1/ N applied as urea in three applications during the growing season.

FERTILIZING CORN WITH MANURE

Samuel D. Evans
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INTRODUCTION

Utilization of manure as a fertilizer and/or soil amendment is still the most practical manner of handling manure from most livestock operations. With the increased cost of fertilizer and energy, land application of manure has received renewed attention in recent years. A number of experiments have been conducted in Minnesota since 1970 involving application of manure to land cropped to corn. A trial was started at the West Central Experiment Station at Morris in 1970 involving very heavy applications of solid and liquid beef manure, and liquid hog manure. In 1972 another experiment was initiated at Morris to look at lower rates of both liquid and solid beef manure on continuous corn production. In 1975 another series of experiments was started at Crookston, Morris, and Waseca to investigate the breakdown rate and availability of nitrogen contained in liquid cattle manures. All of these experiments are underway and today I would like to go over some of the results of this work.

NUTRIENTS IN MANURE

What nutrients do we find in manure that are required by the corn crop? All manures contain the primary, secondary, and micronutrients required by all crops. Analysis of manure samples shows a tremendous variation due to many factors such as type and age of animal, ration, and storage method.

Nitrogen is one of the elements most subject to variation. Some examples of N losses during storage and handling are shown in Table 1.

Table 1. Nitrogen losses in handling and storage.

System	N lost
	- % -
Solid	
Daily scrape and haul	25
Manure pack	35
Open lot	55
Deep pit (poultry)	20
Liquid	
Anaerobic pit	25
Oxidation ditch	60
Lagoon	80

Losses can also be greatly affected by method of application (Table 2). Any method which gets the manure quickly incorporated will essentially reduce N losses to zero.

Table 2. Estimated nitrogen loss within four days from livestock or poultry manures with different application methods.

Method of application	Type of waste	N lost
		- % -
Broadcast	Solid	21
	Liquid	27
Broadcast and immediately	Solid	5
cultivated	Liquid	5
Knifing	Liquid	5
Sprinkler irrigation	Liquid	25

Example analyses of beef and hog manures used in experiments at Morris in 1970-71 are shown in Table 3. As can be seen, the manures contain large amounts of the primary nutrients--N, P_2O_5, and K_2O--and small amounts of the micronutrients--Fe, Mn, Zn, and Cu.

Table 3. Average analysis of three types of manure used in 1970 and 1971 at West Central Experiment Station.

	Type of manure		
Variable	Solid beef	Liquid beef	Liquid hog
	- % -	- % -	- % -
Solids	29.9	10.6	3.8
	lbs/ton	lbs/1000 gal	lbs/1000 gal
N	19.2	67.9	31.4
NH_4^+-N	8.4	45.9	24.4
Organic N	10.8	22.0	8.0
P_2O_5	9.5	65.4	22.6
K_2O	22.2	45.9	25.0
Iron	0.78	0.92	0.72
Manganese	0.07	0.20	0.16
Zinc	0.05	0.21	0.47
Copper	0.01	0.03	0.05

EXPERIMENTAL RESULTS

Experiment I

Solid beef manure was applied at 100 tons/A (wet weight) and liquid beef and hog manures at 68,000 gallons/A in October of 1970 and 1971. The applications were made on a silt loam soil to the same plots each year. One-half of the designated amount of manure was weighed and uniformly spread over the plot area. The soil was then moldboard plowed to a depth of 5 inches as soon as the soil had dried enough to permit adequate traction. The remainder of the manure was then weighed and applied in the same manner. After drying, the soil was then plowed to a depth of 10 inches.

Total primary nutrient application rates are given in Table 4. It can be seen that the levels are much higher than needed by the corn crop. However, yields (Table 5) on the manure treated plots have been comparable to those on plots receiving inorganic fertilizer. Yields on the hog manure treated plots have started to drop the past 2 years.

Table 4. Application rates of total N, P_2O_5, and K_2O, 1970-71.

	Type of manure		
Nutrient	Solid beef	Liquid beef	Liquid hog
		- lbs/A -	
Total N	3840	9230	4270
P_2O_5	1680	6240	3320
K_2O	2160	2990	1090

Table 5. Effect of fertilizer and three types of manure on corn grain yields.

	Treatment				
Year	Check	Fertilizer*	Solid beef	Liquid beef	Liquid hog
			- bu/A -		
1972	66	103	121	109	124
1980	45	120	120	119	106
10-year average	59	101	102	98	99

* Annual application of 120 + 40 + 40 (N + P_2O_5 + K_2O in lbs/A).

Manure applications were discontinued after 1971 due to (1) some salt damage from the high rates of salt in the liquid beef manure and (2) nitrate-nitrogen (NO_3-N) leaching below the rooting depth of corn by the end of the second year. Downward NO_3-N movement has continued as shown in Table 6. By the fall of 1978 there was considerable NO_3-N movement to the 8-foot depth with solid beef and liquid hog manure and to the 12-foot depth with liquid beef manure. The residual NO_3-N levels in the liquid hog manure plots are very close to those in the fertilized plots in the upper 3 feet.

Table 6. Effect of manure application on the NO_3^--N content of the soil profile after eight years (fall 1978).

	Treatment				
Depth	Check	Fertilized	Solid beef	Liquid beef	Liquid hog
- ft -	- ppm, NO_3-N -				
0-1	4	7	14	17	8
1-2	1	21	25	77	15
2-3	3	73	97	164	74
3-4	4	36	116	146	62
4-6	6	11	65	93	34
6-8	4	4	29	45	21
8-10	3	3	16	33	13
10-12	3	2	7	22	8
12-14	3	3	7	10	5
14-16	2	3	6	11	4

Soil tests for P and K have shown a tremendous increase (Table 7). As can be seen, the levels with all three manures are many times higher than recommended for maximum crop yields, but have not caused any major nutrient imbalances which have affected yield. One reason for this may be that secondary and micronutrients are being added in substantial amounts. For example, zinc additions were approximately 10, 29, and 64 lbs/A with the solid beef, liquid beef, and liquid hog manures, respectively.

Table 7. Effect of manure treatments on soil P and K tests* (top 1 foot of soil), 1976-78 average.

	Treatment				
Element	Check	Fertilized	Solid beef	Liquid beef	Liquid hog
	- lbs/A -				
P	16	78	268	352	232
K	426	487	1569	1240	808

* Relative P and K levels - -
Phosphorus: Low = 0-10, Medium = 11-20, High = 21-30, Very high = >30
Potassium: Low = 0-100, Medium = 101-200, High = 201-300, Very high = >300

Experiment II

Due to the salt damage and NO_3-N leaching in Experiment I, a second experiment was started in the fall of 1972 including lower rates of solid and liquid beef manures. The target rates of solid beef manure were 10, 20, and 30 tons of dry matter/A/year. Because of variations in the manure actual applications have averaged 8.9, 17.8, and 26.7 tons/A/year (dry basis) or 32, 64, and 96 tons/A/year (wet basis). The liquid beef manure was applied at the same rate each year on a wet basis--4530, 9060, and 13,590 gallons/A/year. Again, because of variation in the manure from year-to-year the actual rates applied each year were different but averaged 1.6, 3.2, and 4.8 tons/A/year (dry basis). Manure was applied every fall from 1972 thru 1979 except for 1977.

Some of the yields are shown in Table 8. It can be seen that the lowest rates of each manure have plot yields which are equal to or greater than the fertilized plot. Leaching of NO_3-N below the root zone of corn has occurred (Table 9) and increases with increasing rates of manure. The levels of NO_3-N with the lowest rate of each manure are nearly equal to those in the fertilized plots. Soil test levels of P and K (Table 10) are much higher on the manured treatments than on the fertilized treatment. From this work it would appear that LB1 (4530 gallons/A/year of liquid beef manure) was adequate to obtain good corn yields for western Minnesota. However, soil P and K levels were high enough at the end of 1978 so that it would be possible to apply only N as a fertilizer until P and K levels dropped to where fertilizer response could be expected. Even the lowest rate of solid beef manure (SB1) appeared excessive because the N application rates were far above the requirements for corn. A rate of 16 tons/A/year would appear to supply adequate N, but would probably result in increasing levels of soil P and K.

Table 8. Effect of fertilizer and rates of two types of beef manure on corn grain yields.

	Treatment							
Year	Check	Fertilized*	SB1	SB2	SB3	LB1	LB2	LB3
				- bu/A -				
1973	112	129	141	131	138	130	134	137
1980	69	116	122	111	124	123	125	135
8-year average	76	96	104	97	109	100	106	106

* Annual application of 120 + 50 + 50 (N + P_2O_5 + K_2O in lbs/A).

Table 9. Effect of manure application on the NO_3-N content of the soil profile after six years (fall 1978).

Depth	Treatment							
	Check	Fertilized	SB1	SB2	SB3	LB1	LB2	LB3
- ft -	ppm, NO_3-N							
0-1	5	9	16	33	58	9	14	18
1-2	2	50	58	153	121	25	116	127
2-3	3	80	102	202	208	92	105	206
3-4	6	50	34	140	167	34	64	114
4-5	7	20	14	27	101	14	46	36
5-6	6	11	7	10	63	8	23	19
6-7	6	8	7	22	38	8	11	13
7-8	5	8	6	9	22	6	7	7
8-9	4	7	6	8	14	4	6	7
9-10	4	6	4	6	9	4	6	5

Table 10. Effect of manure treatments on soil P and K tests* (top 1 foot of soil), 1976-78 average.

Element	Treatment							
	Check	Fertilized	SB1	SB2	SB3	LB1	LB2	LB3
	- lbs/A -							
P	29	32	173	313	375	71	168	255
K	491	478	1273	2036	2940	583	772	878

* Relative P and K levels - -
Phosphorus: Low = 0-10, Medium = 11-20, High = 21-30, Very high = >30
Potassium: Low = 0-100, Medium = 101-200, High = 201-300, Very high = >300

Experiment III

With the large increases in fertilizer N prices in the mid 70's, it was felt that more efficient use of the N in manure was essential. Therefore, experiments were set up at Crookston, Morris, and Waseca to investigate the breakdown rate of the organic N fraction of various liquid manures. The experiments were started in the fall of 1975 and manure applications were made each fall thru 1979. Response to the N in manure was compared to the response to N applied at equivalent rates as urea. It was assumed that all the NH_4^+-N and 25% of the organic N was available to the next year's crop. Of the organic N remaining each year, it was assumed that 15% became available each year. Adequate P and K were supplied in all treatments.

Presented in Table 11 are the 5-year average yields at the three locations. At all locations the yields with urea are almost the same as the yields with manure. For example, the yields at Morris with 60 lbs/A of N supplied as urea was 81 bu/A while the yields with 60 lbs/A of N supplied as liquid beef manure was 79 bu/A. From this data it can be seen that it is possible to calculate the organic N breakdown rate and use this to estimate the manure required to supply a given rate of N for corn.

Table 11. Effect of urea and liquid cattle manures at various N application rates on corn grain yields, 1976-80.

		Location		
N Rate*	N Source**	Crookston	Morris	Waseca
			- bu/A -	
0	-	58	52	82
Low	F	69	71	108
Low	M	72	68	109
Medium	F	80	81	120
Medium	M	74	79	120
High	F	88	96	123
High	M	84	90	121

* N rates were 25, 50, and 75 lbs/A at Crookston; 30, 60, and 90 lbs/A at Morris; and 60, 120, and 180 lbs/A at Waseca.

** F = N supplied as urea, M = N supplied as liquid beef manure at Morris and liquid dairy manure at Crookston and Waseca.

SUMMARY

From the work I have gone over, you can see that manure can be used as the sole source of nutrients for corn or can supply part of the nutrients while the remainder can be supplied in fertilizer. For the most efficient use of the manure it would be best to adjust application rates to supply the P needed by the corn crop and supplement with N and K if needed. This is because Experiments I and II show a buildup of soil P levels, even with rates of manure that supply adequate N. Calculations must be made taking into account the analyses of the manure, the availability of the N in the manure, and crop requirements. These calculations can be based on average manure analyses but actual analyses from individual farms would be better. In either case it would be advisable to keep good records on each field and to take periodic soil tests to monitor soil P and K levels.

UPDATE ON FERTILIZING SUNFLOWER

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Large increases in the sunflower acreage in Minnesota in the last three years have prompted the need for more information on fertilizing sunflower. At the same time, fertilizer recommendations must be evaluated in relationship to the many other factors in sunflower production. These factors include cultivar selection, plant population, weed control, crop rotations, moisture availability, diseases, insects, lodging, and tillage. Maximum yields can be obtained when they are most favorable and all must be considered by each grower for the area in which he farms. All of these factors are important in sunflower production, but the emphasis here will be on soil fertility. Many experiments have been conducted to determine the response of sunflower to nitrogen, phosphorus and potassium.

Nitrogen experiments conducted on sunflower statewide have given a mixed bag of results (Table 1). Soil test levels are shown for each location at the bottom of Table 1. In each case, response or no response, other factors have contributed heavily to the final results.

Table 1. Nitrogen rate studies on sunflower in Minnesota (1978-79).

	Yield							
	1978					1979		
N Rate	Ueland	Lamberton	Morris	Frodl	Marzahn	Morris	Waseca	Becker
lb/A	lb/A							
0	1940	2030	2090	1980	2550	1520	1930	1010
30	2230	1950	2110	2100	2510	1990	1850	--
60	2210	2000	2100	2100	2460	2090	1780	1750
90	2260	1920	2110	2070	2510	2330	1620	1820
120	1960	2260	2180	2440	2610	2430	1570	1870
150	2260	2040	2140	2080	2520	2320	1580	1940
Significance	N.S.	N.S.	N.S.	*	N.S.	**	*	**
B.L.S.D. (.05)						180	280	250
C.V. (%)	13.4	9.7	4.8	9.8	12.5	6.8	9.8	10.2
Soil Test Nitrate (0-2')	74	73	71	57	59	31	56	10

Phosphorus experiments on sunflower conducted in northwestern Minnesota have produced similar results (Table 2). Again, response was usually dependent on one or more of the other factors cited earlier.

Table 2. Phosphorus rate studies on sunflower in northwestern Minnesota (1978-80).

P_2O_5 Rate	Yield						
	1978	1979				1980	
	Ueland	Crookston	Fosston	McIntosh	Blackduck	Fosston	McIntosh
lb/A	lb/A						
0	1820	1460	1940	1680	1460	1990	1940
40	2270	1600	1990	1610	1420	2100	2400
80	2150	1810	1950	1880	1510	2100	2310
120	1890	1770	2010	2000	1360	2300	2380
160	1980	1580	2160	1960	1700	2170	2340
200	2300	1630	2350	2030	1470	2310	2470
Significance	**	N.S.	**	**	N.S.	N.S.	**
B.L.S.D. (.05)	300		230	260			320
C.V. (%)	9.3	14.2	7.0	8.8	10.7	11.1	8.4
Soil Test P Levels	2	13	20	11	11	30	12

Potassium experiments have also produced similar results (Table 3).

Table 3. Potassium rate studies on sunflower in Minnesota (1979-80).

K_2O Rate	Yield					
	1979				1980	
	Crookston	Fosston	McIntosh	Blackduck	Fosston	McIntosh
lb/A	lb/A					
0	1490	2090	1630	880	1920	2500
50	1590	2080	1630	1080	1930	2400
100	1460	2150	1770	940	1860	2260
150	1800	2120	1840	860	2090	2180
200	1740	2000	1900	--	2100	2360
250	1790	2100	1920	860	2070	2270
Significance	N.S.	N.S.	**	N.S.	N.S.	N.S.
B.L.S.D. (.05)			170			
C.V. (%)	18.7	7.7	6.1	23.2	12.1	7.7
Soil Test K Level	103	227	196	154	340	340

What this seems to point out is the interdependence of all the factors involved. By making decisions to maximize the positive effects of each factor, in this case soil fertility, a grower can hopefully minimize the negative effects and thus obtain maximum sunflower yields.

NEW DEVELOPMENTS IN SOIL TESTING

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MIDWEST

Much of the progress in soil testing made in the Midwest has been brought about by the activities of the NCR-13 Regional Soil Testing Committee. The Committee has been active since 1957 and its members represent 14 state universities and two Canadian provinces. Its main objectives are: (a) to improve methods and operations of soil and plant analysis laboratories; (b) to improve fertilizer and lime recommendations based on analytical results; (c) to disseminate information. The members, assigned to 13 subcommittees, are given tasks ranging from literature reviews and surveys to studies in the laboratory and in the field.

Among its accomplishments, the NCR-13 can list publication of the Regional Bulletin No. 221, Recommended Chemical Soil Test Procedures, 1975. This bulletin gives recommended procedures for determining soil pH, lime requirement, extractable phosphorus and potassium. It also contains a discussion of laboratory techniques. These procedures were adapted after several years of discussion, research and sample exchanges among the member states. The objective of publishing these procedures was to foster uniformity in lab operations among states claiming to use the same procedure but which differed in detail from the original. This publication has gained wide dissemination and acceptance from commercial soil testing laboratories both within and outside of the region. The publication has been revised to include procedures for organic matter, sulfur, micronutrients and for the greenhouse test. The revised bulletin will be available in January 1981.

The NCR-13 has also sponsored Soil-Plant Analysts' Workshops. The purpose of these workshops is to foster cooperation between University and commercial soil testing laboratories. Topics covered deal with soil testing procedures and lab-related problems of interest to both. These workshops have been well-attended by representatives of commercial laboratories and industry. The 8th Workshop will be held during November 1981 in Cleveland, Ohio.

MINNESOTA

An important responsibility of the Soil Science Department is to provide the farmer with reliable information on the use of fertilizer and soil amendments. Continuing research by soil scientists provides information which is implemented into soil test analyses and recommendation programs.

The University's soil testing program has undergone many changes since the establishment of its laboratory in 1950. Testing procedures and equipment have improved and several new tests introduced. Recommendations also have been updated, generally every two years. Mr. William Jokela and I have been asked to bring you up to date on recent changes in soil testing.

Preliminary steps to revise fertilizer recommendations for farm crops were taken during last summer. By December the first draft of recommendations was available. During winter additional changes were made in consultation and meetings with research workers, extension specialists and area agents. In February plans were finalized for the revision of recommendations, sample information sheet and report form.

It seemed most important that the new recommendations would be available to customers by mid-September at the latest. From meetings with the Computing Center people, it became apparent that in order to have the revised recommendations available by fall, no major changes could be made involving the present format of the information sheet or tests offered. By September 15, all planned changes had been made and the program was ready to go.

The revision is not completed. Additional changes in the program will be necessary to incorporate all revisions including additional tests (magnesium, copper), address, sampling depth, and entries desired by the Soil Survey people. It is hoped to have the program completely revised by next fall.

The Soil Sample Information Form

Since very minor changes could be made the form is basically the same as the old one. There is a new category for the depth of sampling entry which is important for the nitrate test (0-6", 6-24", 0-24"). Listed are only those tests that are actually provided. Current testing fees are given. There are some minor changes in the sampling instructions, on the reverse side of the form, mainly relating to the nitrate test.

The Soil Test Report

The test report is quite different from the old one. The old report accommodated up to six samples, gave recommendations for two years and contained many valuable tips on fertilization and liming. Customers, however, often found the recommendations hard to understand and were reluctant to read the "fine print".

The new report form is designed to accommodate only one sampling area (field or part of a field) and to provide fertilizer recommendations for only one year. The front side of the report consists of four main parts. 1. Address, Report No., dates when received and reported. 2. Test results. Although currently the report form accommodates only one sample, space is available for reporting results of three samples collected from different sampling depths either from the plow layer or the subsoil. Space is also available for additional tests which may be introduced in the future. 3. Recommendations. Over 50 percent of the available space is reserved for the printout of specific recommendations. 4. Location, soil series, receipt, county agent's name and telephone number. An explanation of soil tests, relative levels of nutrients and a listing of crops according to their tolerance of soluble salts is given on the reverse side of the report form.

Testing Fees

The University of Minnesota Soil Testing Laboratory was forced by inflation to increase its testing fees on September 15, 1980. The testing fee charged for the regular series (pH, lime requirement, P, K, texture and estimated O.M.), for example, is now $4.00 per sample, compared to $3.00 charged previously.

Turn-around-time

Service laboratories are continuously pressured to speed up sample processing and reporting of results. We have been quite successful in achieving a turn-around-time of 5 to 7 days. Reports of samples received on Monday or Tuesday usually are mailed out about five days later, while those of samples received either on Thursday or Friday are ready in seven days. Since at least two days are required for mailing or shipping a sample and another two or three days for mailing the report, the customer actually may have to wait 10 to 14 days for the recommendations.

There is considerable interest among industry, ag consultants and extension concerning the possiblity of further cutting the turn-around-time by intercepting the analytical results as they become available. The new computer of the St. Paul Campus Computing Center has capability of using remote facilities for both data entry and report retrieval.

REVISED COMPUTERIZED FERTILIZER RECOMMENDATIONS PROGRAM

UNIVERSITY OF MINNESOTA - 1980

William E. Jokela
Assistant Extension Specialist - Soils

WHY REVISE THE U OF M RECOMMENDATIONS PROGRAM?

Any changes in the recommendations program are made to provide an improved product to the customer: the fertilizer dealer, the agricultural consultant, and ultimately the farmer. In the current revision these changes are in two general areas: new report form that provides more complete information in an easily understandable form and an update in the actual fertilizer recommendations based on current research results and production practices.

NEW REPORT FORM

The most visible change is the new report form (figure 1). The results of only one field or sample area are reported on one report sheet. This provides space on the report for explanatory comments that adjust or refine the basic fertilizer rate recommendations. The capacity of the computer is more fully utilized to tailor the report to the specific needs of the customer on the basis of various soil and crop inputs.

The report contains the following information:

a) Soil test results.

b) Recommended nitrogen, phosphorus, and potassium rates for the crop and yield level indicated.

c) Adjustments to the basic NPK rates and other recommendations for the specific crop and soil conditions.

d) Secondary and micronutrient recommendations.

e) Information on sample area location for use in adjusting recommended rates according to subsoil properties.

UPDATED FERTILIZER RECOMMENDATIONS

Fertilizer recommendations need to be updated periodically to keep abreast of recent research results, changing crop production practice, and increasing yield potentials. The major changes in the present revision are as follows:

a) Adjustment of rates of phosphate and potash, as well as nitrogen, according to yield level.

Where high yields are attainable it is more critical to build low or medium soil test levels quickly than where other factors limit yields. In addition the removal of plant nutrients varies greatly depending on yield harvested.

An example is potash topdress application on alfalfa (table 1). The recommendation for most of the higher yield levels has been increased considerably, whereas that for the lowest level has been reduced.

b) "Maintenance only" recommendations of phosphate and potash on high testing soils at high yield levels of corn, soybeans, and alfalfa.

As shown in the example of phosphorus on corn (table 2) maintenance rates are recommended in the 31 to 40 P test range for expected yields over 115 bu/A. Although a direct yield response to phosphorus application may not occur in this range the recommendation is made for maintenance purposes to prevent the soil test from dropping to a level where yields will be reduced.

c) Increased previous crop credit for nitrogen on corn.

Research from Iowa, Wisconsin and Minnesota has shown that corn following soybeans or small grain requires about 40 lbs/acre less fertilizer nitrogen than continous corn for top yields. This is more nitrogen credit than had been given for these previous crops in the past. This new information has been incorporated into the nitrogen recommendations for corn at higher yield levels.

d) Increased emphasis on use of the nitrate test to make nitrogen recommendations.

The rate of nitrogen fertilizer required for optimum yields can vary considerably from year to year depending on weather, soil properties, and crop and fertilizer history. This rate can be estimated from past crop, organic matter level, and expected yields, but a much more accurate recommendation can be made for many crops in western Minnesota by use of a nitrate test. The nitrate test, which requires a sample taken to a depth of two feet, is presently used to make nitrogen recommendations for small grain, sugarbeets, potatoes, sunflowers, dry edible beans, and a few other crops.

The nitrate test is not new in Minnesota but the revised program places more emphasis on its use. For applicable crops in western Minnesota for which a nitrate test has not been run, the following statement appears on the computer printout:

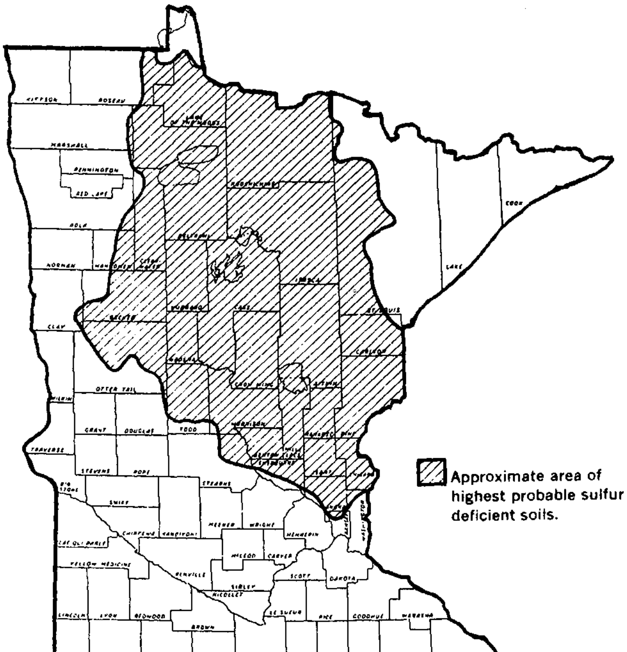
N RECOMMENDATION IS A GENERAL ESTIMATE BASED ON PREVIOUS CROP AND ORGANIC MATTER LEVEL. A TWO FOOT SAMPLE FOR NITRATE TESTING IS STRONGLY RECOMMENDED FOR MORE ACCURATE N RECOMMENDATION.

The nitrate test is not presently used for corn. However, progress is being made at developing recommendation guidelines for corn based on four years of research in southwestern Minnesota and other parts of the state. At present farmers may want to use deep nitrate test as supplementary information where high nitrate levels are suspected.

d) Sulfur recommendation.

The sulfur soil test is a useful aid in determining which soils are most likely to be sulfur deficient, but it must be used in combination with other factors that affect the sulfur status of crops. The greatest probability of sulfur deficiency is on coarse textured soils of low to medium organic matter. These sulfur responsive soils are located primarily in central and north central Minnesota (figure 2). Consequently, sulfur has been recommended for low soil tests in this area only in the past.

figure 2.



The same principles have been used to develop the present sulfur recommendations (table 3), which are based on the sulfur test, the texture and organic matter of the soil and the specific crop, regardless of the area of the state.

Additional considerations not accounted for in the table are contributions from atmospheric sulfur in the vicinity of metropolitan or industrial center and the occurence of sulfur as gypsum in the subsoil of some western Minnesota soils.

FUTURE DEVELOPMENTS

Certain developments are anticipated that will lead to further improvement of fertilizer recommendations to the customer. Soil survey maps and related information provide an opportunity to utilize soil type to refine present recommendations. Information on subsoil pH and nutrients, drainage characteristics, and other soil properties, with the help of the computer, could be integrated with soil tests and other soil, crop and even weather information, to improve the reliability of the recommendation.

More widespread availability and use of computers provides another means of improving service to the customers. Direct access to the University computer system would allow out state customers and county agents to obtain soil test results and recommendations as soon as they are entered in the main computer, thus eliminating delays due to mailing time.

In addition, the University fertilizer recommendations program may soon be available for use by commercial soil testing labs in Minnesota or out of state. This would allow them access to recommendations that are continually updated according to current University research. Also, work is presently being done to adapt the computerized fertilizer recommendations program to use in the many micro computers located around the state. This would allow the individual dealer, farmer, or county agent the flexibility to quickly adjust recommendations to accommodate changes in cropping plans, expected yield levels, and other factors.

Table 1

ALFALFA

ANNUAL POTASSIUM RECOMMENDATIONS FOR ESTABLISHED STANDS

Expected Yield (tons/acre)	Potassium (K) Soil Test (lbs/A) 0-75		76-150		151-225		226-300		301-350		Over 350
	-lbs/acre K_2O to apply*-										
	F-M	C	F-M	C	F-M	C	F-M	C	F-M	C	
Over 7	370	400	320	350	270	300	220	250	120	150	0
7	320	350	270	300	220	250	170	200	90	120	0
6	270	300	220	250	170	200	120	150	60	90	0
5	220	250	170	200	120	150	70	100	40	50	0
4	170	200	120	150	70	100	40	50	0	0	0
3 or less	120	150	70	100	40	50	0	0	0	0	0

*F-M is fine or medium texture (L, SiL, SiCL, CL, C)
C is coarse texture (S, LS, SL)

Table 2

CORN

PHOSPHORUS RECOMMENDATION

Expected Yield		Phosphorus (P) Soil Test (lbs/A)												
		0 - 10			11 - 20			21 - 30			31 - 40			Over 40
		Subsoil P Level												
Grain (bu/A)	Silage (tons/A)	L	M	H	L	M	H	L	M	H	L	M	H	
Over 175	Over 24	160	140	120	130	110	90	110	90	70	60	50	40	0
156-175	22-24	145	125	105	115	95	75	100	80	60	60	50	40	0
136-155	19-21	130	110	90	100	80	60	90	70	50	50	40	30	0
116-135	16-18	115	95	80	90	70	50	80	60	40	50	40	30	0
96-115	13-15	100	80	70	80	60	50	70	50	30	0	0	0	0
76-95	10-12	90	70	60	70	50	40	60	40	30	0	0	0	0
75 or less	9 or less	80	60	50	60	40	40	50	30	0	0	0	0	0

Table 3

SULFUR RECOMMENDATIONS

	Low or Medium Organic Matter And Sand, Loamy sand, Sandy Loam, or Loam		High Organic Matter and/or Finer Texture		
	Sulfur Soil Test				
Crop	0-6 ppm (low)	7-12 ppm (med)	0-6 ppm (low - med)	7-12 ppm (med - high)	>12 ppm (high)
	lbs/acre actual sulfur to apply				
Alfalfa	50 every 3 yrs (every 2 yrs if irrig.)	Irrig: 50 every 2 yrs Non-irrig: Trial only	Trial only	None	None
Corn, Dry edible beans	20 bdcst or 10 row	Irrig: Trial only Non-irrig: None	Irrig: Trial only Non-irrig: None	None	None
Potatoes	30 bdcst or 15 row	Irrig: 30 bdcst or 15 row Non-irrig: Trial only	Trial only	None	None
All other crops	20 bdcst or 10 row	None	None	None	None

University of Minnesota
Soil Testing Laboratory
St. Paul, MN 55108

SOIL TEST REPORT

BLUE RIVER COOP

BLUE RIVER, MN

Report No: 09052

Date Received: 10/15/80

Date Reported: 10/21/80

D & B FARMS

SOIL TEST RESULTS

Field and Sample Numbers	Laboratory Number	Sampling Depth Inches	Soil Texture	Organic Matter	NO_3 - N Nitrate (lb/A)	Soil pH	Buffer Index	P Phosphorus (lb/A)		K Potassium (lb/A)
40 C	03608		CL	H		7.2		32		220

Field and Sample Numbers	Mg Magnesium (lb/A)		S Sulfur (ppm)	Zn Zinc (ppm)	Cu Copper (ppm)		Soluble Salts (mmhos)	
40 C			16	0.6				

RECOMMENDATIONS

CORN

FOR A 165 BU/ACRE EXPECTED YIELD OF CORN FOLLOWING SOYBEANS APPLY 130 LBS/ACRE N, 60 LBS/ACRE P205, 105 LBS/ACRE K20, 0.0 TONS/ACRE LIME.

P205 IS RECOMMENDED TO MAINTAIN SOIL TEST LEVEL. DIRECT YIELD INCREASE MAY NOT BE OBSERVED. FOR CONVENIENCE RATE MAY BE DOUBLED AND APPLIED EVERY OTHER YEAR.

IF CATTLE OR HOG MANURE IS APPLIED, REDUCE RECOMMENDED RATES BY 5 LBS N, 2 LBS P205 AND 5 LBS K20 FOR EACH TON OR EACH 250 GAL APPLIED. SEE EXT. FOLDER 168 FOR OTHER MANURES AND FURTHER INFORMATION.

UNDER CONDITIONS OF LIMITED DRAINAGE, COOL SPRING SOIL TEMPERATURES, HIGH RESIDUE MINIMUM TILLAGE, AND/OR LOW P OR K SOIL TEST A SMALL AMOUNT OF NPK FERTILIZER IS RECOMMENDED FOR ROW APPLICATION.
CAUTION: DO NOT APPLY FERTILIZER CONTAINING UREA, DAP, THIOSULFATE, OR MORE THAN 15 TO 20 LBS/ACRE N + K20 IN DIRECT CONTACT WITH SEED.

ZINC LEVEL IS MEDIUM. YIELD INCREASE POSSIBLE. APPLY 5-10 LBS/ACRE ZINC (14-28 LBS/ACRE ZINC SULFATE) BROADCAST. REPEAT IN 3-4 YEARS. SEE EXT. FOLDER 435.

SULFUR TEST IS HIGH . NONE RECOMMENDED

FOR RECOMMEDATIONS FOR OTHER CROPS OR FOR DIFFERENT EXPECTED YIELDS OR PREVIOUS CROP CONTACT YOUR COUNTY EXTENSION OFFICE (BELOW) OR REFER TO EXT. BULLETIN 416, GUIDE TO COMPUTER PROGRAMMED SOIL TEST RECOMMENDATIONS.

County: BLUE EARTH

Township: DANVILLE

Section:

Soil Series(type) or Mapping Unit

For additional information contact your county extension agent:

DONALD HASBARGEN 507-625-3031

Receipt: This is to acknowledge receipt of payment in the amount of $

EXPLANATION OF SOIL TEST REPORT

SOIL TEXTURE ABBREVIATIONS

C = clay	SICL = silty clay loam	L = loam	LS = loamy sand	P = peat
CL = clay loam	SIL = silt loam	SL = sandy loam	S = sand	M = muck

RELATIVE ORGANIC MATTER LEVELS

L = low	0 to 3.0%	H = high	greater than 4.5%
M = medium	3.1 to 4.5%	VH = very high	peats and mucks

LIME EXPLANATIONS

Lime recommendations given for mineral soils are to raise the soil pH to 6.5. Exception: In western Minnesota a pH of 6.0 is considered adequate unless alfalfa is hard to establish, then only a modest lime application is necessary. If you desire a pH of 6.9 add an additional 2 tons per acre to the recommendation given.

Lime recommendations given for organic soils are to raise the soil pH to 5.5.

RELATIVE LEVELS OF PHOPHORUS AND POTASSIUM

Relative level	Phosphorus lbs/A	Potassium lbs/A
Low	0 - 10	0 - 100
Medium	11 - 20	101 - 175
Medium - high	21 - 30	176 - 250
High	31 - 40	251 - 300
Very high	over 40	over 300

The relative levels of phosphorus and potassium are given only as a general reference for some of the common agronomic crops grown in Minnesota. For many of the crops, even the high relative levels listed here would be considered low.

SOLUBLE SALT TEST VALUES AND RELATIVE SALT TOLERANCE OF FIELD AND VEGETABLE CROPS

0 - 2 mmhos Non-tolerant	3 - 4 mmhos Slightly tolerant	5 - 7 mmhos Moderately tolerant	8 - 16 mmhos Tolerant
	Field Crops		
field bean	alfalfa	bromegrass	barley
clovers:	corn	corn	birdsfoot trefoil
alsike, ladino, red	flax	oats	sugarbeet
pea	orchardgrass	perennial ryegrass	tall wheatgrass
soybean	sunflower	rape	
	timothy	reed canarygrass	
		rye	
		sorghum	
		sudangrass	
		tall fescue	
		wheat	
	Vegetable Crops		
carrot	cabbage	asparagus	
celery	cucumber	broccoli	
green bean	lettuce	garden beet	
radish	potato	spinach	
	sweet corn		
	tomato		

Above 16 mmhos — few if any agricultural crops do well.

Sunflower Insects 1980

David M. Noetzel, extension entomologist

Seed weevil (primarily *Smicronyx fulvus*) was wide spread in west central Minnesota although at subeconomic levels in nearly all instances. The West Central Crop Pest Management group under Scott Sederstrom's leadership sampled most monitored fields at season's end to determine how accurate monitoring was and also to determine yield reductions from seed weevil injury.

Sunflower midge was more abundant than anticipated in 1980. It has not normally been a problem during dry seasons. However in the areas (Borup-Felton, Beltrami, and Argyle) where severe damage took place in 1979, enough midge emergence occurred in 1980 to contribute to some sunflower injury. Limited insecticide trials including two new synthetic pyrethroids did not produce significant reduction in plant injury or prevent reduction in yields. In our judgment major emphasis should switch from considering chemical control to attempting to breed midge tolerant sunflower hybrids. There is a differential plant response to midge feeding. Perhaps the definition of the biochemical basis for either or both would permit a relatively simple method of selecting resistant and/or tolerant lines. Certainly all of the currently labeled and candidate insecticides appear to be ineffective against midge.

We have no idea whether midge larva can successfully carry through a dry summer into a second season. If so, then a moist season will cause difficulties from midge similar to the 1979 growing season particularly in those areas previously mentioned.

Banded sunflower moth (*Phalonia hospes*) became unusually abundant in 1980. The insect has not been economically important in past growing seasons but was damaging locally this year. The green to pinkish larvae of this moth feed on the seed kernel consuming about three seeds per larva. Monitoring must be based on adult counts as does the monitoring for sunflower moth. On the basis of damage equivalents it would appear that 8 adults per five plants would equal 2 adult sunflower moths. However it is very difficult to obtain good adult counts and damage appeared to exceed counts in a limited number of instances. Single applications of recommended insecticides did not provide significant nor acceptable control.

Sunflower beetle numbers were the highest observed the past several years. Larval damage was economically important in the Thief River Falls area and many fields were treated. Adults of this summer generation literally overwhelmed some fields in August-September completely defoliating plants on the margins of some fields. Extensive fall feeding by overwintering adults has not been previously observed.

Stem weevil (*Cylindrocopturus*) was present in less than economic numbers this year. Its distribution was about the same as in the past 2 years, but the numbers were reduced. Because this is a dry land insect we anticipate somewhat greater numbers in the west central part of Minnesota in 1981. Whether early season drought with late season rainfall as was experienced in northwestern Minnesota will lead to increased numbers is not known. Monitoring works extremely well with this species of stem weevil.

CUTWORM STUDIES IN SUNFLOWER 1980

A need continues for a more effective cutworm control "rescue" treatment in sunflower. Current work at the Minnesota experiment stations and by extension includes better definition of economic thresholds for cutworm injury (table 1) and comparisons of candidate insecticides for cutworm control (table 2).

Economic injury threshold

In 1979 simulated cutworm injury plots were established in nine growers' fields throughout Minnesota and at the West Central Experiment Station. 1979 results at all locations were fairly consistent. In 1980, one trial was established in a uniform, later planted grower's field and one trial was located at the West Central Experiment Station.

Plots were 4 rows by 25 feet, replicated four times. Plants were removed at the eight leaf stage in the patterns indicated. We felt the removal of plants in a gap pattern (that is, next to each other) would have the most marked effect on yield and are, as a result, reported. Yields were taken from the center rows.

Table 1. Simulated cutworm damage in sunflower--David Noetzel, Jerrel Christensen, and Scott Sederstrom 1979-80

Treatment	Final plant population	Yield in pounds per acre		
		1979	1980	2 year average
(1) Three plant gap	18,122	2,040	1,814	1,927
(2) Thinned evenly	20,000	1,948	1,847	1,898
(3) Two plant gap	18,819	1,980	1,805	1,893
(4) Five plant gap	16,728	1,941	1,804	1,873
(5) Thinned evenly	15,000	1,983	1,705	1,844
(6) Thinned evenly	10,000	1,825	1,805	1,815
(7) Field stand	23,208-20,000	1,738	1,854	1,796
(8) Four plant gap	17,425	1,854	1,705	1,780
(9) Eight plant gap	14,637	1,912	1,599	1,756
(10) Ten plant gap	13,243	1,608	1,774	1,691
(11) Twelve plant gap	11,849	1,701	1,543	1,622

A preliminary analysis indicates differences in yields at the 5 percent level but not at the 1 percent level. At the 5 percent level only the twelve and ten plant gap plots had significantly lower yields. Thus it would appear that if an initial stand of 20,000 (or more) plants per acre is obtained, yields will not be significantly reduced until plant populations are reduced to below 15,000 plants per acre.

Cutworm control

Local severe cutworm (redbacked and darksided) infestations (20 to 33/sq. ft.) in barley-volunteer sunflower and in flax permitted a set of trials in Roseau County. At the time the plots were established (June 6, 1980) there had been virtually no previous spring rainfall. We felt that under such conditions rescue treatment might not be effective.

However, 24 one hundredth of an acre plots were staked out. Eight treatments were replicated three times in a randomized complete block design. Treatments were put on between 7 and 10 p.m. in approximately 25 gallons per acre of total spray.

Readings were taken by Blake Peterson, Roseau County extension director, and local growers 48 hours after treatment. These evaluations were based on a scale of 1-4 with 1 = superior control and 4 = no control. None of these evaluators knew what treatments had been used. Results are included in table 2.

Table 2. Cutworm control in barley-volunteer sunflower. Roseau County, 1980, David M. Noetzel and Blake Peterson

Insecticide	Rate in pounds actual per acre	Control rating
Lorsban	1.5	1.0*
Ambush	0.2	1.7
Pydrin	0.2	1.7
Larvin	0.5	2.3
Pounce	0.2	2.7
Sevin	1.5	3.0
Toxaphene	3.0	3.0
Check	-	4.0

* 1 = superior control
4 = no control

An unreplicated application of 5 percent Sevin apple pomace bait was rated at 2.5 effectiveness.

Potato insects--1980

Most of the dryland potato production in the state was under severe drought stress through much of the growing season. Potato prices began the season at a low level but became extremely attractive in August. Systemic insecticides, which are the basis of the better potato insect control programs in the state, did not perform well in 1980 probably due to drought. The Colorado potato beetle was common early and became quite abundant later building to economic levels in August and September. Indeed defoliation due to adult feeding was significant in some fields. The Northwest Crop Pest Management group, under the leadership of Mike Hutter, experienced some difficulty in estimating defoliation from potato beetle due to the uneven distribution of injury. Growers indicated that commonly used foliar insecticides appeared to them to be less effective against potato beetles.

Because of continued grower concern about the possibility of insecticide resistance in Colorado potato beetle, Richard Johnston, Gerrit Cuperus, Whitney Cranshaw, and Ted Radcliffe compared effectiveness of most labeled compounds and some candidate compounds against this insect. Their comparisons are contained in table 3.

The plots were single rows of Russet-Burbank potatoes, 30 feet in length. Treatments were applied in approximately 25 gallons of water/A on June 28. Counts were taken 24 hours after treatment.

Table 3. Control of Colorado potato beetle larvae: Glyndon, MN 1980, Johnston, Cuperus, Cranshaw, and Radcliffe

Treatment	Rate in AI/A	Percent* control at 24 hours
Azodrin	.5	97.4
Monitor	.75	95.9
Diazinon	.5	92.7
Phosphamidon	.5	87.6
Guthion	.5	82.2
Lannate	.45	65.7
Orthene	1.0	23.6
Pirimor	0.5	1.1
Furadan	0.5	100.
Sevin	1.5	92.4
Thiodan	.75	96.5
Check	-	0.0
CANDIDATE COMPOUNDS		
Pay off	.04	100.
FMC 45806	.05	100.
Ambush	.05	99.0
Pydrin	.1	98.9
Vydate	.45	98.7
NorAm 72129	.25	95.2
Pounce	.1	94.7

Economic thresholds--their meaning and use

The recent emphasis on Integrated Pest Management (IPM) and/or Crop Pest Management (CPM), has again directed attention to two terms which are not only basic to these concepts but to general pest control. The first of the terms is the Economic Threshold (ET) and the second the Economic Injury Threshold (EIT). Their definitions, which follow, are deceptively simple. All of us in pest management have gone about the business of reducing pest incidence without being overly concerned about these definitions. On the whole pretty good judgments for control have been made even though we may not always have appreciated or understood how the decision was arrived at.

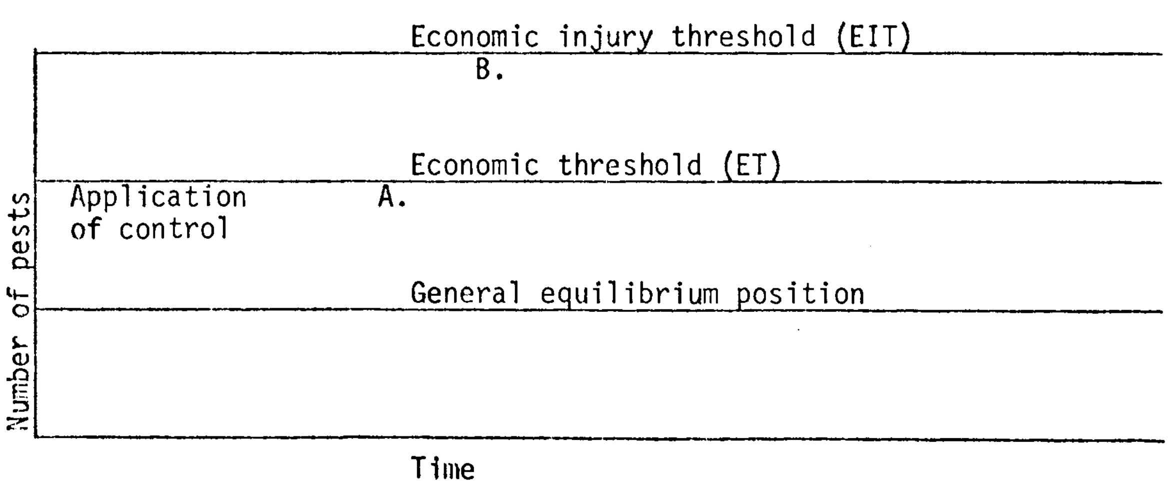
However, three additional externalities have arisen that have forced us in pest management to increase our own understanding of what does go into judgment making. First was the switch to nonpersistent insecticides. The second has been the relatively enormous increase in direct pesticide costs. The last of these externalities has been the public pressure against pesticide use. All have marked economic implications.

The Economic Injury Threshold (EIT) is "the lowest population density that will cause economic damage." Economic damage is the amount of injury which will justify the cost of the artificial control measure. It is quickly evident that this threshold will usually be a variable value based on biological factors (for example, plant stress, etc.) as well as on economic values. Generally this threshold value is the first determined and the ET, the pest density requiring a control measure, is derived from it.

The ET, as originally defined by California workers, is the "pest density at which control measures should be determined to prevent an increasing pest population from reaching the Economic Injury Threshold (EIT)". It is lower than the EIT so that control can be initiated before the value of the damage exceeds (or potentially exceeds) the cost of control. In practice this value will probably vary more from state to state than the EIT. And it is different for each specific control method being considered.

The relationship of the EIT and the ET is best illustrated by the simple schematic in figure 1.

Figure 1. Schematic diagram of the relationship of the general equilibrium position, Economic Threshold (ET) and Economic Injury Thresholds (EIT) of a pest species



In figure 1 the general equilibrium position is the long term average population density of the pest. The curved line represents the changing numbers of the pest being considered. If the pest, for example corn rootworms, has a single generation per year than the curved line represents an annual pattern of population change from one valley to the next (or from peak to peak). If there are two annual generations it goes from valley 1 to valley 3, and so forth.

The line representing ET is below the EIT line indicating that a judgment for need for control (Point A) will be made before damage exceeds control cost (Point B).

A number of questions, however, arise. First, how do we arrive at threshold values? What do the thresholds listed in our bulletins and used in our crop pest management programs mean? And why do there appear to be differences in thresholds between neighboring states?

To shed some light on these questions, let's begin first with how thresholds are arrived at. When there is no data to show a relationship between pest numbers and yield reduction but where the pest is obviously reducing yield, we can simply state that our intuition says that control is needed. The quality of this intuitive ET is largely related to the experience of the individual making it. When that experience includes several observations on the pest, the quality will normally be better. When the experience includes measurements of one kind or another then the quality is improved even more. However, until pest numbers and yields are related in well designed experiments these thresholds remain empirical ones. And keep in mind that thresholds based just on observations lead to more disagreements between observers than those experimentally arrived at. The current ET on sunflower moth is an example of this type.

The most precise thresholds come from well designed experiments which provide data relative to quantitative relationships between pest density and yield reduction. Such data should be reproducible. To say it another way, the more data supporting a threshold and the better the experimental design in obtaining the data, the more valid or reproducible is the threshold. Both European corn borer and corn rootworm thresholds in corn are examples of this.

To obtain an economic injury threshold from pest density-yield reduction data one must incorporate economic values as well. Thus, the cost of chemical application, the effectiveness of control by the chemical, the price of the crop at the point of sale, and the yield all must be considered. Perhaps the most straightforward economic point of all is that the grower must, at the very least, obtain yield returns on a dollar for dollar basis just to break even on cost of chemical application. It is predictable that if the pest density is below the ET, the grower will lose part or all of the control cost.

We have suggested a relatively simple equation proposed by Huai Chiang of our staff that will permit a grower, dealer, or applicator to calculate many economic thresholds (ET).

The equation follows:

$$ET = \frac{CC}{CE \times Y \times P \times YR \times SC} \times CF$$

where: CC = cost of control

CE = control efficiency or % kill

Y = yield

P = price

YR = yield reduction in percent for given pest population (usually one insect per host)

SC = survival coefficient

CF = critical factor

The two terms which need to be explained are the survival coefficient and the critical factor. The survival coefficient is the percent survival from the stage of the insect which we would monitor to the stage producing the damage. Thus if we monitor for adult beetles we must measure how much natural mortality will occur in adult, egg, and larval stages between the time of the count and the time of the damage. If we monitor the stage which does the damage, then the survival coefficient will be rather near 100 percent.

The critical factor (CF) is a value between 1 and 2. If conditions between the time of monitoring (for example, adult counts) and damage (for example, larval feeding) permit maximum reduction in yield, the CF value would be 1. This is break-even for the grower under the best conditions for the insect or when damage is maximum for the given monitored density. At the same time if conditions for the insect were so poor and the minimum predicted damage occurred, then CF should be 2.

In addition if there are some environmental costs which control costs (CC) do not include, the CF value would tend toward 2.

And if the grower wishes to realize some net profit over cost of chemical application under the best conditions for the pest, then CF would have to be larger than 1. Thus, the CF will have to average something above 1 over time or the grower will just break even with control cost.

We would encourage you to make up a hypothetical problem and work it through using the formula. Normally control efficiencies range from 50 to 95 percent, yield reduction will be 3 percent (.03) or less per individual pest, and survival coefficient from 30 to 80 percent. Vary but one value so that you obtain an appreciation on how a change, for example, in control efficiency from 50 to 95 percent changes the ET.

There are, as always, some problems of insect control to which these calculations do not lend themselves. For example, in corn borer and/or corn earworm control in sweet corn, consumers will not accept more than about 2 percent damaged ears. The ET is nearly zero then. Thus, control procedures will be initiated when adult moth flights indicate that unaccepatble numbers of ear-infesting larvae will appear.

Although management of this insect complex in sweet corn is an outstanding example of CPM, sweet corn production is still a system which deserves considerable additional research. For example, the problem of honey bee kills resulting from sweet corn insect control is a negative environmental side effect which additional study might solve.

In some instances, for example insect injury in potatoes, it is nearly impossible to obtain precise thresholds. It is also true that the value of the potato crop is often so high that a single hundred weight of yield will pay for one application of chemical. Then researchers like Radcliffe and his coworkers examine various experimental strategies which, if followed, prevent pest populations from affecting yield altogether. Thus, the 10 leafhopper numphs/100 leaves, 30 aphids/100 leaves and 10 percent defoliation, the respective economic thresholds (ET), are so low that yield is unaffected. We do need to keep in mind that since these are based on data which demonstrate no effect on yield the economics (that is, control cost and value per weight) of the crop do not enter into a change in threshold values.

A great deal of work comparing pest densities to yield reductions is under way. It is much more difficult research than most of us realize. The most rapid progress occurs when the pest can be reared so that standard infestation levels may be established as with corn borer. Artificial infestation capability is of even greater importance when attempting to develop plant resistance. However, despite considerable progress with some pests, with others, researchers depend on the vagaries of natural insect outbreaks to obtain pest density-yield reduction relationships.

There is somewhat less research time being spent on moving from the pest density-yield reductions correlations to the actual work with economic threshold values. Thus, applied workers are faced with the daily need for usable economic thresholds and must often extrapolate from research information which itself may be incomplete. It is understandable that different workers arrive at slightly different values. And as research proceeds these often arbitrary economic thresholds will be continually sharpened.

FUNGICIDES FOR FIELD CROPS

H. L. BISSONNETTE, EXTENSION PLANT PATHOLOGIST

Growers of field crops such as corn, wheat, barley, oats and soybeans often do not use fungicides to control plant diseases. For some reason, growers seem quite willing to accept plant disease losses as part of the cultural practice of growing crops. For the life of me I do not understand why, after the major production costs of land, fertilizer, seed, planting, and weed control have been made, the grower will not protect the potential crop yield by controlling plant diseases. Every year one may identify examples where crop loss could have been prevented with the use of plant disease control practices.

A few years back, smut on oats caused considerable loss to growers, including the very good variety Froker. Seed treatment would have prevented this loss. Every year cereal leaf spot diseases reduce the yields of wheat, oats, and barley. Two applications of fungicide control these diseases.

With specialized crops, e.g. potatoes, sugar beets, dry beans, etc., many growers do use regular disease protection practices to prevent or reduce crop loss. Sometimes, for reasons unbeknown, the disease control practices are not begun until the plant disease has become well established. For example, Cercospora Leaf Spot was identified on sugar beets early in August and by September was almost beyond control. Many growers started control practices in September, after the damage had been done.

Fungicides are chemicals that can be used to protect crops from plant diseases.

Fungicides for use on field crops

SEED TREATMENT - WHEAT, BARLEY, AND OATS

Common name	Trade names	Bunt control	Seedling blight control	Remarks
Captan	Captan Orthocide Evershield (several other names		G**	Combination with maneb or zineb for bunt control
Captan-HCB	Ortho seed protectant	G	G	
Carboxin	Vitavax			For control of loose smut
Carboxin + thiram	Vitavax 200 Evershield	F	F	For bunt, seedling blight and loose smut control

Maneb	ABSCO DB Green ABSCO DB Yellow cover-up Granol NM	F	G	DB Green + Granol NM are combined with Lindane
Maneb HCB	Granox NM	G	G	
PCNB	Terra-coat LT2	G	F	Combined with Terrozole
	Terra-coat	G	F	Combined with Terrozole
Polyram		F	G	
TCMTB	Busan (cover-up L)	G	F	
Thiram	Arasan-75	F	G	
	Evershield Thiram	F	G	

*Seed injury may occur if high moisture seed is treated and stored.

** F = Control Fair
G = Control Good

Cereal Leaf Diseases

Dithane M-45
Manzate 200
Zineb
Kocide 101

Apply by airm using a minimum of 5 gallons of water per acre.
Check label for rate and limitations

Sugar Beets

Cercospora Leaf Spot

Fungicides [1/] for Leaf Spot Control

Benlate
Dithane M-45
Duter
Fixed Coppers (Kocide 101)
Manzate 200
Mertect
Polyram

[1/] Similar materials may be sold under different local names.

Powdery Mildew

Fungicides for Powdery Mildew Control

Benomyl
Duter
Mertect
Magnetic 6
Sulfur

Check label for rate and limitations

Potatoes

Fungicides For Use On Potatoes

Seed piece treatment	Blight* and foliage disease
captan	Bravo
maneb	Copper (Iocide 101)
Polyram	Difolatan
zineb	Dithane M-45
zineb + 100 ppm streptomycin	Duter (no spreader-sticker)
	Maneb
	Manzate 200
	Polyram

*Late Blight -- may be severe and difficult to control on the variety Norchip -- if it gets a start

Rhizoctonia and scab

PCNB - emulsifiable concentrate
(Broadcast or in-furrow application)
See label for rates and limitations

Corn

Seed Treatment

Most seed corn is treated prior to delivery. Over treatment with Vitavax 34 is recommended to prevent the introduction of corn Head Smut. By spores on the seed. Treat just shortly before planting.

Eyespot, Rust[1/]

Maneb fungicides

[1/] check label for limitations on use of sweet corn silage. Late planted sweet corn is subject to crop loss by rust.

Dry Beans

Seed Treatment

Captan
Streptomycin sulfate

White Mold

Benlate

Rust

Dithane M-22
Pop-Cop

Bacterial Blight

Kocide
Cit-Cop
Pop-Cop

Check label for rate and limitations.

CLOSED SYSTEMS FOR HANDLING PESTICIDES

Robert W. Brazelton
Extension Specialist
Department of Agricultural Engineering

INTRODUCTION

When Rachael Carson's "Silent Spring" was published, attention to pesticide usage increased rapidly and, with time, substantial advances were made in efforts to reduce and eliminate hazards. Negative activities involved both well founded and irresponsible publicity. Much of the criticism, when factually accurate, proved very valuable and led to major positive advances in the development and application of pesticides. The proliferation of inflammatory and unfounded statements indicated that an intensive investigation of the status of deaths and injuries should be undertaken.

THE CALIFORNIA STUDY

In California, a team from the State Department of Food and Agriculture and the State Department of Health Services set out, in 1973, to conduct field investigation for each reported injury. The state requires that every physician who encounters a patient complaining of symptoms, which in the physician's opinion indicates possible pesticide exposure, must make a "Physician's First Report of Injury". These reports were used as a basis for the team's investigation in 1973 and since. The findings of the studies are summarized here:

OCCUPATIONAL PESTICIDE ILLNESS *

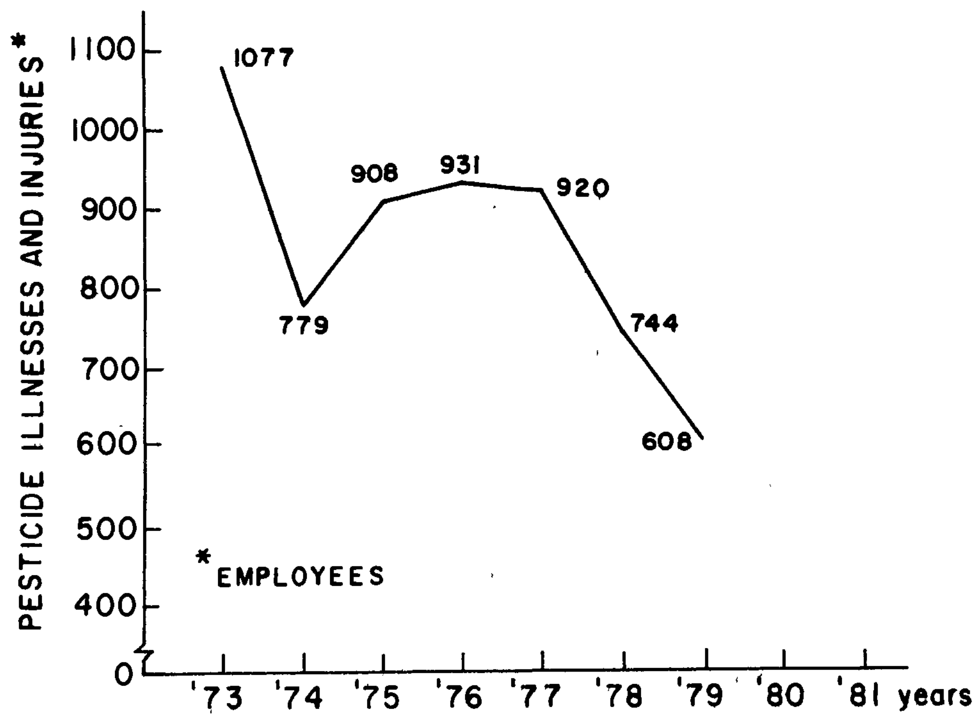
	TOTAL NUMBERS BY EMPLOYMENT						
	1973	1974	1975	1976	1977	1978	1979**
PILOTS	14	17	7	8	7	8	1
FLAGGERS	20	6	16	14	15	24	9
MIXERS/LOADERS	165	141	143	122	143	142	132
AGR. GROUND APPLICATORS	424	225	264	254	236	163	161
FIELD WORKER RE-ENTRY	157	112	167	156	184	95	53
GARDENERS (COMMERCIAL)	66	103	106	159	155	138	92
NURSERY AND GREENHOUSE	112	73	90	119	72	69	48
FUMIGATOR (FIELD)	71	29	22	14	16	20	21
MACHINE CLEAN AND REPAIR	22	28	40	26	33	21	19
TRACTOR DRIVERS, IRRIGATORS	—	23	22	30	29	20	23
DRIFT EXPOSURE (PERSONS NEARBY)	26	22	31	29	30	44	19
							Other 30**
TOTAL ALL OF AGRICULTURE	1077	779	908	931	920	744	608
TOTAL OTHER THAN AGRICULTURE	397	378	435	521	598	450	411
GRAND TOTAL FOR YEAR	1474	1157	1343	1452	1518	1194	1019
% BY AGRICULTURE	73	67	68	64	61	62	60

*FROM DOCTOR'S FIRST REPORT OF ILLNESS AND OTHER MEDICAL REPORTS

**1979 Agriculture includes for the first time, animal applicator and self employed categories.

It should be noted that the data summarized came from workers compensation claims which the team's in-field investigation proved to be authentic. In making the determination that a symptom is pesticide related, the physician is faced with the fact that many pesticide related symptoms are identical to those of other illnesses. Headaches, drowsiness, respiratory irritation, etc. may result from flu, colds, weekend hangovers, allergies, etc. In each case reported here, those factors were carefully explored to ascertain that each case counted could be clearly documented as pesticide related. It should also be noted that this statistical reporting system, as in all such regulatory activities involves employees.

Investigation of these numbers reveals some interesting facts which have been used as a basis for more intensive regulatory activity and which resulted in the development of closed system pesticide handling. The reader will note that, as might be expected, those workers most directly involved in handling concentrated materials in mixing and loading operations and in actually applying pesticides were most affected. This involved mixer/loaders, agricultural ground applicators, field workers reentering fields prior to the completion of the proper reentry time interval, gardeners and nursery and greenhouse workers. Obviously, then, a logical approach to the solution of the exposure problem involved eliminating the potential for exposure. In the hot fields where temperatures often exceed 100°F, the use of personal protective equipment such as waterproof clothing and respirators is unlikely, so by requiring the transfer of material to be made in a closed manner which protects the worker from contact with the material seemed to be a more effective method. Hence, the development of the requirement for closed systems. The graph below indicates the progress through the years. While no clearcut documentation is available to account for the '74 through '77 fluctuaions, it is interesting



AGRICULTURALLY RELATED PESTICIDE ILLNESS AND INJURIES IN CALIFORNIA to note that the study and proposed regulatory activity was widely publicized late in 1973 and substantial pesticide safety training activities and operator awareness was in evidence. The sharp decline in injuries in 1974 might be attributed to that factor. At that time, no closed systems existed and in fact no firm regulatory requirement complete with positive enforcement was in place. It is felt that the return to higher rates in '75, '76 and '77 may have reflected that. The closed system requirement became effective on January 1, 1978 and while there is no specific proof that closed system use alone can account for the sharp decline since, it certainly must be a contributing factor. No doubt the licensing and educational requirements have also been responsible for part of this improvement. Specific field studies of large scale pesticide application firms' employees complete with blood and urine analysis confirm the effectiveness of the closed system principle.

THE CLOSED SYSTEM

The California requirements for the design and use of closed systems can best be presented by referring to the regulations as reproduced here as an Appendix A. Along with the requirements, the department lists the names and addresses of the various manufacturers who have designed systems which meet the department requirements. It should be noted that, since the department review, technical, economic and marketing problems may have caused one or more of the organizations to discontinue manufacture. If there is any intent to attempt to manufacture a system intended for use in California, it will be wise to check with the department first to ascertain that no technical or regulatory change has been made in the design requirements as discussed here, since changes are often made as new facts become available.

Early systems suffered substantially from failure of seals, gaskets and hoses. It became obvious that such parts must be designed to be compatible with the pesticides to be encountered. Early negative response by some users disenchanted with what was viewed as excessive regulation was often offset by successful operation of such systems by other users. Some systems proved too complex and/or too expensive for the smaller operator.

By 1979, numerous applicators were successfully operating closed systems which generally were custom built utilizing the most desirable components of perhaps several manufacturers combined with some homemade elements. Some of the factors to consider are:

1. There are two basic system types. Pesticide containers cannot be pressurized, so the material must be extracted either by gravity or by vacuum. Gravity systems such as the Goodwin system (Soares) or Captain Crunch work very well except that they cut the container so that the entire contents is emptied. The vacuum method employs some vacuum source such as a vacuum pump or suction from a regular pump and certain models can extract partial contents of the container.

2. Highly viscous materials are difficult to move with a vacuum system. For best results, a container suction probe should approach one inch in diameter and be operated with at least 15 inches of mercury vacuum.

3. Rinse water pressure must be carefully controlled to avoid probe blowout or can rupture.

4. Seals, gaskets, hoses, and similar parts must be made of materials reasonably compatible with the pesticides to be used.

5. Excellent maintenance is a key to the successful use of closed systems. Systems should always be thoroughly rinsed after use, for if the pesticide is left in the system, the possibility of damage to system parts is increased greatly.

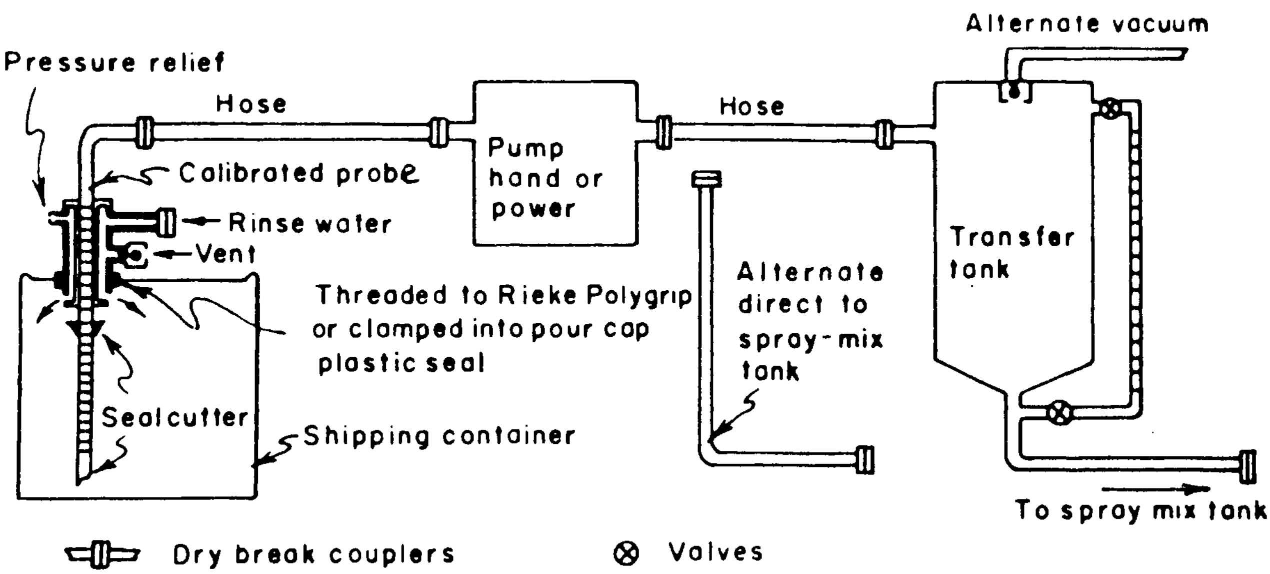
6. The system or system components must be carefully selected to assure handling capabilities appropriate to the type of operation contemplated.

7. Gravity feed or venturi operated suction systems seem to be more free of trouble than systems involving special pumps, vacuum systems, etc.

8. Closed system operators must have adequate training and generally may have to be selected for a higher degree of skill than common labor often used in the past.

The Container Closure Problem

If the container is not to be cut open for extraction of the entire contents, it must be entered in some other manner. The most logical method will involve entry through the container closure. Therein lies a monumental problem for there are dozens of different container designs with many different types of closures. Reference to the diagram below of a typical system which utilizes



CLOSED CHEMICAL TRANSFER SYSTEM

vacuum to extract the material will quickly indicate the key problem in the design of such systems. The probe must enter the container in a manner which will not permit escape of any material and remain sealed during the transfer operation. Standardization of pesticide container closures remains a key need in this process. Both the industry and government agencies continue to work toward a successful solution of this problem.

State of California — Edmund G. Brown JR., Governor

DEPARTMENT OF FOOD AND AGRICULTURE
1220 N Street
Sacramento 95814

May 25, 1979

TO: AGRICULTURAL PEST CONTROL OPERATORS, GROWERS, AND OTHER INTERESTED PERSONS

SUBJECT: Liquid Pesticide Closed System Requirements

Hand pouring has been found to be the most hazardous activity involving the handling of highly toxic pesticides and has resulted in many serious illnesses. California's pesticide worker safety regulations require that employees who handle liquid pesticides displaying the signal word "DANGER" on the lable shall use "closed systems". This requirement applies to all employees except those involved in structural, home, institutional, or industrial pest control.

"Closed system" is defined as "a procedure for removing a pesticide from its original container, rinsing the emptied container and transferring the pesticide and rinse solution through connecting hoses, pipes and couplings that are sufficiently tight to prevent exposure of any person to the pesticide or rinse solution. Rinsing is not required when the pesticide is used without dilution. The system's design and construction shall meet the Director's closed system criteria."

Based upon evaluations of systems already in use in California, the use of closed systems should:

1. Significantly reduce the number of human illnesses attributed to pesticide exposure.
2. Reduce the number of cholinesterase tests needed.
3. Reduce the need and expense for protective clothing and equipment.
4. Reduce medical expenses and insurance costs associated with illness and disability associated with exposure to pesticides and lifting heavy containers.

Firms having closed systems or components commercially available that have beenfound to meet California's requirements are listed with this letter. To meet California's requirements, a closed system must meet the attached criteria. Components must be accompanied by directions clearly indicating how the component is to be used in the construction of a closed system.

Sincerely

(Signed) (Copy of original)

William A. Betts, Program Supervisor
Pesticide Enforcement
(916) 322-5032

Attachment

This is a list of closed systems that meet the criteria.

J. E. Soares, Inc (Goodwin System)
Route 1 Box 42A
Belgrade, Montana 59714
Jim Soares (406) 388-6069

Coastal Ag-Chem
1015 East Wooley Road
Oxnard, CA 93030
Earl Griffin (805) 487-4961

Soilserv Inc.
1427 Abbott Street
Salinas, CA 93901
Hugh Shaw (408) 422-6428

Blackwelders
101 Blackwelder Drive
Rio Vista, CA 94571
John Kincheloe (707) 374-6441

Protect-O-Metering Concepts (Agrinautics)
P. O. Box 11045
McCarran Airport
Las Vegas, Nevada 89111
George Sanders, (702) 736-3794

Terminator Products (Calibrator)
1550 - 105th Avenue
Oakland, CA 94603
Jim Stevenson (415) 638-3654

Squire Farm Service
2931 Tully Road
Hughson, CA 95326
Ralph Squires (209) 883-2283

Load Safe Systems, Inc.
P. O. Box 42]
Heber Springs, Arkansas 72543
Harold Reeder (501) 362-8404

FMC Corporation
Agricultural Machinery Division
222 East 14th
Ripon, CA 95366
Dan Nelson (209) 599-4147

Vacutrans
Pneumatic Conveyor Systems
16451 Illinois Ave.
Paramount, CA 90723
Dan Freeman (213) 630-3335

Cherlor Mfg. Co. Inc.
P. O. Box 2174
Salinas, CA 93902
Dave Anderson (408) 422-5477

Massey Aviation
P. O. Box 716
1402 S. Lexington
Delano, CA 93215
Gerry Massey (805) 725-8750

Strong Steel
P. O. Box AK
Ventura, CA 93001
Sonny Boynton (805) 648-6841

Dan Riggi
P.O. Box 997
Blythe, CA 92225
Dan Riggi (714) 922-3806

Captain Corporation (Captain Crunch)
P.O. Box 384
Sheldon, IA 51201
Jerry Ralston (712) 324-4633

Mid-Continent Aircraft Corporation
Planemate Division
Drawer L
Hayti, MO 63851
Earnie Babcock (314) 359-0500

State of California
Department of Food and Agriculture

CRITERIA FOR CLOSED LIQUID PESTICIDE SYSTEMS

1. The liquid pesticide shall be removed from its original shipping container and transferred through connecting oses, pipes, and/or couplings that are sufficiently tight to prevent exposure of any person to the pesticide concentrate, use dilution, or rinse solution.

2. All hoses, piping, tanks, and connections used in conjunction with a closed liquid pesticide system shall be of a type appropriate for the pesticide being used and the pressure and vacuum to be encountered.

3. All sight gauges shall be protected against breakage. External sight gauges shall be equipped with valves so that the pipes to the sight gauge can be shut off in case of breakage or leakage.

4. The closed system shall adequately measure the pesticide being used. Measuring devices shall be accurately calibrated to the smallest unit in which the material is being weighed or measured. Consideration must be given to any pesticide remaining in the transfer lines as to the effect on accuracy of measurement.

5. The movement of a pesticide concentrate, beyond a pump by positive pressure, shall not exceed pressure of twenty-five (25) pounds per square inch.

6. A probe shall not be removed from a container except when:

   (a) The container is emptied and the inside of the container and the probe have been rinsed in accordance with 8;

   (b) The Department of Food and Agriculture has evaluated the probe and determined that by the nature of its construction or design it eliminates significant hazard of worker exposure to the pesticide when withdrawn from a partial container; or

   (c) The pesticide is used without dilution and the container has been emptied.

7. Shut off devices shall be installed on the exit end of all hoses and at all disconnect points to prevent leakage of pesticide when the transfer is stopped and the hose removed or disconnected.

   (a) If the hose carried pesticide concentrate and has not been rinsed in accordance with 8, a dry coupler that will minimize pesticide drippage to not more than 2 milliliters per disconnect shall be installed at the disconnect point.

   (b) If the hose carried a pesticide use dilution or rinse solution, a reversing action pump or a similar system that will empty the hose and eliminate dripping of liquid from the end of the hose may be used as an alternative to a shut off device.

8. When the pesticide is to be diluted for use, the closed system shall provide for adequate rinsing of containers that have held less than 60 gallons of a liquid pesticide. Rinsing shall be done with a medium, such as water that contains no pesticide.

   (a) The rinsing system shall be capable of spray rinsing the inner surfaces of the container and the rinse solution shall go into the pesticide mix tank or applicator veh cle via the closed system. The system shall be capable of adequately rinsing the probe (if used) and all hoses, measuring devices, etc.

   (b) A minimum of 15 pounds pressure per square inch shall be used for rinsing.

   (c) The rinsing shall be continued until a minimum of one-half of the container volume or 10 gallons, whichever is less, of rinse medium has been used.

   (d) The rinse solution shall be removed from the pesticide container concurrently introduction of the rinse medium.

   (e) Pesticide containers shall be protected against excessive pressure during the container rinse operation. The maximum container pressure shall not exceed five (5) pounds pressure per square inch.

9. Each commercially produced closed system or component to be used with a closed system shall be sold with a complete set of instructions on its operation. These instructions shall consist of a functional operating manual and a decal and/or system of decals placed on the system covering the basic operation.

   The instructions shall also describe any restrictions or limitations relating to the system such as pesticides that are incompatible with materials used in the construction of the system, types (or sizes) of containers or closures that cannot be handled by the system, any limits on ability to correct for over measurement of a pesticide, or special procedures or limitations on the ability of the system to deal with partial containers.

This criteria does not preclude closed mixing systems utilizing procedures other than those outlined above. Questions concerning the ability of other procedures to meet California's closed mixing system requirement may be directed to:

Department of Food and Agriculture
Pesticide Enforcement
1220 N Street, Room A-170
Sacramento, California 95814
(916) 322-5032

(Rev. 5/79)

HEAD SMUT OF CORN

Erik L. Stromberg, Assistant Professor
Plant Pathologist, USDA, APHIS, PPQ
Department of Plant Pathology
University of Minnesota

Head smut of corn, caused by the fungus Spacelotheca reiliana (Kuhn) Clint, was first reported in Minnesota on August 1, 1980 in fields at the Staples Vocational Technical School Irrigation Farm, Wadena County by the author. Since this original discovery surveys made by Stromberg, personnel from the Division of Plant Industries, Minnesota Department of Agriculture, and smut samples submitted by the public have resulted in the location of additional confirmed head smut infested fields in Minnesota.

HISTORICAL ASPECTS

Head Smut was originally described on sorgham in Egypt in 1868 and it was only first described as a disease of corn in 1876 in India. In North America it was first found on corn in 1895 in Kansas. By 1919 it was reported on corn near Pullman, Washington and since that time it has been found periodically in the river deltas and intermountain valleys of California, Oregon, Washington and Mexico. In 1962 head smut was first described in Idaho. By 1965 thirty-two corn fields were known to have infections of this pathogen ranging from a trace up to 40%. Idaho has had, since the initial discovery of this disease, some severe head smut problems. Sweet corn has been more severely affected than field corn and Idaho produces about 90% of the nations hybrid sweet corn seed. In 1975 an outbreak of corn head smut was reported from the high plains area of Texas. Losses of 30-50% were reported from some of these infested fields. By selecting more resistant corn hybrids and avoiding heavily infested fields this disease has become of little economic concern to Texas corn farmers. Up until 1979 head smut in the corn belt or on the Great Plains has been practically unknown, however, in August of 1979, head smut was reported in Southern Ontario and found to cause losses ranging from a trace to 35%.

DISEASE CYCLE AND SYMPTOMOLOGY

Head smut differs from common smut, caused by Ustilago maydis, in that the head smut pathogen, Sphacelotheca reiliana, is primarily soil-borne. The teliospores (smut spores) from the smutted tassels or ears, disseminated by wind, rain, and/or harvesting equipment, overwinter in the soil and are the source for infection in the succeeding corn crops.

This pathogen infects the susceptible corn plant in the seedling stage. Once infecting the plant the pathogen becomes systemic, that is, it is growing within the infected host plant, but does not manifest itself until the plant produces its tassels and/or ears. At this time the tassels and/or ears of infected plants are transformed into smut sori (or galls). Inside the sorus (or smut gall) are millions of dark brown-black teliospores (smut spores). In addition to the teliospores are the remains of the vascular (water conducting) tissue of the tassel and ear structures. This vascular tissue appears as a "stringy mass". The head smut sorus, unlike the common smut sorus, is not bounded by a distinct persistent covering (or periderm). The common smut sorus (seen as distinct galls) can be found on leaves, stalks, tassels, ears, or on individual kernels of the ear, while the head smut sorus is found on ears and/or tassels and rarely on leaves.

A head smut infected corn plant never produces a marketable ear, therefore a 10% incidence of this disease in a field produces a direct 10% yield loss. Common smut does not produce a yield loss unless it infects an ear or kernel directly.

The infection of seedling appears to be favored by soil temperatures ranging from 72 - 85^{o}F. In addition, dry soils and soil pH ranging from neutral to slightly acid seems to favor the infection process. These infection optima seem to be associated with the finds of head smut infested fields in Minnesota.

STRATEGIES FOR CONTROL OF HEAD SMUT

It is apparent that the use of resistant hybrids is the only means to control head smut disease. Searches for resistant hybrids in Texas and Ontario, Canada show that there are adequate sources of resistance to this disease in commercial hybrids. In the areas of Minnesota and Ontario where head smut has been found the hybrids in common use are found to be some of the most susceptible. This fact, and the practice of continuous corn production, have set up the conditions to select for head smut once the pathogen has been introduced into these areas.

Chemical control in the form of seed treatment and/or band application has been found to be of little value in a 1980 test in Ontario (Lynch - personal communication). Chemical control has, however, been of some value in Idaho in managing this disease.

In accessing a control strategy it is important to realize that Sphacelotheca reiliana is not seed-borne, that is, it does not grow within the seed. Seed grown in a field infected with the pathogen, can become contaminated with teliospores during harvesting and shelling. These seed, coated with teliospores, could possibly introduce the pathogen into a previously uninfested field, and in this case chemical seed treatments maybe of value in preventing this type of disease dissemination.

THE SEARCH FOR RESISTANT HYBRIDS FOR MINNESOTA FARMERS

During the 1981 crop season commercial corn hybrids, inbreds, and public hybrids and inbreds will be screened for resistance to this disease at the Staples Vocational Technical School Irrigation Farm under heavy disease pressure. The relative degree of resistance will be evaluated and this information will be made available to farmers to aid in their selection of hybrids by the University of Minnesota Extension Service.

This past year plant pathologists from the University of Guelph, Ontario, Canada have been screening commercial hybrids for resistance to this disease. In the short term (1981 crop season) this Canadian hybrid resistance data is the only information available to assist farmers in selecting hybrids. As this information becomes available it shall be disseminated by the Extension Service.

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WEED CONTROL IN CORN AND SOYBEANS IN THE 1980's

Gerald R. Miller
Professor and Extension Agronomist
Department of Agronomy and Plant Genetics
University of Minnesota

During the past three decades we have seen major changes in weed control practices. Farmers have shifted from relying primarily on cultural practices, tillage, crop rotations, cultivation and hand labor to the general use of herbicides supplemented by cultivation as needed. Over 90 percent of the corn and soybean acres in Minnesota are treated annually with herbicides and one-third to one-half of the acreage is treated more than once. Mixtures of two or more herbicides and multiple treatments are commonly used. The rapid adoption of herbicides has been encouraged by the economic benefits of improved weed control that resulted in higher yields, higher quality crops and reduced labor and fuel requirements.

Although one can only speculate as to the trends in weed control in the 1980's, it could be helpful to evaluate our present practices in order to make necessary adjustments that will avoid problems in the future. Several trends and developments are worth careful attention.

1. Weed populations have changed with more intensive row crop production and intensive herbicide use. Weed species that are increasing include wild proso millet, woolly cupgrass, nightshades and velvetleaf. In addition, strains of several weed species including foxtails, pigweed and Canada thistle that are more tolerant to some herbicides are occurring more frequently. Herbicide rotations, mixtures and new herbicides will be needed to avoid the problem of tolerant weeds.

2. Conservation tillage practices are resulting in changes in weed populations and making it necessary to rely more on herbicides and less on tillage for weed control. Increases in perennial weeds, biennial weeds and annual grasses have occurred frequently in reduced tillage systems. Without improved herbicides, this shift toward soil-conserving tillage would not be possible.

3. Improvements in postemergence herbicides may make it possible in the future to rely even more on chemicals for weed control. New postemergence grass control herbicides for soybeans look very promising. These herbicides will accelerate the trend toward solid-seeded soybeans and reduced tillage.

4. Herbicides have made it possible for farmers in Minnesota to use at least 10 million gallons less fuel annually in growing corn and soybeans. With improved herbicides, fuel savings will be even greater as farmers further reduce tillage. Some of the new herbicides are more active, thus less chemical is needed, and some of the new concentrated dry formulations require less petroleum products to formulate the chemical. These savings in petroleum products in the manufacturing, formulating and transporting of herbicides as well as reduced fuel requirements for crop production will be very significant in the 1980's.

5. Breakthrough's in the understanding of weather and other environmental effects on herbicideswill make it possible to adjust application techniques to improve the consistency of herbicide performance. Improved incorporation techniques have reduced the problems of poor performance of soil-applied herbicides due to lack of timely rains. Recent research on dew, rainfall, temperature, humidity and time-of-day effects on postemergence herbicides will be widely used to improve performance of postemergence herbicides.

6. Safer handling techniques including closed systems, bulk handling and returnable containers will greatly reduce exposure of people to herbicides and avoid many of our present disposal problems.

Controlling weeds in corn and soybeans will continue to require a well planned, multi-faceted weed management system including crop selection, productive cultural practices, selection of appropriate chemicals, accurate application of chemicals, chemical rotation and cultivation. The planning of the weed control system for a particular field must include consideration of the kinds of weeds involved, the crops to be grown for several years, the organic matter content in the soil, the soil texture, crop tolerance to the herbicides and the previous herbicide use history. Proper analysis of these factors makes it possible to intelligently select an herbicide or combination of herbicides that will effectively control the weeds without causing unnecessary risk of crop injury or soil residues that will affect crops grown in following years.

Crop pest management programs are being used by more farmers to help them obtain the individual field information necessary to develop sound weed control systems. These pest management programs include field scouting to identify and map weed problems and to collect soils information needed to select herbicides and rates of application. Crop pest management programs are now offered in Minnesota by the Agricultural Extension Service, private consultants and cooperatives. As farms become larger and technology becomes more complex, farmers are likely to make more use of expert consultant services to assist them in developing more effective weed control systems.

The information in Tables 1 and 3 shows the effectiveness of herbicides on various weed species and illustrates the need for properly identifying the weeds in a field before selecting the herbicide. In many fields, it is necessary to use mixtures of multiple treatments to attain broad spectrum weed control. Suggestions for herbicide treatments for corn and soybeans in 1981 are given in Tables 2 and 4.[1/]

1/ Trade names are used to identify the herbicide discussed. Omission of other trade names of similar herbicides is unintentional. The inclusion of a trade name does not imply endorsement and exclusion does not imply nonapproval. These rates will need to be properly interpreted for the formulation you use and for band width and row width if the chemicals are not applied broadcast. See Agricultural Chemicals Fact Sheet No. 5, How to Calculate Herbicide Rates and Calibrate Herbicide Applicators. The proper rate depends on such things as soil characteristics, kind of weeds and crop, temperature, and moisture conditions. Read labels for detailed use instructions and restrictions on crop use.

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

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

[1] G = good; F = fair; P = poor; N = none.

Table 2. Suggestions for chemical control of weeds in corn.

Method of application Chemical-common name (Trade name)	Rate—lb/A of active ingredient or acid equivalent broadcast	Remarks
Preplanting incorporated		
Alachlor (Lasso)	2 to 4	Preplanting application of alachlor or metolachlor at the high rates is suggested if nutsedge is a problem, but for annual grasses only, shell incorporation or preemergence application is preferred. Incorporate butylate or EPTC immediately after application.
(Lasso II)	2.4 to 3.9	
Atrazine (AAtrex, others)	2 to 3	
Butylate (Sutan+)	4 to 6	
Cyanazine (Bladex)	2 to 4	
Metolachlor (Dual)	1-1/2 to 3	
Atrazine + alachlor	1 to 2 + 1-1/2 to 2-1/2	
Atrazine + butylate	1 to 1-1/2 + 3 to 4	
Atrazine + metolachlor	1 to 2 + 1-1/4 to 2-1/2	
Cyanazine + alachlor	1 to 2.2 + 2 to 2-1/2	
Cyanazine + metolachlor	0.8 to 2-1/2 + 1-1/4 to 2-1/2	
Atrazine + EPTC (Eradicane)	1 to 1-1/2 + 3 to 4	
Cyanazine (Bladex) + butylate	1 to 2 + 3 to 4	
Cyanazine + EPTC (Eradicane)	1-1/2 to 2 + 3 to 4	
EPTC + protectant (Eradicane)	3 to 6	
Preemergence		
Alachlor (Lasso)	2 to 3-1/2	Atrazine may carry over and affect crops the next year. Other chemicals do not carry over. Do not use preemergence applications of cyanazine, propachlor, dicamba, or linuron on sandy soils. Linuron is suggested for use only on soils between 1 and 4 percent in organic matter.
(Lasso II)	2.4 to 3.9	
Atrazine (AAtrex, others)	1 to 3	
Cyanazine (Bladex)	2 to 4	
Metolachlor (Dual)	1-1/2 to 3	
Propachlor (Ramrod, Bexton)	4 to 6	
Atrazine + alachlor	1 to 2 + 1-1/2 to 2-1/2	
Atrazine +metolachlor	1 to 2 + 1-1/4 to 2	
Atrazine + propachlor	1 to 1-1/2 + 2 to 3-3/4	
Cyanazine + alachlor	1 to 2.2 + 2 to 2-1/2	
Cyanazine + metolachlor	0.8 to 2-1/2 + 1/1-4 to 2-1/2	
Cyanazine + propachlor	1 to 1.8 + 2-1/2 to 6	
Dicamba (Banvel) + alachlor	1/2 + 2 to 2-1/2	
Linuron (Lorox) + alachlor	1/2 to 1-1/2 + 1 to 3	
Linuron + propachlor	1 to 1-1/2 + 2 to 3	
Postemergence		
Atrazine (AAtrex, others) + oil	1.2 to 2	Apply when weeds are less than 1-1/2 inches tall.
Bentazon (Basagran)	3/4 to 1	Apply when weeds are 2 to 6 inches. Earlier application is more effective on most weeds.
Bentazon + atrazine + oil conc.	3/4 + 3/4 + 1 qt	Controls only broadleafs. Apply when weeds are less than 2 to 4 inches and corn has 1 to 5 leaves.
Cyanazine (Bladex 80W)	2	Apply when weeds are less than 1-1/2 inches tall and before corn has more than 4 leaves.
Pendimethalin (Prowl) + atrazine	3/4 to 1-1/2 + 1 to 1-1/2	Apply up to 2-leaf stage of corn and weeds up to 1 inch.
Pendimethalin + cyanazine 80W	3/4 to 1-1/2 + 1 to 2-1/2	Apply up to 2-leaf stage of corn and weeds up to 1 inch.
Dicamba (Banvel)	1/8 to 1/4	Apply dicamba before corn is 2 feet tall and not within 15 days of tasseling. Follow drift control precautions on label.
Dicamba + 2,4-D amine	1/8 to 1/4	
2,4-D amine	1/4 to 1/2	Apply when corn is 4 inches to 3 feet tall. Use drop nozzles after corn is 8 inches tall. Earlier applications
2,4-D ester	1/6 to 1/3	

(continued)

Table 2 continued.

Method of application Chemical-common name (Trade name)	Rate—lb/A of active ingredient or acid equivalent broadcast	Remarks
Postemergence (continued)		
		on small weeds are more effective.
2,4-D amine	1/2 to 1	Apply after corn is 3 feet tall.
2,4-D ester	1/3 to 2/3	Use drop nozzles so only base of stalk is sprayed. Do not apply between tasseling and dough stage of corn.

Table 3. Effectiveness of herbicides on major weeds in soybeans.

	Preplanting									Preemergence						Postemergence			
	Alachlor (Lasso)	Chloramben (Amiben)	Fluchloralin (Basalin)	Metolachlor (Dual)	Metribuzin (Lexone/Sencor)	Pendimethalin (Prowl)	Profluralin (Tolban)	Trifluralin (Treflan)	Vernolate (Vernam)	Alachlor (Lasso)	Chloramben (Amiben)	Chlorpropham (Furloe Chloro IPC)	Linuron (Lorox)	Metolachlor (Dual)	Metribuzin (Sencor, Lexone)	Acifluorfen (Blazer)	Bentazon (Basagran)	Diclofop (Hoelon)	2,4-DB
Soybean tolerance	G	G	F	G	F	F	F	F	F	G	G	G	F	G	F	F	G	G	P
Grasses																			
Giant foxtail	G	G	G	G	F	G	G	G	G	G	G	P	F	G	F	P	N	G	N
Green foxtail	G	G	G	G	F	G	G	G	G	G	G	P	F	G	F	P	N	G	N
Yellow foxtail	G	G	G	G	F	G	G	G	G	G	G	P	F	G	F	P	N	F	N
Barnyardgrass	G	G	G	G	F	G	G	G	G	G	G	P	F	G	F	P	N	G	N
Wild proso millet	F	P	F	F	P	F	F	F	F	F	P	P	P	F	P	P	N	P	N
Nutsedge	G	P	N	G	P	N	N	N	G	F	P	N	P	F	P	P	F	P	N
Broadleafs																			
Eastern black nightshade	F	F	P	F	P	P	P	P	P	G	F	P	P	G	P	G	F	N	-
Hairy nightshade	F	P	F	P	P	P	P	P	P	G	G	P	-	P	P	P	G	N	-
Cocklebur	P	P	N	N	F	N	N	N	P	P	P	P	P	N	F	F	G	N	F
Kochia	P	G	G	P	G	G	G	G	-	P	G	P	F	P	G	-	-	N	-
Lambsquarters	F	G	G	P	G	G	G	G	G	F	G	P	G	P	G	P	P	N	P
Mustard	P	F	N	P	G	N	N	N	F	P	F	F	G	P	G	G	G	N	P
Pigweed	G	G	G	G	G	G	G	G	G	G	G	P	G	G	G	G	P	N	P
Common ragweed	P	G	N	P	G	N	N	N	P	P	G	P	G	P	G	F	G	N	P
Giant ragweed	P	F	N	P	F	N	N	N	P	P	F	P	F	P	F	P	F	N	F
Smartweed	P	G	P	P	G	F	P	P	P	P	G	G	F	P	G	G	G	N	P
Velvetleaf	P	F	N	P	F	F	N	N	F	P	F	P	F	P	F	P	G	N	P
Venice mallow	P	G	P	P	G	P	P	P	G	P	G	P	G	P	G	-	G	N	P
Wild sunflower	P	P	N	P	F	N	N	N	P	P	P	P	P	P	F	G	G	N	P

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

Table 4. Suggestions for chemical control of weeds in soybeans

Method of application Chemical-common name (Trade name)	Rate—lb/A of active ingredient or acid equivalent broadcast	Remarks
Preplanting incorporated		
Alachlor (Lasso)	2 to 4	Preplanting application of alachlor or metolachlor is suggested if nutsedge is a problem, but for annual grasses only, preemergence application or shallow incorporation is preferred. See label instructions on incorporation methods. Metribuzin may be mixed with alachlor, fluchloralin, metolachlor, pendimethalin, profluralin or trifluralin; and chloramben may be mixed with alachlor, metolachlor, pendimethalin or trifluralin for preplant and incorporated application. Chlorpropham may be tank mixed with profluralin, trifluralin, vernolate or alachlor.
(Lasso II)	2.4 to 3.9	
Fluchloralin (Basalin)	1/2 to 1-1/2	
Metolachlor (Dual)	1-1/2 to 3	
Pendimethalin (Prowl)	1/2 to 1-1/2	
Profluralin (Tolban)	1/2 to 1-1/2	
Trifluralin (Treflan)	1/2 to 1	
Vernolate (Vernam)	3	
Preemergence		
Alachlor (Lasso)	2 to 4	Do not use linuron or metribuzin on sandy soils. Linuron is suggested only for soils with between 1 and 4 percent organic matter. Metribuzin should not be used on soils with less than 0.5 percent organic matter nor on alkaline soils. Several of these preemergence chemicals are effective in combinations over chemicals applied preplanting.
(Lasso II)	2.4 to 3.9	
Chloramben (Amiben)	3	
Chloramben + alachlor	2 + 2	
Chlorpropham (Furloe Chloro IPC)	2 to 3	
Linuron (Lorox) + alachlor	1/2 to 1-1/2 + 1 to 3	
Metribuzin (Lexone, Sencor) + alachlor	1/4 to 1/2 + 2 to 2-1/2	
Metolachlor (Dual)	1-1/2 to 3	
Chloramben + metolachlor	2 + 1-1/2 to 2	
Linuron + metolachlor	1/2 to 1-1/2 + 1-1/4 to 2-1/2	
Metribuzin + metolachlor	1/4 to 1/2 + 1-1/4 to 2-1/2	
Postemergence		
Bentazon (Basagran)	3/4 to 1-1/2	Apply when soybeans are in the first trifoliolate leaf stage for annual broadleaf control. Apply a second treatment for Canada thistle or nutsedge control.
Acifluorfen (Blazer)	3/8 to 1/2	Apply when soybeans are in the first trifoliolate leaf stage and weeds are less than 2 inches tall and up to 4 leaves.
Diclofop (Hoelon)	3/4 to 1-1/4	Apply when soybeans are between the first and sixth trifoliolate leaf stage, before annual grasses exceed 4 leaves and before volunteer corn exceeds 10 inches.
2,4-DB amine (Butyrac, Butoxone)	1/5	Apply 10 days before soybeans bloom up to mid-bloom or as a directed spray when soybeans are 8 to 12 inches tall.

INFRARED - A DETECTION TOOL IN AGRICULTURE

BY

Howard L. Bissonnette, Extension Plant Pathologist

Infrared has been used in Minnesota for several years to detect certain plant diseases and plant stress problems. I have been working with this system of remote sensing mostly in the Red River Valley and western parts of this state. The early work was done with Harley Shurson at Fosston. At this time, there are about 10 or more private businesses providing an infrared survey for their customers. Some of the businesses are connected directly with aerial applicators that provide other service to their customers, others only engage in doing the photography and do not perform further service. I have been involved with most of these people in the "how to do it", the interpretation of the photos and how the grower can best use such a service.

Infrared will detect the differences in heat absorption or reflection by a surface plant, soil, etc. Special infrared film used in a 35 mm camera with a raton 12 filter will detect these differences which will appear as a change in color on the infrared negative. With the advent of the color infrared film, more uses for this remote sensing activity are being found.

In its simplest form, infrared will show where plants may be under stress during the growing season. Visual inspection of the slide usually will not identify the cause of the stress. National Aviation & Space Administration has equipment that will allow a person to identify plant species, and some of the causes of plant stress. However, with visual inspection of infrared slides, a grower can go into his field and identify quickly the areas of plant stress. With experience and knowledge of the particular field, a diagnosis often can be made. The use of infrared is a quick method of surveying a large area without actually doing all of the walking.

Areas in which infrared - remote sensing is being used in Minnesota:

Potatoes	Disease detection (successful) Late Blight Early Blight Verticillium wilt
Cereals	Leaf spot detection (unsuccessful)
Corn	Water stress (irrigation) (good) Fertilizer effects (good, where there are differences)
Soybean	Cyst nematode detection (good)
Sugar Beets	Leaf spot detection (good) Mildew (?)

Dry Beans	Disease detection (various degrees of success) Compaction (soil)?
Irrigation	Nozzle malfunction Lack of coverage

You will note that in most of this work, we are using infrared as a tool for early detection of a problem where some corrective action can be taken once the problem is observed. Usually plant diseases fall into this type of use pattern. Because of the often nonuniform occurrence of a plant disease within a field at the early stage of the disease, this remote sensing technique allows a grower to observe all parts of the field at the same time. In contrast, infrared can also be used to detect more permanent type problems, e.g. soil type, drainage, etc. Even though such problems may be known to exist on a particular piece of land, an infrared photo would make a permanent record. Such a survey might show a grower where not to plant and thus lower the cost of production. I would think that this would be a good way to survey a new piece of land before buying. Of course this should be done when a crop is growing on the land.

For infrared plant disease detection, it is suggested that photos be taken on a weekly basis. This may involve 4 or 5 photos depending on the crop or disease. The photography should be at low level - 750 to 1000 feet. Personally, I prefer oblique to vertical photos. Also, I recommend that film processing be done immediately, locally so that the information is available at least the next day. In the case with potatoes, we usually start about the second week in July. Each week the new photo is checked and compared with the previous weeks' photo. In potatoes, we are able to detect the early stages of Late Blight and can identify Early Blight and follow the development through the crop. When photos were taken while the crop was being cultivated, you could observe slight wilting in the cultivated potatoes. Some growers have cut back on cultivation because of such observations. Verticillium wilt usually shows up on infrared slides, however, we do not have a chemical control to apply. However, the grower can identify seriously affected areas of his field. In all cases, the film only detects problem areas. Identification requires follow-up ground truth. Using the photo, the grower can go directly to the affected area.

I am sure that this tool will be put to many new uses in agricultural production. My concern is that this detection tool is not misused.

THE TECHNIQUE FOR LOW ALTITUDE COLOR INFRARED PHOTOGRAPHY

Donald L. Breneman
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The photographic technique for monitoring plant diseases with low altitude color infrared photography is relatively simple. It requires only a basic knowledge of photography and a conventional 35mm camera equipment.

Film

Kodak Ektachrome infrared film is ideally suited for photography with hand held 35mm camera equipment. This film can be handled like any other 35mm film except that more stringent storage conditions are required. It should be stored in a freezer at -18^{o}C to -23^{o}C (0^{o}F to -10^{o}F) in the original sealed package. To prevent moisture from condensing on the cold film allow it to warm up for one and one-half hours before opening the plastic can.

Ektachrome infrared film is sensitive to violet and blue light as well as infrared wave lengths. A yellow (Wratten 12) filter must be used to eliminate this unwanted portion of the spectrum. The Wrattan 12 filter is not commonly stocked by most camera stores, but can be special ordered by a dealer from Tiffin Optical Company. With the filter in place, Ektachrome infrared film has an exposure index of approximately one hundred and you should set your exposure meter accordingly.

An exposure meter is designed to measure visible light rather than infrared, so you should consider the readings given by it only as approximate. Infrared radiation can vary at least one F stop from the visible light reflectance so bracket your exposure in half stop incriments at least one stop on either side of your meter setting. For example, if your meter reading calls for a shutter speed of 1/250 @ F8 you should make a series of exposures beginning with 1/250 @ 5.6; make the next shot with the aperture between 5.6; and 8; then 8; another between 8 and 11; and finally an exposure at F11. This process takes longer to describe than it actually takes in practice but it quarantees a correctly exposed transparency that will record the maximum plant information.

Processing the film is complicated by the fact that it requires an older E-4 process rather than the E-6 chemistry currently standard for all other Ektachrome films. Most photo labs no longer have processing equipment for E-4 film so finding a local processor is getting difficult. In Minnesota, the 3M Dynacolor Lab in Northfield still processes E-4 film and will take Ektachrome Infrared film. Processing mailers can be obtained by calling area code 507-645-9534 collect.

Camera Equipment

Any good quality 35mm camera can be used for color infrared work. The single lens relex design SLR (see attachment 1) with built in exposure meter is most convenient. These cameras will take a wide variety of interchangeable lens and accessories. A standard 50mm lens is all that is needed for field monitoring. You can vary the area you are photographing by varying your altitude. Most current SLR cameras will except a motorized film advance. This device automically advances the film each time you release the shutter and is a useful accessory in that it makes it possible to shoot more frames while you're over a target. It also makes it more convenient to bracket your exposure as you do not have to stop and wind the camera after each shot.

The only other essential accessory is a metal lens hood to prevent extraneous light from striking the lens and impairing contrast. Lens hoods are available in metal and soft rubber. Avoid the soft rubber hoods as they tend to collapse over the lens when the camera is held out in the prop wash.

Occasionally it may be desirable to compare the infrared image with the visual image recorded on regular color transparency film. This is made easier by mounting 2 motorized cameras side by side on a short bar of angle aluminum. (Picture 1) The cameras are attached to the bar by a ¼/20 bolt through the tripod socket. Each camera can be operated separately or an electric switch can be installed that will fire both simultaneously.

Technique

Color infrared photography is most successful when the sun is near its Zenith so try to schedule your flight between 10 a.m. and 2 p.m. Nearly any high wing aricraft can be used if it has a door or window that can be opened. On Cessna aircraft the window brace can be removed to make it possible to fully open the window. (Picture 2) The pop wash will usually hold the window up beneath the wing. Avoid touching any part of the plane with the camera as vibration will be transmitted to the camera. To insure sharpness try to work with a shutter speed of 1/250 of a second or faster.

Make an exposure meter reading before you leave the ground and another when you are air borne over your target. If there is much haze your aerial reading will usually be higher. Set your camera about half way between the two readings and use that as your starting point. As mentioned earlier bracket your exposure at least one stop in each direction to insure your results.

With the sun overhead, lighting direction will not be a significant factor but it will probably easier to work with the sun behind you, so plan your mission accordingly. The altitude is not critical provided that you stay above the 500 ft. minimum. Simply vary your altitude until you get the area in the frame that you wish to photograph. After a little experience you will soon find an altitude that works most convenient.

Oblique views are generally preferred to vertical shots for row crops such as potatoes. Oblique views tend to mask off the soil that could be confused with disease plant material. You'll have to experiment with different altitudes and different distances from the field to get the angle that you want.

Safety

Your personal safety should always be your first consideration in aerial photography. Work only with a commercially licensed pilot who is experienced in flying aerial photography. Even if you are a pilot don't try to take pictures and fly at the same time. It's too easy to become preoccupied with the photography and end up in disaster. Check with the FAA and get the necessary clearances for low altitude aerial photography before you set out.

Make sure your pilot understands where the field is and how you want to approach it. If you're in a plane with side by side seating, the pilot can not see the ground area you can so you must be able to direct him over the target. Work out a set of hand signals in advance as it is very difficult to hear once you have the windows open in the aircraft.

Make enough passes over the target so that you're satisfied that you have the pictures you need. It is far less expensive to make a few extra passes while you're up than to reschedule an entire mission.

With a little experience you will find the aerial infrared photography is relatively simple and a reliable technique for monitoring certain plant diseases. Two publications you will find extremely helpful are Photography From Light Planes and Helicopters, Bulletin M-5 and Applied Infrared Photography, Bulletin M-28, both are available from Professional and Finishing Markets Division, Eastman Kodak Company, Rochester, New York 14650.

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University of Minnesota
Department of Information
and Agricultural Journalism

Selecting A Camera

DONALD L. BRENEMAN

SELECTING A CAMERA

Selecting a camera is often a confusing and expensive process. Cameras of many different types and makes are available ranging in price from under $25 to over $1,000. This information sheet can help you decide what type of camera you want and how much quality you really have to pay for to meet your needs.

DETERMINE YOUR NEEDS

Before selecting a camera consider the following criteria:

- Principal use. What kind of pictures do you need and why?
- Quality of pictures required.
- Price. How much can you really afford to spend?
- Ownership. Will it be yours personally or will it be used cooperatively by several people?

FILM AND FORMAT

Cameras are classified by format, which is the size and shape of the image they produce on film. Your use of pictures is the major criterion in selecting a camera of one format instead of another.

If you want to make snapshots or color slides with a minimum of technical involvement, an automatic cartridge-loading camera using 110 or 126 film is satisfactory.

For color slides, 35mm is the most popular, and the largest selection of color film is available in this format. You can also make color transparencies with larger cameras; however, large format projectors are much more expensive and are not very popular.

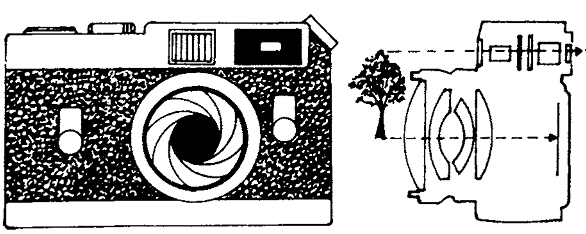
To make black and white pictures for publications, exhibits, and other uses, select a larger format camera that will produce negatives of 2¼ inches square or larger. A 35mm camera will also produce excellent black and white enlargements if a person is willing to carefully process his or her own film.

Color enlargements of 8 x 10 inches or larger will usually be better if made from a negative 2¼ x 2¼ inches or larger.

VIEWING AND FOCUSING SYSTEMS

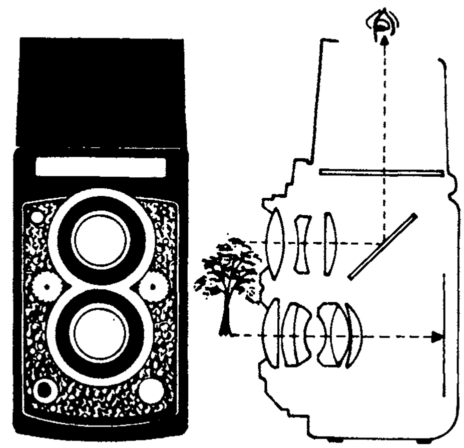
All cameras designed for hand-held shooting can be classified into three types according to the viewing system.

Viewfinder



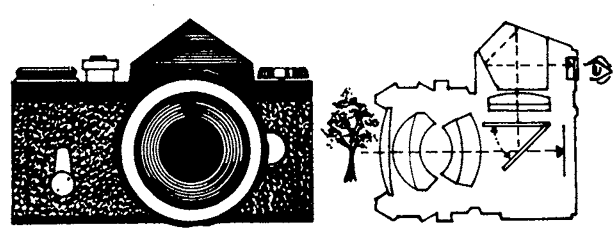
The viewfinder camera has a window built into the top of the camera. You look through it to compose your picture. This window is often equipped with an illuminated frame showing the margins of your picture, and the more expensive models have a rangefinder to aid in focusing. This type of camera is excellent for general photography of scenery and people and for flash photography. The viewfinder camera is not well suited for extreme close-ups, due to the problem of parallax (see separate heading). Viewfinder cameras are available in most film sizes.

Twin Lens Reflex



A twin lens reflex camera has two lenses, one directly above the other. The top lens is used for viewing and focusing, while the lower lens takes the picture. This type of camera is most popular in a medium format producing negatives 2¼ inches square on 120 roll film. Although not much larger than many 35mm cameras, a twin lens reflex produces a negative nearly twice as large, making it more satisfactory for black and white or color enlargements. It is well suited for general photography but suffers from the problem of parallax in close-up situations.

Single Lens Reflex

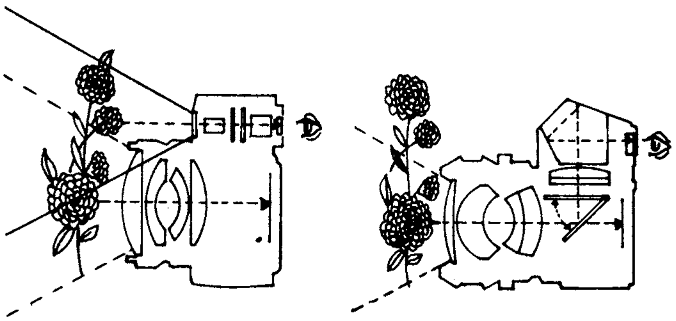


If you plan to do much close-up photography of plants and insects or wildlife photography using a telephoto lens, the single lens reflex camera is the most convenient type. With a single lens reflex, you view and focus directly through the taking lens via a hinged mirror behind the lens. This completely eliminates the problem of parallax in close-up photography.

Attachment 1

Because you are actually viewing through the taking lens you can focus and frame a picture very accurately when using telephoto lenses. Single lens reflex cameras are available in most film sizes and can be adapted to nearly any type of photographic need. Because they are more complex than the other types, they are considerably more expensive.

Parallax



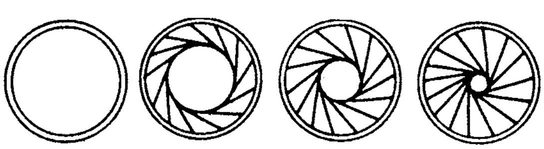
Parallax is the difference between what you see through the viewfinder (solid lines), and what the camera actually photographs (dotted lines). Parallax becomes a problem when you are working at distances under 5 feet with a viewfinder or twin lens reflex type camera where the viewing and taking lenses are separated. At greater distances, parallax becomes insignificant. A single lens reflex camera completely eliminates this problem, because you view and photography through the same lens.

CAMERA FEATURES

Focusing device—permits adjusting the lens for camera-to-subject distance in order to obtain the sharpest possible picture. Viewfinder type cameras have a coupled rangefinder for this, while reflex cameras focus on a ground glass screen.

Adjustable Shutter Speed—controls the amount of time that light can strike the film during an exposure. Shutter speeds are marked in fractions of a second, usually ranging from 1 second to 1/500 or 1/1000 of a second maximum.

Adjustable lens diaphragm—allows controlling the intensity of light transmitted by the lens. The diaphragm is calibrated in f stops, and a typical scale would read 2, 2.8, 4, 5.6, 8, 11, and 16. At f 2 the lens would transmit the most light, and each smaller f stop would reduce the light intensity by one half that of the previous stop.



Adjustable Diaphragm

Lens speed—many 35mm cameras are available with a choice of two or more normal lenses: one a moderate speed lens of about f 2 maximum aperture and another about f 1.4 of higher maximum aperture. The faster f 1.4 lens transmits one stop more light than the f 2 lens and is better for photography in low light situations. Many people believe the faster lens is better for all types of photography because it is $30 to $60 more expensive than the f 2 lens. This is generally not true. In fact, the f 2 lens will usually produce a sharper image in all but the poorest lighting conditions. Unless you are interested in doing a lot of low light photography, you can save some money buying the slower lens.

Interchangeable lenses—allow removing the lens and replacing it with another, such as a wide-angle or telephoto lens. Nearly all cameras selling for $200 and up have this capability. It is a valuable feature, but you must be prepared to invest in the additional lenses.

Built-in Exposure Meter—is a convenience feature that adds to the camera's versitility. Most single lens reflex cameras now have meters that read directly through the camera's lens. To set the correct exposure, sight through the viewfinder and adjust the shutter speed or lens diaphragm until a needle lines up on a certain mark. Some meters measure only a small portion of the subject being photographed, while others measure the entire picture area. Either system works well when you master its use. Lens meters are especially useful for close-up photography and when using telephoto lenses.

Automatic Exposure Control—carries convenience, complexity, and cost one step further by doing all exposure adjustments for you. The small gain in convenience over a built-in meter is hardly worth the additional cost. If you decide to buy a fully automatic camera, be sure it also provides for manual controls so you can still use the camera when the meter malfunctions or the batteries are dead. Many automatic cameras now have an electronic rather than mechanical shutter. Electronic shutters depend entirely on battery power to function and will not work when the battery dies. Avoid using them in extreme cold and always carry a spare battery with you.

USED CAMERAS

A used camera can be a good investment, but be careful. Camera repairs are very expensive and can tie up your equipment for a long time. If you are not familiar with photographic equipment, do not buy it used unless you can consult someone who knows equipment. Purchase it only from a dealer offering a 10 to 30 day trial period, and use this time to check over all functions of the camera thoroughly by shooting several rolls of film in it.

Check for dents or scratches on the camera that would indicate rough handling, scratches on the lens surface, mold or mildew between the lens elements, scratches on the film, accuracy of the built-in exposure meter, uniformness in exposure from one side of the negative to the other, flash synchronization, and correct focusing.

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Picture 1

Side by Side Mounted Cameras

Picture 2

Camera in shooting position with open plane window

WEED CONTROL SUGGESTIONS FOR SMALL GRAINS AND FORAGES

Oliver E. Strand
Extension Agronomist

SMALL GRAINS

Throughout Minnesota broadleaf weeds have been considered the major weed problem in small grains. In recent years, however, with the use of 2,4-D and other broadleaf herbicides, and since the advent of the shorter-strawed semi-dwarf wheat varieties together with higher usage rates of nitrogen fertilizer, annual grass weeds such as the foxtails have been increasingly competitive with small grains in Minnesota. This is especially true in years of late spring seeding if adverse temperature and moisture conditions limit the early spring growth of small grains.

Recent weed surveys conducted in Minnesota (Table 1) show the importance of the annual grass weeds as competitors in small grains (wheat, barley and oats).

In northwestern Minnesota, another annual grass weed, wild oat, has been and continues to be a serious weed problem in small grains in spite of the availability and use of several wild oat herbicides. Certain broadleaf weeds, such as wild buckwheat and smartweed are resistant to some of the commonly used broadleaf herbicides such as 2,4-D and MCPA. These broadleaf weeds have been increasing in importance throughout the state. Also, the common and widespread annual broadleaf weeds such as common lambsquarters, pigweed and common ragweed continue to be very competitive in small grain fields throughout Minnesota.

According to the Minnesota Crop-Livestock Reporting Service, about 82 percent of the wheat acres and 54 percent of the other small grain acres were treated with herbicides in 1979. In spite of this, County Extension Directors estimated in 1976 that 50 percent of the small grain acres in Minnesota were moderately to severely infested with green or yellow foxtail. Also they estimated that about 40 percent of the small grain acreage was moderately to severely infested with wild oat and wild mustard. I believe that Minnesota farmers can do a better job of weed control in small grain. The following weed control practices are suggested:

Requirements for Small Grain Weed Control

1. Identify the weed problem(s).
2. Select the best herbicide or herbicide combination to handle the weed problem (Tables 2 and 3).
3. Select and use tillage practices that complement and favor good weed control (consistent with soil and water conservation needs).
4. Rotate tillage practices and herbicides together with crops, if necessary, for improved weed control.
5. Identify and control perennial weeds after small grain harvest by herbicides/tillage as needed.
6. Do not allow annual weeds to "go to seed" if it is possible to prevent it. Clip or till stubble fields after harvest to prevent spread of

common ragweed, foxtail and other annual weeds.

7. Sow "clean" seed that is free of weed seeds.
8. Eradicate "occasional" and "scattered" weed species by rogueing or spot spraying with glyphosate (Roundup) or other herbicides as needed.
9. Practice "timely" tillage herbicide spraying and other cropping practices to favor the crop and suppress the weeds. Seed small grains as early as possible in the spring after soil is tillable.
10. Select and adopt recommended crop seeding rates, herbicide rates and effective equipment usage.

FORAGE CROPS

In contrast to most other cultivated crops, where considerable herbicides are used, there is little herbicide usage on alfalfa and other forage crops. This is primarily true because grass weeds are not recognized as a serious problem in alfalfa and other legume crops and there are few herbicides that can effectively control broadleaf weeds in the broadleaf legume crops without injury to the crop species.

The best way to control weeds in the legume forage crops is to seed the alfalfa or other legume without a companion crop either in the spring with the use of a suitable herbicide(s) or in the summer when a herbicide is often not needed. Perennial weeds should be controlled prior to seeding with glyphosate (Roundup 2,4-D or other suitable herbicides. Most broadleaf weeds can be controlled in grass pasture with herbicides and a combination of fertilizer and good management practices. See table 4 for herbicide suggestions.

Table 1. Survey of most common weeds in small grain in Minnesota. (Survey by County Extension Agents/County Agricultural Inspectors). Weeds listed in order by severity of infestation.

1976 Opinion survey		1979 Field survey	
Weed species	Average Severity Index 1/	Weed species	Weed index 2/
Green/yellow foxtail	.439	Green foxtail	105
Wild mustard	.374	Yellow foxtail	89
Wild oat	.368	Common lambsquarters	56
Canada thistle	.289	Smartweed sp.	49
Common lambsquarters	.275	Wild buckwheat	46
Quackgrass	.257	Pigweed sp.	35
Wild buckwheat	.249	Common ragweed	28
Pigweed sp.	.241	Wild oat	25
Smartweed sp.	.223	Canada thistle	24
Perennial sowthistle	.196	Giant foxtail	22
Common ragweed	.190	Wild mustard	19
Barnyardgrass	.150	Quackgrass	13
Kochia	.147	Perennial sowthistle	11
Field bindweed	.110	White cockle	7
Giant foxtail	.106	Barnyardgrass	6

1/ Weed severity index: fields lightly infested = 0.25; fields moderately infested = 0.50; fields severely infested = 1.0.

2/ Weed index: weed frequency % + 3 x field uniformity (number of 0.25 meter quadrats out of 20/field sampled that contained the weed) + 7 x field density (number of weeds/square meter) all divided by 3.

Table 2. Effectiveness of herbicides on major weeds in small grains and flax 1/

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

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

1/ 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 3. Herbicides for weed control in small grains and flax.

Crop	Herbicides 1/	Rate lb/A (AI or AE)	Time of application	Weeds controlled 2/
Wheat or barley	2,4-D amine	1/4 to 2/3	Fifth leaf (or tillering) to early boot	Certain broadleaf weeds
	2,4-D ester	1/6 to 1/2	Fifth leaf (or tillering) to early boot	Certain broadleaf weeds
	MCPA amine	1/4 to 2/3	2 leaf to early boot	Certain broadleaf weeds
	MCPA ester	1/6 to 1/2	2 leaf to early boot	Certain broadleaf weeds
	bromoxynil (Brominal/ Buctril)	1/4 to 1/2	2 leaf to early boot	Certain broadleaf weeds
	bromoxynil and MCPA esters (Brominal Plus/ Bronate)	1/4 + 1/4	2 leaf to early boot	Certain broadleaf weeds
	picloram and 2,4-D amine (Tordon 22K)	1/64 to 3/128 + 1/4 to 3/8	4 leaf to early boot	Certain broadleaf weeds
	diclofop (Hoelon)	3/4 to 1 1/4 (wheat)	1 to 4 leaf stage (wheat)	Certain annual grasses
		3/4 to 1 (barley)	1 to 3 leaf stage (barley)	Certain annual grasses
Wheat or oats	dicamba (Banvel) and MCPA amine	1/8 + 1/4	2 to 5 leaf stage	Certain broadleaf weeds
Spring wheat	trifluralin (Treflan)	1/2 to 3/4	Postplanting incorporation. See label.	Certain annual grasses and broadleafs
	propanil (Stampede)	1 1/2	3 to 5 leaf stage of wheat	Certain annual grasses and broadleafs
	propanil and MCPA isooctyl ester	1 1/8 + 1/4	2 to 4 leaf stage of grass weeds	Certain annual grasses and broadleafs

Table 3. (continued)

Crop	Herbicides 1/	Rate lb/A (AI or AE)	Time of application	Weeds controlled 2/
Oats	2,4-D amine	1/4 to 1/2	6th leaf to early boot	Certain broadleaf weeds
	MCPA amine	1/4 to 2/3	2 leaf to early boot	Certain broadleaf weeds
	MCPA ester	1/6 to 1/2	2 leaf to early boot	Certain broadleaf weeds
	bromoxynil (Brominal/ Buctril)	1/4 to 3/8	2 leaf to early boot	Certain broadleaf weeds
Rye	2,4-D amine	1/4 to 3/4	Rye fully tillered to boot stage	Certain broadleaf weeds
	2,4-D ester	1/4 to 1/2	Rye fully tillered to boot stage	Certain broadleaf weeds
Flax	MCPA amine or ester	1/4	Flax 2 to 6 inches	Certain broadleaf weeds
	dalapon (Dowpon)	3/4	Flax 2 to 6 inches	Certain annual grass weeds
	EPTC (Eptam) 3/	2 to 3	Preplanting incorporation	Certain annual grass and broadleaf weeds
	bromoxynil (Brominal/ Buctril)	1/4 to 1/2	Flax 2 to 8 inches	Certain annual broadleaf weeds

1/ See herbicide labels for EPA limitations on crop. If small grain or flax is underseeded with legumes, do not use unless specific herbicide label permits usage. Check labels for crop safety precautions.

2/ See table 2 for effectiveness of herbicide on particular weeds.

3/ Not for use in spring 1981. Label temporarily withdrawn.

Table 4. Herbicides for weed control in forage crops.

Crop	Herbicides 1/	Rate lb/A (AI or AE)	Time of application	Weeds controlled
Direct seeded alfalfa and certain other legumes (See label)	benefin (Balan)	1 1/8 to 1 1/2	Preplanting incorporation	Certain annual grasses and broadleafs (see label)
	EPTC (Eptam)	2 to 3	Preplanting incorporation	Certain annual grasses and broadleafs (see label)
	profluralin (Tolban)	1/2 to 1	Preplanting incorporation	Certain annual grasses and broadleafs (see label)
	2,4-DB amine	1/2 to 1 1/2	1 to 4 trifoliolate leaf stage of legumes	Certain broadleaf weeds (see label)
	2,4-DB ester	1/2 to 1	1 to 4 trifoliolate leaf stage of legumes	Certain broadleaf weeds (see label)
Established alfalfa	2,4-DB amine	1/2 to 1 1/2	When annual weeds are 1 to 3 inches tall (2 to 5 leaves)	Certain broadleaf weeds
	2,4-DB ester	1/2 to 1	When annual weeds are 1 to 3 inches tall (2 to 5 leaves)	Certain broadleaf weeds
	simazine (Princep)	0.8 to 1.6	Fall	Certain broadleaf and grass weeds
	metribuzin (Sencor/ Lexone)	3/8 to 1	Fall or spring when alfalfa is dormant	Certain broadleaf and grass weeds
	terbacil (Sinbar)	1/4 to 3/4	Fall or spring when alfalfa is dormant	Certain broadleaf and grass weeds
	pronamide (Kerb)	1 to 2	Fall	Certain grass weeds

Table 4. (continued)

Crop	Herbicides 1/	Rate lb/A (AI or AE)	Time of application	Weeds controlled
Established grass pastures	2,4-D	1/2 to 2	After perennial weeds are 6 to 8 inches tall and before bud stage	Certain broadleaf weeds
	MCPA	1/4 to 2	After perennial weeds are 6 to 8 inches tall and before bud stage	Certain broadleaf weeds
	dicamba (Banvel)	1/2 to 1	After perennial weeds are 6 to 8 inches tall and before bud stage	Certain broadleaf weeds
	dicamba + 2,4-D	1/3 to 1/2 + 1 to 2	After perennial weeds are 6 to 8 inches tall and before bud stage	Certain broadleaf weeds

1/ See herbicide labels for EPA limitations on crop use and for specific weeds controlled. Also note potential crop injury warnings.

Stalk Borer and Hop Vine Borer in Corn

John A. Lofgren

The hop vine borer (Hydraecia immanis Guenee̅) is a relatively new pest of corn in Minnesota whereas the stalk borer [(Papaipema nebris (Guenee̅)] is a well established species.

Habits and Damage

Both borers attack corn and although infestations are usually very localized, occasionally they are found distributed throughout a field. This distribution is associated with grasses, and possibly other weeds, on which the eggs overwinter. Eggs of both species are laid in grasses in late summer and fall. The eggs overwinter and hatch in the spring. The young stalk borers bore into the grass stems and begin to feed. As they grow, they become too large for grass stems, so they crawl out and start to bore into plants with large stems. They have a wide host plant range and may be found in small grains, potatoes, tomatoes, flowers and weeds as well as corn. In corn, they feed on the leaves in the whorl and then tunnel into the stalk. This usually kills the plant. However, a stalk borer will complete its life in one corn plant.

When full grown, the larvae pupate and produce the adult moths in August or September. There is one generation a year.

The hop vine borer moths also oviposit on grass in the fall. The larvae which hatch in the spring are soon found feeding at the base of corn plants. It is not known if they first feed on the grasses.

The larvae tunnel into the stem below ground killing the plant. They do not appear to move very far, and one larva usually completes its growth in one plant.

When full grown, the larvae pupate in the soil. The moths emerge in August and lay eggs in the grasses. As with the stalk borer, there's one generation a year.

There are no effective chemical controls available for either of these borers at this time.

Since the eggs of both species are laid in August and September in grasses, the best way to reduce the problem is to control the grassy weeds and to rotate from corn to another crop, such as soybeans, if possible.

The heaviest infestation of both species have been observed in corn following corn near areas infested with quack grass and other grasses the previous seasons.

Reduced fall tillage practices combined with poor weed control can result in damaging infestations. Narrow strips of corn in contour strip planting may suffer more severe damage than larger fields.

Otherwise, the borers will usually be found in the border rows adjacent to grassy field margins and will not be economically important.

Descriptions

Both species of borer are members of the cutworm family so when full grown, the larvae are 1½ to 2 inches long.

The stalk borers are dirty white with distinct dark gray or brownish longitudinal stripes. The striped pattern is interrupted about 2/3 the distance from the tail to the head with a dark saddle-like area. This color pattern is lost in the last instar and the larva is a dirty white color.

The hop vine borer is a whitish larva with distinct pattern of brownish or pinkish spots arranged in bands around the body segments. The head is orange or reddish brown. It also loses its color pattern in the last larval instar.

The adults are heavy bodied moths similar in size to cutworm and armyworm moths. The hop vine borer moth is light brown with a darker line across the wings.

The stalk borer moth is dull grayish brown with many white spots arranged in two rows across the front wings and a faint white line across the wing beyond the spots.

1980 European Corn Borer Fall Survey

District	Av. % Plants Infested	Av. No. Borers per 100 plants	
		1979	1980
West central	28	64	43
Central	27	29	29
East central	28	33	30
Southwest	29	37	34
South central	32	61	36
Southeast	30	27	28
State average	29	42	33

1980 Corn Rootworm Adult Survey

District	Av. No. beetles per acre	
	1979	1980
West central	19,300	32,500
Central	15,900	34,900
East central	18,700	5,100
Southwest	44,600	68,900
South central	22,300	43,700
Southeast	37,600	52,300
State Average	26,400	39,500

90% northern, 10% western

Surveys from Minnesota Department of Agriculture, Division of Plant Industry

Corn Rootworm Insecticides 1980
Waseca (Lueschen, Miller)

Chemical	Average Root Rating (1-6)
Amaze 20 G	2.6
Furadan 15 G	2.8
10 G	3.1
Thimet 15 G	2.8
20 G	1.9
Dyfonate 20 G	2.9
Counter 15 G	3.1
(in furrow)	2.3
Lorsban 15 G	3.3
Mocap 10 G	3.7
15 G	2.4
Check	4.5
BASF 263-08 10 G	2.1
Landrin 15 G	2.6
Tattoo 10 G	2.9
CGA 73102 10 G	2.4

Lamberton (Ford)

Chemical	Average Root Rating (1-6)
Furadan 10 G	1.9
Amaze 20 G	2.0
Counter 15 G	2.0
Thimet 15 G	2.1
Dyfonate 20 G	2.2
Lorsban 15 G	2.4
Mocap 15 G	2.3
10 G	2.5
Check	2.8
Landrin 15 G	2.2
CGA 73102 10G	2.2

Morris (Warnes)

Chemical	Average Root Rating (1-6)
Counter 15 G	2.0
Amaze 20 G	2.1
Thimet 15 G	2.1
20 G	2.4
Furadan 15 G	2.2
Dyfonate 20 G	2.2
Mocap 15 G	2.2
10 G	2.4
Lorsban 15 G	2.7
Check	2.8
Landrin 15 G	2.1
CGA 73102 10 G	2.1

Insecticide - Herbicide Trials

Furadan "problem" plots

Chemical	Waseca Av. Root Rating	Morris Av. Root Rating
Eradicane + Furadan	2.3	2.1
Eradicane + Tatoo	2.1	2.3
Eradicane + BASF 263	1.8	1.9
Eradicane + Amaze	1.8	2.1
Eradicane + Check	2.8	2.5
Eradicane + Extender + Furadan	2.1	2.1
Eradicane + Extender + Amaze	2.0	2.1
Lasso + Furadan	2.2	2.4
Lasso + Tattoo	2.2	2.1
Lasso + BASF 263	1.9	2.0
Lasso + Amaze	2.2	2.1
Lasso + Check	2.9	2.6
Check + Check	2.6	2.4

How Root Damage Ratings Relate to Yield

We have assumed that the 1 to 6 rating scale is a good way to measure the direct damage done by rootworms to the root system and a measure of insecticide effectiveness. The yield data from rootworm insecticide plots are quite variable each year and affected by many things besides rootworm feeding.

We have assumed also that a root rating of about 3 is the point at which measureable effects on yield begin to take place.

By selecting data from our trials over the last few years in which the untreated check root ratings exceeded 3.0 we find the following:

Year Location	Av. of all Insecticides		Av. untreated checks	
	Av. root rating	Av. Yield	Av. root rating	Av. Yield
1975 Lamberton	2.5	75 bu.	4.3	54 bu.
1975 Waseca	2.5	122 bu.	4.3	80 bu.
1978 Waseca	2.3	145 bu.	3.4	131 bu.
1979 Waseca	2.2	165 bu.	3.5	163 bu.
1979 Morris	2.7	103 bu.	4.9	98 bu.

SUMMARY OF 1981 CROP INSECT

CONTROL SUGGESTIONS

Alfalfa

Alfalfa weevil

Harvesting first crop early will prevent economic losses in Minnesota in most years. Biggest threat so far has been to regrowth after first cutting.

Treatment of first crop is justified when over 30% of the plant tips show signs of larval feeding and harvest is at least a week away.

After first crop is removed check regrowth. If larval feeding delays growth (50% or more of the tips showing feeding or about 8 larvae per sq. ft.) treat the stubble.

Chemical	Rate	Limitations (days preharvest)
azinphosmethyl (Guthion)	1/2 to 3/4 lb.	16 to 21 days, one application per cutting.
carbufuran (Furadan)	1/4 to 1/2 lb.	7 days - 1/4 lb; 14 days - 1/2 lb.
methyl parathion	1/4 lb.	15 days
phosmet (Imidan)	1 lb.	7 days; one application per cutting
methoxychlor plus diazinon or malathion		7 days. Several commercial combination products are available, use as labelled.
methidathion (Supracide)	1/2 lb.	10 days.

Leafhoppers

Potato leafhoppers often build up on second or third cuttings. If regrowth is 4 to 8 inches treat at 1 leafhopper per net sweep; 2 per sweep if alfalfa is over 8 inches.

azinphosmethyl (Guthion)	1/4 to 1/2 lb.	14 to 16 days
carbaryl	1 lb.	no preharvest time limit
diazinon	1/2 lb.	7 days
methoxychlor (or mixtures with diazinon or malathion)	1 lb.	7 days
malathion	1 lb.	no preharvest time limit
methidathion (Supracide)	1/2 lb.	10 days
phosmet (Imidan)	1 lb.	7 days

Grasshopper.

Treat field at over 8 hoppers per sq. yd., margins at 20 or more per sq. yd. Do not treat blooming alfalfa.

azinphosmethyl	1/2 to 3/4 lb.	16 to 20 days,
carbaryl	1 to 1 1/2 lb	no time limits
carbofuran	2 to 4 oz.	7 days, one application
diazinon	1/2 lb.	7 days
dimethoate	1/4 to 1/2 lb.	10 days; one application
malathion	1 1/2 lb.	no time limits.

Corn

Armyworm

carbaryl	1 1/2 to 2 lb.	no time limits
chlorpyrifos (Lorsban 4E)	1/2 to 1 lb.	no more than 3 pts of 4E per season. 50 day limit before feeding grain, silage or fodder.
malathion	1 lb.	5 days
methomyl	1/4 to 1/2 lb	3 days forage

toxaphene	2 lb	no time limit for grain. Do not graze, ensile or feed treated plants.
trichlorfon	1 lb	no time limit
<u>Corn rootworms</u>		
Amaze 20 G	6 oz.	75 days before harvest. Do not plant crops other than corn within 18 months of last treatment with Amaze.
carbofuran (Furadan 10G)	12 oz.	Field corn only. Do not plant crops other than alfalfa, corn, peppers, potatoes, sorghum strawberries, sugar beets and tobacco within 18 months of last application. Soybeans or oats may be planted the next season.
chlorpyrifos Lorsban 15 G	8 oz	field corn only
ethoprop Mocap 10 G	12 oz.	
15 G	8 oz.	
fonofos Dyfonate 20 G	6 oz	
phorate Thimet 15 G	8 oz.	
20 G	6 oz.	
terbufos Counter 15 G	8 oz.	

Apply at planting time in 7 inch band over the row, lightly incorporated Do not use a furrow placement unless labelled.

Some liquid formulations are labelled and available. If used, apply in band as with granules or in split band application with liquid fertilizer placed 2 inches away from the seed. Amaze, Furadan, Mocap, Dyfonate, Thimet and Counter are also registered for use as a basal treatment at cultivation.

The best way to prevent rootworm damage is to rotate crops to avoid corn following corn. Extremely heavy infestations may cause injury even in treated fields. Certain unfavorable weather conditions may cause poor performance. It has been observed that consecutive years of treatment with the same compound, especially carbamates, may result in control failures. To minimize this problem rotate chemicals from year to year and especially avoid using a carbamate in successive years.

Cutworms

carbaryl	1 to 2 lb. (bait or spray)
chlorpyrifos (Lorsban 4E)	1 to 1 1/2 lb.
trichlorfon	1 lb.

Some subterranian species such as glassy or sandhill may not be controlled.

Lorsban, Dyfonate and Mocap are labelled for control or suppression of cutworms when applied at planting time as for rootworm control and may give some degree of control.

European corn borer

Bacillus thuringiensis (Dipel, Biotrol, Thuricide) as labeled

carbaryl	1 1/2 lb.	no time limits
carbofuran	1 lb.	field corn only
diazinon	1 lb.	10 days forage
fonofos	1 lb.	30 days
EPN	1/4 to 1/2 lb.	14 days
methyl parathion	1/2 lb	3 days (12-forage)
methomyl	1/2 lb	3 days forage

For field corn treat when 50 to 75% of the plants have shot-holes in the whorl leaves (30 to 50% irrigated corn and 25% seed fields). For second brood borers in sweet corn treat at egg hatch or 7 to 10 days after first moths appear in light traps.

Grasshoppers

carbaryl	1 1/2 lb	no time limit
chlorpyrifos	1/4 to 1/2 lb.	no more than 3 pts. 4E per acre per season
diazinon	1/2 lb	no time limits
malathion	1 lb.	5 days
toxaphene	1 1/2 lb	for grain only

Check Lists of Insecticides Suggested for Use on Field Crops

Crops	Chemicals
Alfalfa	azinphosmethyl (Guthion) carbaryl (Sevin) carbofuran (Furadan) diazinon dimethoate malathion methidathion (Supracide) methomyl (Lannate, Nudrin) methoxychlor methyl parathion phosmet (Imidan) trichlorfon (Dylox, Proxol)
Corn	Amaze <u>Bacillus thuringiensis</u> (Biotrol, Dipel, Thuricide) carbaryl (Sevin) carbofuran (Furadan) chlorpyrifos (Lorsban) diazinon disulfoton (DiSyston) EPN ethoprop (Mocap) fonofos (Dyfonate) malathion methomyl (Lannate, Nudrin) parathion, ethyl parathion, methyl phorate (Thimet) phosmet (Imidan) terbufos (Counter) toxaphene trichlorfon (Dylox, Proxol)
Small Grains	acephate (Orthene) on wheat dimethoate on wheat disulfoton (DiSyston) on wheat malathion parathion, ethyl parathion, methyl phorate (Thimet) on wheat toxaphene trichlorfon (Dylox, Proxol)
Soybeans	acephate (Orthene) azinphosmethyl (Guthion) <u>Bacillus thuringiensis</u> (Biotrol, Dipel, Thuricide) carbaryl (Sevin) dimethoate toxaphene

Crop	Chemicals
Sugarbeet	aldicarb (Temik) carbaryl (Sevin) carbofuran (Furadan) chlorpyrifos (Lorsban) diazinon endosulfan (Thiodan) fonofos (Dyfonate) parathion, ethyl terbufos (Counter) trichlorfon (Dylox,Proxol)
Sunflower	chlorpyrifos (Lorsban) on seed production fields endosulfan (Thiodan) methadithion (Supracide) parathion, methyl toxaphene
Peas, canning	<u>Bacillus thuringiensis</u> (Biotrol, Dipel, Thuricide) carbaryl (Sevin) diazinon dimethoate malathion methomyl (Lannate, Nudrin) parathion, ethyl
Beans, dry	carbaryl (Sevin) diazinon dimethoate endosulfan (Thiodan) malathion
Flax	trichlorfon (Dylox, Proxol)
Wild Rice	malathion
Potato	aldicarb (Temik) azinphosmethyl (Guthion) carbaryl (Sevin) carbofuran (Furadan) diazinon dimethoate disulfoton (DiSyston) endosulfan (Thiodan) fonofos (Dyfonate) malathion methamidophos (Monitor) methomyl (Lannate, Nudrin) monocrotophos (Azodrin) oxydemeton-methyl (Meta Systox) phorate (Thimet) phosphamidon (Dimecron) pirimicarb (Pirimor)

Chemical	Crops
acephate (Orthene)	soybeans wheat
aldicarb (Temik)	potato sugarbeet
Amaze	corn
azinphosmethyl (Guthion)	alfalfa potato soybeans
Bacillus thuringiensis (Biotrel, Dipel, Thuricide)	corn soybeans peas
carbaryl (Sevin)	alfalfa corn soybeans sugarbeets dry beans peas
carbofuran (Furadan)	alfalfa corn potato sugarbeet
chlorpyrifos (Lorsban)	corn sugarbeet sunflower, seed production
diazinon	alfalfa corn sugarbeet peas dry beans
dimethoate (Cygon, Defend, Rebellate, Dimex)	alfalfa wheat soybeans peas potato dry beans
disulfoton (DiSyston)	corn wheat potato

Chemical	Crop
endosulfan (Thiodan)	sunflower sugarbeet potato dry beans
EPN	corn
ethoprop (Mocap)	corn
fonofos (Dyfonate)	corn sugarbeet potato
lindane	seed treatments only
malathion	alfalfa corn small grains soybeans wild rice peas dry beans
methidathion (Supracide)	alfalfa sunflower
methamidophos (Monitor)	potato
methomyl (Lannate, Nudrin)	alfalfa corn peas potato
monocrotophos (Azodrin)	potato
oxydemetonmethyl (Metasystox-R)	potato
parathion, ethyl	corn small grains sugarbeet peas
parathion, methyl (Pencap M)	alfalfa corn small grains sunflower
phorate (Thimet)	corn wheat potato

Chemical	Crop
phosmet (Imidan)	alfalfa corn
pirimicarb (Pirimor)	potato
terbufos (Counter)	corn sugarbeet
toxaphene	corn small grains soybeans sunflower
trichlorfon (Dylox, Proxol)	alfalfa corn small grains sugarbeet flax

Status of Restricted Use Pesticides
November 1980

1. <u>Presently restricted, EPA</u>

Acrolein (Aqualin)
Aldicarb (Temik)
Allyl Alcohol
Aluminum phosphide (Phostoxin, Detia)
Permethrin (Ambush, Pounce)
Azinphosmethyl (Guthion)
Bolstar
Calcium cyanide
Carbofuran (Furadan 4F, 75 WP)
Chlordane
Chlorfenvinphos
Chlorophacinone (Rozol)
Chlorpyrifos (Killmaster II only)
Clonitralid (Bayluscide)
Demeton (Systox)
Diflubenzuron (Dimilin)
Dioxathion (Delnav)
Disulfoton (Disyston Liquid & EC)
Endrin
Ethoprop (Mocap Liquid & EC)
Ethyl Parathion
Fenamiphos (Nemacur)
Fensulfothion (Dasanit Liquid & EC)
Fonofos (Dyfonate Liquid & EC)
Chlordimeform (Fundal, Galecron)
Heptachlor
Hydrocyanic Acid
Methomyl (Lannate, Nudrin)
Methyl Bromide
Methyl Parathion
Mevinphos (Phosdrin)
Monocrotophos (Azodrin)
Nitrofen (Tok)
Paraquat
Phorate (Thimet Liquid and EC)
Phosacetim (Gophacide)
Phosphamidon (Dimecron)
Picloram (Tordon)
Fenvalerate (Pydrin)
Sodium Cyanide
Sodium Fluoracetate (1080)
Strychnine
Sulfotepp
TEPP
Zinc Phosphide

2. Presently Restricted, Minn.

Lindane
Arsenicals
Compound 1080, 1081
Phosphorous paste

3. Proposed for Restricted use by EPA

Carbofuran (Furadan granules 10% and greater)
Carbon disulfide
Chloropicrin
Cyclohexamide (Actidione)
Disulfoton (DiSyston granules
Dicrotophos (Bidrin)
Ethoprop (Mocap granules)
EPN
Fenamiphos (Nemacur granules)
Fensulfothion (Dasanit granules)
Fenthion (Baytex)
Fonofos (Dyfonate granules)
Methamidophos (Monitor)
Methidathion (Supracide)
Nicotine Alkaloid
Oxamyl (Vydate)
Phorate (Thimet granules)
Temephos (Abate)
Terbufos (Counter)