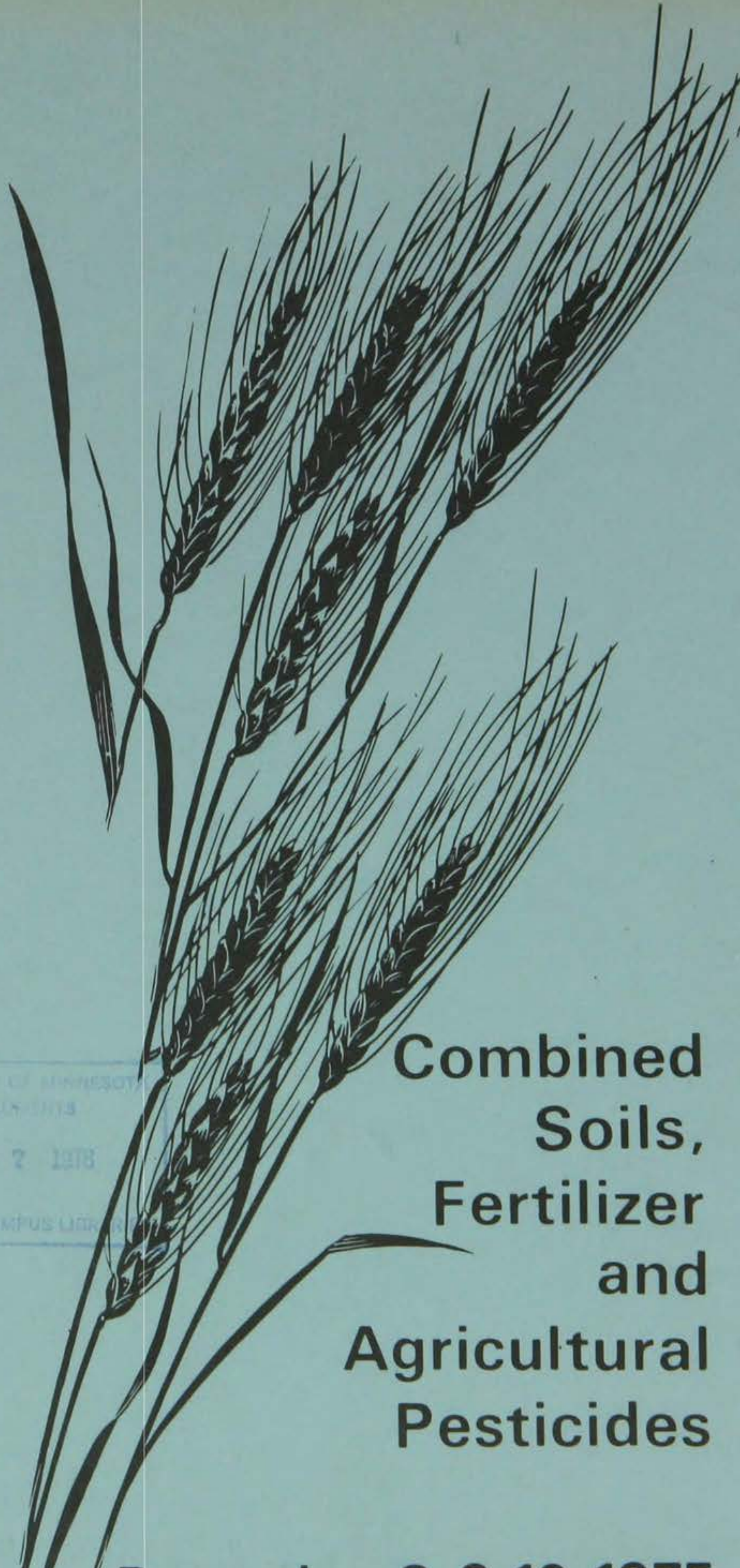

Combined Soils, Fertilizer and Agricultural Pesticides

December 8, 9, 10, 1975
Minneapolis Auditorium

Agricultural Extension Service
UNIVERSITY OF MINNESOTA
Office of Special Programs
Institute of Agriculture

COMBINED SOILS, FERTILIZER AND AGRICULTURAL PESTICIDES SHORT COURSE

PROCEEDINGS

December 8,9,10, 1975
Minneapolis Auditorium

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

in cooperation with
Minnesota Plant Food Association
Minnesota Agricultural Chemical Association
Minnesota Aerial Application Association
Minnesota Certified Applicators Association
Minnesota Limestone Producers Assocation
Minnesota Department of Agriculture

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Soil, Fertilizer and Agricultural Pesticides Short Course -- 1975

Soils Research for Production Efficiency

W. P. Martin, Soil Science Department
University of Minnesota

The world is short of food and the U. S., fortunately, has been able to produce beyond domestic needs. We have been able to feed millions of people outside the U. S. A. with exports that have been vital to our balance of payments. We currently export approximately two-thirds of our wheat crop, a quarter of our corn crop and half of our soybean crop.

But what of the domestic scene? We enjoy the world's most abundant, varied, nutritious and least expensive food supply. However, we are besieged by inflationary forces which are increasing food prices, but more importantly from the farmers standpoint, the costs of producing and processing foods. In the 25 years following World War II, the farmer's total production costs tripled. His farm wages increased 143 percent and his farm real estate taxes 370 percent. And, in addition, the farmer has not shared equally in the income received for his products and labor. On an average his income today is only about 70 percent of that earned by the rest of the nation.

The farmer thus has little choice but to improve his productivity by utilizing the research based technology most of which has come from the Federal and State agricultural research establishments. The farmer must increase crop yields from the soil, and make more effective use of natural resource inputs and of course capital. And we researchers must be certain that we retain the ability to apply theory and fundamentals to practical problems so as to continually improve the production technologies to help both the farmer and the consumer.

This is where the Soil Science Department's research effort comes strongly into the picture. We have four major science areas: (1) Soil Classification and Survey (2) Soil Chemistry and Fertility (3) Soil Microbiology and Biochemistry and (4) Soil Physics and Climatology. Researchers in all of these areas one way or another contribute to production efficiencies.

In the Soil Physics area, for example, researchers and extension specialists have been underwriting the quiet revolution that has been taking place in the reduced tillage necessary for land preparation for crop production. With fall plowing, usually not more than one or two field operations in the spring, which include planting, fertilizing, and chemical weed control, superior crops can be grown. Reduced tillage traps more precipitation for use by crops, reduces erosion and moderates pollution. Savings in land preparation alone vary from $5 to $10 an acre and energy in farm machinery use is saved as well as maintenance. It is conservatively estimated that the Minnesota farmer is saving at least $35 million annually in production costs.

Irrigation and water conservation procedures, which have been researched for sandy soils combined with improved weather forecasting from our climatologists, have made it possible to schedule farm operations more efficiently, select better crops and varieties, and improve the overall management of the farm enterprise so as to maximize crop production. Yields of the semi-dwarf wheat, Era, were increased 35 bu./acre from 100 pounds of nitrogen plus irrigation in experiments at Staples and substantial yield increases occurred also on corn, edible beans and other crops. If only 30 percent of the irrigable acreage in Minnesota were planted to corn and wheat, and with proper fertilization based on soil test, the additional return to farm income would be over $23 million annually.

Research by our soil microbiologists on the nodulation of soybeans in southern Minnesota with nitrogen fixing bacteria showed a 30% increase in yield over no-nod isolines of Chippewa maturity. There is still much work to be done to assure nodulation with highly effective strains of the nitrogen-fixing bacteria vs the less effective ones already present in the soil. Effective nodulation can increase yields worth millions of dollars in production efficiencies to Minnesota farmers who are now spending about $350 thousand annually for soybean inoculants alone. The effectiveness of herbicidal chemicals as related to soil fertility levels including level of organic matter and soybean variety interactions including susceptibility to chlorosis (yellowing) also means dollar savings for farmers in more efficient use of weed chemicals.

Fertilizer use efficiency and the need for lime have been strongly researched by our soil chemists and fertility specialists. The farmer must be informed on the many factors that can be costly in the inefficient use of fertilizer materials. Fertilizer price increases have averaged over 100 percent the past two years alone. Matching fertilization to soil fertility level based on soil test, backed by extensive field testing, assures economic use of fertilizers on corn, small grains, forages and horticulture crops. Agricultural limestone should be used on acid soils so as to maximize the utilization of applied fertilizers by crops. Excessive fertilization will not increase yields in either wet or dry years and where phosphor levels have been built up over time to high levels, high yields can be obtained with only moderate applications of fertilizer. Time of application and method (band and/o broadcast) are also important in fertilizer use efficiencies. Many thousands of dollars can be lost by improper use of high-cost fertilizers and savings of $10-$30/acre can be easily realized by following reliable recommendations based on soil test and by the use of improved plant varieties based on research which are responsive to fertilizer nutrients.

Much research is currently underway on the ways in which organic wastes and waste-waters, sewerages and animal manures, for example, can be efficiently utilized for crop production. Nitrogen, phosphorus and other nutrients can be utilized by crops but they must first be released from organic combination by soil microorganisms. How they are applied to the soil and their composition will largely determine the rate of release of plant nutrients for use by the crop. Toxic elements often present in sewage must be avoided and the crop will not do well if the ratio of carbon to nitrogen in the organic materials is too high. Fertilizers must usually be applied in addition to assure adequate supplies of plant nutrients when needed by the crop for optimum production. Again soil testing is essential but the value of farm manures alone on the basis of nutrient composition is $16-$32 million annually.

Researchers in soil classification and land use areas are rapidly completing a Minnesota Soil Atlas for the different kinds of soils found in Minnesota together with interpretive information for developing land use plans and the constraints on use that relate to such problems as susceptibility to erosion, drouthiness, drainage and the like. Productivity indexes for the major soil types are also being recorded based on thousands of samplings of actual production records in farmer's fields. This information is exceedingly important for zoning activities so as to preserve the best soils for intensive agriculture and the development of farm management plans so as to maximize production of the several crops best adapted to the enterprise system. This can only result in overall production efficiencies and can save the Minnesota farmers millions of dollars annually.

It is evident that if we are to assure adequate food supplies in this country at a fair price, a surplus for export, and a return for the farmer equal to the national average, we must continue to stress researches that are concerned with the efficiency of crop production factors. There must be substantial improvement in crop yields per acre and per unit of energy used in the production process. We must also find ways of optimizing farm enterprise systems based on soil and crop management researches.

NITRIFICATION INHIBITORS - SOMETHING NEW?

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The efficient use of nitrogen fertilizer in agricultural production has received considerable attention in recent years. Much of the concern has been related to a number of factors including the higher prices for fertilizer, the scare of a potential fertilizer shortage, and environmental impacts of excess fertilization. There is extensive research emphasis into methods for improving nitrogen fertilizer efficiency in major production areas of the United States. Considerable attention is focused on the use of nitrification inhibitors. For many years certain chemicals have been known to inhibit the process of nitrification. The use of these chemicals in the U.S. for commercial purposes is, however, a recent event (1974). This presentation will therefore be concerned with examining the function of nitrification inhibitors and evaluating their importance to Minnesota agriculture.

ADDITION AND FATE OF NITROGEN FERTILIZERS TO SOIL

After its initial reaction with water in the soil much of the nitrogen fertilizer applied to agricultural land is converted to the ammonium form (NH_4^+). This includes all the nitrogen applied as anhydrous ammonia and urea, one-half of the nitrogen in ammonium nitrate, and at least a portion of that present in nitrogen solutions. That which is not in the ammonium form will usually be present as the nitrate form.

The ammonium form of nitrogen in the soil may be adsorbed directly by the plant root. That which remains in the soil is held by the clay and organic matter fraction and therefore does not move readily through the soil. The ammonium present in the soil is, however, susceptible to microbial transformation to nitrates (NO_3^-). This process is termed nitrification.

The nitrate forms of nitrogen in the soil whether they are added as fertilizers or produced by nitrification may also be used directly by plant roots. The nitrate ion because of its negative charge is not held by the clay and organic matter fraction and therefore may move readily through the soil with soil water leading to potential leaching losses. The nitrate ion may also be influenced by a process termed denitrification. Microbial denitrification is thought to take place primarily under wet or waterlogged soil conditions and is caused by certain anaerobic microorganisms which are capable of obtaining oxygen from inorganic sources such as nitrates. The result is the step-wise removal of oxygen to the point at which the nitrogen is lost to the atmosphere as N_2 gas. It should be noted that although both ammonium and nitrates may be used directly by plant roots the nitrate form may be positionally more available since it can be moved to the plant root with the soil water. Because ammonium does not move readily it would be necessary for the plant root to come in close proximity with the ammonium ion for absorption to take place. The ideal situation would be to maintain the nitrogen in ammonium form until it is needed by the plant and then have it transformed to nitrates.

NITRIFICATION REACTION IN SOILS

The process of ammonium conversion to nitrate takes place in two steps:

$$2NH_4^+ \text{ (Ammonium)} + 3O_2 \xrightarrow[\text{(bacteria)}]{\text{Nitrosomonas}} 2NO_2^- \text{ (Nitrite)} + 2H_2O + 4H^+$$

$$2NO_2^- + O_2 \xrightarrow{\text{Nitrobacter}} 2NO_3^- \text{ (Nitrate)}$$

In the spring after fertilization the nitrification reaction takes place fairly rapidly with most of the fertilizer nitrogen converted to nitrate in as little as 3-4 weeks. The chemicals known as nitrification inhibitors are toxic to the nitrosomonas bacteria therefore preventing the formation of nitrites (NO_2^-). Chemicals which would interfere only with the second reaction (nitrobacter) would not be satisfactory inhibitors since they would allow the accumulation of nitrites which are toxic to plants in very low concentrations.

There are many chemicals which have been found to inhibit the nitrification reaction. The efficiency of the inhibitors will vary considerably depending on the rate of application, type of soil, and the environmental conditions encountered. It has been observed in a number of locations that the nitrification reaction may be delayed from one to three months with the use of these nitrification inhibitors.

There are currently 10-12 chemicals which have been investigated and show varying success as acceptable nitrification inhibitors. Most of these products are of Japanese origin where the commercial sale of nitrification inhibitors has been taking place for the last 10-15 years. Some of the most promising nitrification inhibitors include:

Common or Trade Name	Chemical Name	Manufacturer
N-Serve (Nitrapyrin)	2-chloro-6-trichloromethyl pyridine	Dow Chem.
AM	2-amino-4-chloro-6 methyl pyrimidine	Mitsui Toatsu (Japan)
Terrazole	5-ethyleneoxide-3-trichlormethyl-1-2-4 thiodiazole	Olin Mathieson
ST	2-sulfanilamide-thiazole	Mitsui Toatsu (Japan)
DCS	N-2, 5-dichlorophenylsuccinic acid	Sumitomo Chem. (Japan)

Common or Trade Name	Chemical Name	Manufacturer
MAST	2-methyl-4-amino-6-trichloromethyl-5-triazine	Mitsubishi Chem. (Japan)
ASU	1-amidine-2-thiourea	Nitto Chem. (Japan)

Of the above products only one, N-Serve (Nitrapyrin-2-chloro-6-trichloromethyl pyridine), is commercially available in the U.S. for use strictly as a nitrification inhibitor. The product 'AM' has been investigated extensively and has been commercially used in Japan for over 10 years. Terrazole is gaining considerable interest not only because it is an effective nitrification inhibitor but because of its added benefit as a fungiside. Presently, terrazole is marketed in the U.S. as a chemical to control "damping off" and is effective for the control of Pythium, Fusarium, and Rhizoctonia.

Since N-Serve is currently the only chemical available as a commercial product for nitrification inhibition in the U.S., it therefore has been researched most extensively. Purdue University in Indiana has reported some tremendous yield increases with N-Serve on "heavy" (silty clay) soil (Table 1). Yield increases on "lighter" (sandy loam) soils were not as dramatic (Table 2). The Purdue research team concluded that best results were obtained on light soils where leaching losses were expected or on heavy soils where denitrification was likely. As a sidelight to the nitrification inhibitor work, Purdue also noted that N-Serve decreased the incidence of stalk rot in corn (Table 3). Thus far Purdue is the only University to report such dramatic findings with stalk rot retardation.

Although Purdue's research findings are very promising, responses such as these cannot be classified as typical. Results from the University of Illinois at Urbana indicate no yield response in corn with the use of N-Serve (Table 4). Similarly their results concerning the reduction of stalk rot were mixed. Varied responses to nitrification inhibitors can be found in many states throughout the midwest. Information from Southern Illinois University may tend to put the nitrification inhibitor situation more into perspective. The data (Table 5) is from 1974 which was characterized by a wet spring and early summer thereby possibly stimulating losses by denitrification and leaching. Under these conditions both the inhibitors N-Serve and Terrazole increased the yield of corn. Yields, however, were higher when anhydrous was sidedressed (no inhibitor) late in June. This exemplifies the fact that the most efficient way to apply nitrogen is to "feed" it to the plant as it is needed. This, however, is not always feasible. Nitrification inhibitors may therefore have a place in certain situations where large losses of nitrogen due to leaching and denitrification are anticipated. It should be noted that climatic conditions in any one particular year may alter any anticipated responses from nitrification inhibitors.

POTENTIAL FOR NITRIFICATION INHIBITORS IN MINNESOTA

The primary selling point of nitrification inhibitors in any area must revolve around its potential for increasing nitrogen fertilizer use efficiency. If inhibitors can do this in Minnesota then it will add a further benefit, that being the increased versatility in fertilizer application programs. We may be able to maintain a high efficiency of utilization with early fall applications of nitrogen with the use of nitrification inhibitors. This, however, remains to be investigated in Minnesota. Nitrification inhibitors are currently being investigated at Waseca, Minnesota to evaluate their potential in that area.

Table 1. Corn yields with fall applied anhydrous ammonia with and without N-Serve. Sullivan County Indiana* - 1974 (silty clay soil).

lbs N/A	Yield - Bu/A	
	Without	With
120	100	140
200	126	157

Table 2. Wheat yields with fall applied nitrogen with and without N-Serve- Indiana* - 1974 (sandy loam soil).

lbs N/A	Sullivan County		Knox County	
	Without	With	Without	With
40	33	36	46	48
80	36	39	49	53

Table 3. Influence of fall applied nitrogen with and without N-Serve on stalk rot. Sullivan County, Indiana* - 1974.

lbs N/A	% Stalk rot	
	Without	With
120	39	13
200	35	14

* Scott, Spies, Huber, Warren, Nelson and Griffith - Purdue University.

Table 4. Effect of nitrogen rate and N-Serve on corn yield and stalk rot rating. Urbana Illinois* - 1975 (silt loam soil).

N-Serve	Lbs N/A 0	120	240
	----------Yield bu/A--------------------		
Without	126	160	169
With**		157	171
	------stalk rot rating***---------------		
Without	4.17	2.62	2.83
With**		2.70	1.96

* HOEFT - University of Illinois

** 0.5 lbs/A active ingredient

*** Larger the number greater the infection-scale = 1-6

Table 5. Corn grain yield as influenced by nitrogen rate, inhibitor coating and nitrogen source.* - 1974.

	lbs N/A		
Treatment	60	120	180
** Urea	77	107	117
** Urea+0.5% N-Serve	84	118	137
** Urea+0.5% Terrazole	96	122	137
*** NH_3 Sidedressed	130	150	140

* Southern Illinois University - Craig Kvien - M.S. Thesis

** Spring Applied - May 24

*** Applied June 27th

CROP FERTILITY PROBLEMS - FIELD SURVEY

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and
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Over 14" of rainfall was recorded at the official weather station in Albert Lea from May 22, 1975, through July 6, 1975. In some areas of the county farmers reported as high as 18" during this same period. This condition caused a pale unhealthy color in knee high corn the first week of July on a large percentage of our corn acreage. I visited with producers and looked at a number of these field during this time and in most cases good yield potentials appeared to have a slim chance. My experiences with knee-high-yellow corn on the 4th of July in the past indicated just that.

Soil Scientists at the University of Minnesota tell us that the yellowing and stunting is due to either a low soil oxygen content or nitrogen losses to the air (denitrification). Both conditions being present under excessive soil moisture. Soil pores not filled with water constitute the soil atmosphere. Plants and soil organisms use soil oxygen and give off carbon dioxide, so oxygen supply becomes critical in water filled soils, as well as nutrient uptake. The other cause of yellowing being denitrification; and research shows a water saturated soil at 75° F can lose up to 95% of its nitrate nitrogen in a nine day period.

Some observations that I made this past summer along with producers are as follows:

(1) Corn following corn was more pale and unhealthy appearing than corn following either soybeans or alfalfa, even though additional nitrogen had been applied the previous fall.

(2) Most problem fields were second year corn or more and had a complete fertilizer applied the previous fall with the nitrogen portion being in the nitrate form.

(3) Fields with late fall applied anhydrous had a better color, as did the corn fields following soybeans.

(4) Some corn roots were at least 36" deep and appeared healthy in water logged soil-with the majority in the upper 8 - 10 inches.

(5) Corn "mudded in" was more stunted and unhealthy in color.

(6) Tests for nitrate nitrogen showed from 27# to 90# in the top 12 inch plow layer on four different problem fields with 107# at the 30" depth to 145# at the 48" depth on one of the fields

(7) Corn following soybeans where ammonium nitrate was applied in the fall of 1974 looked as good early in the season as fields where anhydrous was used. However, in visiting with producers their yields where more disappointing where the ammonium nitrate form was used.

(8) Several producers side-dressed 60# of anhydrous and one applied 60# of 28-0-0 liquid the first week in July on fields fall treated with ammonium nitrate. Each reported only small yield differences, if any.

(9) Corn producers in my area are applying mostly the anhydrous form of nitrogen this fall. Those who have used fall applied ammonium nitrate the past several years feel they lost up to 25 bu/acre this year due to denitrification.

DENITRIFICATION AND NITRIFICATION

Gyles W. Randall
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Nitrogen (N) in soils is almost continually undergoing a series of transformations or chemical changes. Two of these transformations, nitrification and denitrification, are extremely important to the N fertilization segment of corn production. Nitrification is largely responsible for converting N, both added and native, to an available form for plant upstake. On the other hand, denitrification leads to losses of N from the soil to the atmosphere. Both of these transformations are biological in nature. Consequently a number of conditions either favor or govern them.

NITRIFICATION

Nitrification is the conversion of ammonia to nitrate. This has already been described in some detail in the paper "Nitrification Inhibitors" by Malzer. Consequently this discussion will be brief. Conditions which favor nitrification by the nitrifying bacteria are: 1) ready supply of ammonia, 2) a population of nitrifying organisms, 3) warm soil temperatures (primarily 50-90^{o}), 4) optimum moisture for plant growth, 5) good aeration and 6) soil pH of 6 to 8.

Soil temperature is one factor that we should consider strongly when we talk about nitrification of fall-applied anhydrous ammonia (82%) or urea (45%). The relationship of nitrification rate to soil temperature is not completely independent of other factors such as moisture, fluctuation in soil temperature and other factors mentioned above. However, we can generally visualize the affect of temperatures on nitrification as shown in Figure 1. At temperature less than 50^{o}F, nitrification rates become slow and a greater proportion of the fall-applied ammonia (82% or 45%) remains as ammonia, a form resistant to leaching and denitrification losses. As the temperatures increase above 50^{o} the nitrification rate increases until about 80 or 90^{o}F. At these higher temps ammonium forms of fertilizer are converted more rapidly to the nitrate forms, which are susceptible to leaching and denitrification losses.

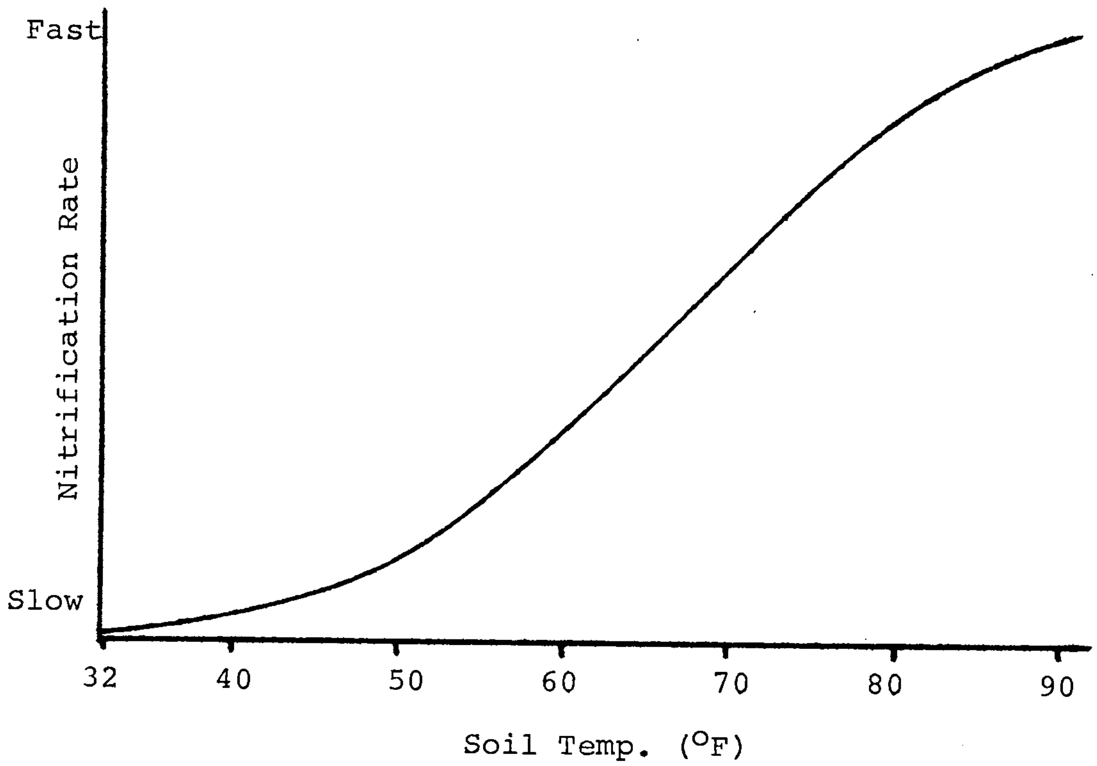

Figure 1. Effect of temperature on nitrification rate.

Soil temperatures at Waseca for the fall of 1974 and 1975 and the 10 year average (1965-74) are shown in Figure 2. These average temperatures (combined 4" and 8") over the 10 year period dip below and remain below 50° on about October 8. In 1974, they fell below 50° in early October and remained less than 50 except for brief periods around October 12th and 30th. Slight conversion of ammonia to nitrate could have been expected during those periods.

Soil temperature during the fall of 1975 were quite warm. They fell below 50° in late September but rose to the low 60's during October 5-15. They did not fall below 50° again until the 27th of October. The period from November 1 thru the 10th again had temperatures above 50°. These conditions more than likely resulted in significant nitrification of any ammonia applied before October 20 to the nitrate forms. As a result, wet conditions could result in significant denitrification or leaching losses of these nitrate forms.

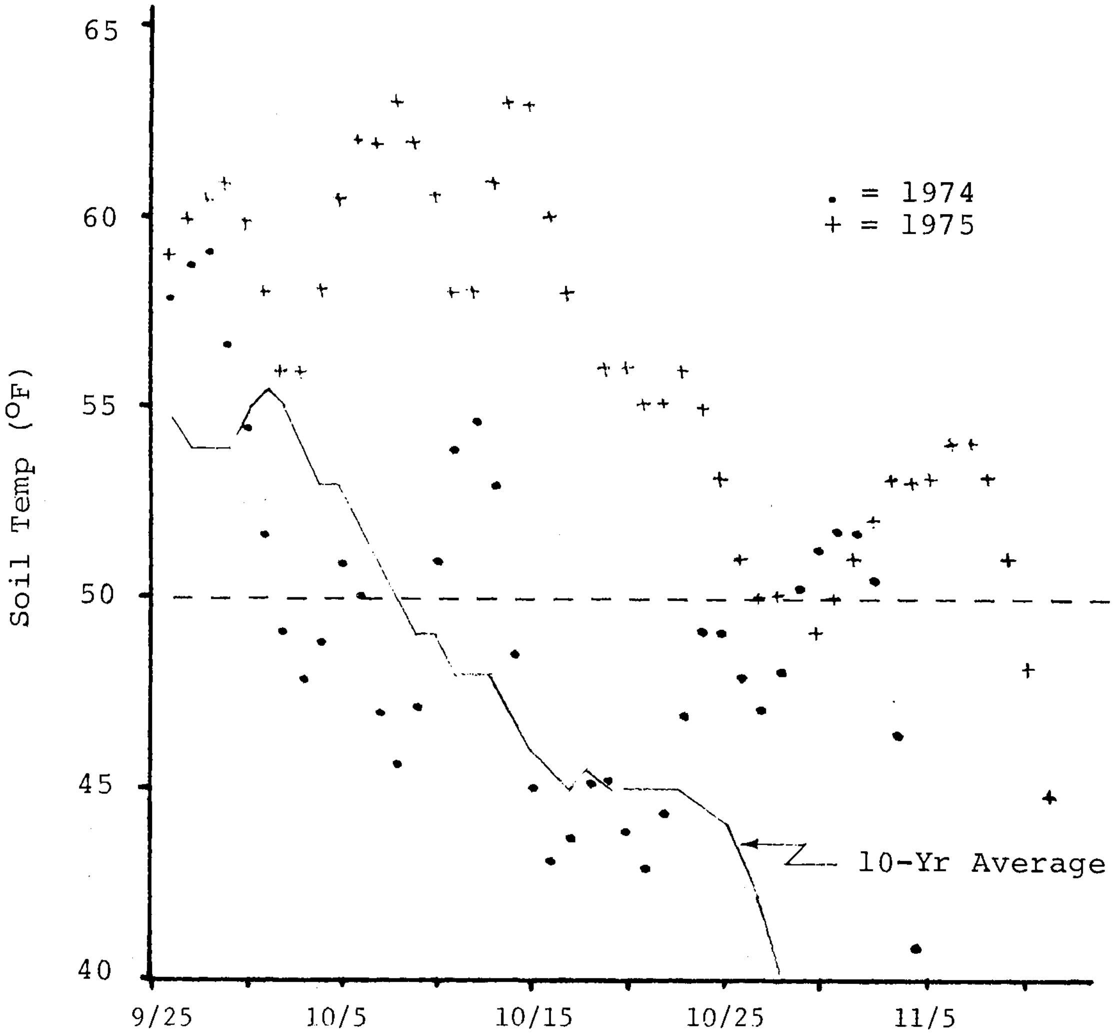

Figure 2. Combined 4" and 8" fall soil temperatures at Waseca.

DENITRIFICATION

Once N has been converted to the nitrate form it is susceptible to loss thru a process called denitrification.

Denitrification is the biological conversion of nitrates to gaseous forms of N that are lost to the atmosphere. Ammonium forms of N are not lost thru this process. It can be simply stated as:

$$2NO_3 \xrightarrow[\text{conditions}]{\text{water logged}} N_2\text{(atmosphere)} + 3O_2\text{(microorganisms)}$$

Factors affecting denitrification are: 1) soil pH, 2) moisture level, 3) soil oxygen and 4) soil organic matter. Incidence of denitrification most generally occurs after periods of prolonged rainfall resulting in waterlogged soil conditions. This is especially true in fine textured, poorly drained soils.

During 1974 and 1975 there were several periods in May and June when denitrification could have occurred(Table 1).

Table 1. Rainfall amounts and soil temperatures during periods in 1974 and 1975 when denitrification could have occurred at Waseca.

Period	Length	Rainfall	Soil Temp.
	Days	Inches	^{o}F
May 8-16, 1974	9	2.79	48
June 2-10, 1974	9	2.86	62
May 29-June 22, 1975	25	7.68	62

The upper two feet were saturated during each of the 1974 periods while the whole profile was waterlogged in 1975.

FIELD RESEARCH

Nitrogen Source Studies

Studies have been conducted with continuous corn on a Webster clay loam at Waseca to evaluate various forms of nitrogen fertilizer. This soil is naturally poorly drained but does have tile installed at a 75' spacing. Sources of N have included anhydrous ammonia (82%), urea (45%), ammonium nitrate (33%) and beginning in 1974 N solution (28%). All sources have been fall-applied after soil temps were less than 50^{o}. The 28, 33 and 45% materials were broadcast and plowed under within 24 hours. Anhydrous was applied after plowing. Spring applications of 28, 33 and 45% were broadcast and disked in within 24 hours. Application rates have been 75 and 150 lb N/A.

Soil and leaf samples, lodging, grain yields, grain moisture and protein data have been obtained annually to evaluate the treatments. Yields from 1973 thru 1975 are shown in Table 2.

Three-year yield averages show urea (45%) to be equal to anhydrous ammonia (82%). Yields from fall application were similar to spring applications of these ammonium forms of N. The nitrate forms, however, provided a vastly different picture.

Spring application of both 28% and ammonium nitrate (33%) were far superior to the fall applications. Three-year averages show a 13 to 15 bushel annual advantage for the spring application of ammonium nitrate. Moreover, two-year averages show about the same advantage for spring-applied 28% over fall applications. Equal yields were obtained from all N sources when applied in the spring at the 150 pound rate.

Table 2. Continuous corn yields as influenced by source, rate and time of application of N at Waseca in 1973-1975.

Treatment			Grain Yield				
Source	Rate	Time	1973	1974	1975	1973-75 Avg.	1974-75 Avg.
	lb N/A		- - - - - - - - -	- -	bu/A	- - - - -	- - - -
Anhyd. Am.	75	F	145.4	103.3	52.1	100.3	77.7
(82%)	75	S	143.2	100.6	53.4	99.1	77.0
"	150	F	145.8	111.1	64.1	107.0	87.6
"	150	S	146.8	112.3	57.3	105.5	84.8
Urea	75	F	136.8	80.4	51.9	89.7	66.2
(45%)	75	S	126.8	95.1	52.8	91.6	74.0
"	150	F	145.3	112.9	71.7	110.0	92.3
"	150	S	144.3	113.0	69.8	109.0	91.4
Am. Nitrate	75	F	122.7	75.6	34.8	77.7	55.2
(33%)	75	S	128.7	96.0	51.4	92.0	73.7
"	150	F	137.3	96.8	46.5	93.5	71.6
"	150	S	146.0	108.9	64.4	106.4	86.6
N Solution	75	F	--	84.0	33.0	--	58.5
(28%)	75	S	--	103.0	51.3	--	77.2
"	150	F	--	103.7	47.8	--	75.8
"	150	S	--	113.0	60.9	--	87.0
Significance:			*	**	*		
CV (%) :			7.3	9.3	25.4		
BLSD (.05) :			17.1	13.1	23.3		

These results would indicate that losses of nitrogen due to denitrification are very probable in south-central Minnesota. Fall application of ammonium forms of N after soil temperatures are below 50^{o} will minimize these losses and improve fertilizer efficiency as well as yields. Fall application of nitrate forms (28% and 33%) should not be attempted.

Nitrogen Carryover After a Dry Year

Because 1974 was a dry year, there was interest in possible carryover of N from 1974 to 1975. Research work done in a few other states has shown significant carryover under dry conditions, resulting in reduced N recommendations for the next year. Various empirical formulas were used to arrive at some of these 1975 recommendations.

How much carryover of N did we get from the 1974 season?

Nitrogen rates of 0, 100, 200, 250 and 300 lb N/A were applied annually to continuous corn grown on a Webster clay loam at Waseca from 1972 thru 1974. In 1975 to estimate carryover from 1974, N was not applied to any of the treatments. The 1975 yields are shown in Table 3.

Table 3. Continuous corn yields from residual N treatments at Waseca in 1975.

Total N Applied 1972-1974	1975	Yield
---lb N/A---		bu/A
0	0	62.5
300	0	67.2
600	0	69.5
750	0	69.1
900	0	65.8
	Significance:	ns

Results from this study would indicate no carryover of N from 1974. More than likely the denitrifing conditions during late May and June were responsible for the loss of any potential carry-over nitrate-N from 1975.

Crop Rotations

Efficiency of N fertilizer was reduced markedly by denitrification in some areas of south-central Minnesota in 1975. One method of improving this fertilizer efficiency would be to consider crop rotation systems rather than mono-culture systems such as continuous corn. However, the degree to which a farmer switches to the rotation systems will depend largely on economics; namely, net return per acre.

To determine the N needs of corn following various crops, a study was established on a Webster clay loam at Waseca in 1974. The crop systems were: 1) continuous corn, 2) corn-soybean, 3) corn-wheat and 4) corn-wheat seeded with alfalfa. Nitrogen rates and the 1975 yields are shown in Table 4.

Table 4. Corn yields following various crops at Waseca in 1975.

	Corn yield following			
N rate	Corn	Soybeans	Wheat	Wheat + Alf.
lb N/A	bu/A			
0	56.3	84.0	82.7	96.3
40	59.7	110.2	86.1	94.5
80	75.9	98.3	97.8	103.0
120	68.6	101.3	102.7	102.2
160	84.3	124.4	104.9	124.3
200	83.3	111.0	106.3	108.2
Avg.	71.4	104.9	96.8	104.8

These first year results show corn yields following soybeans, wheat or wheat plus alfalfa to be substantially higher than continuous corn yields. This was true at all levels of applied N.

Eight years' results obtained by the University of Wisconsin at Lancaster are similar. Corn yields following soybeans and receiving no N fertilizer were equal to or greater than yields of corn following corn receiving up to 300 lb N/A. Continuous corn yields from 0, 75 and 150 lb N/A were 78.3, 113.2 and 125.1 bu/A, respectively while corn yields following soybeans were 125.0, 131.5 and 133.6 bu/A for the same N treatments.

SOIL NITRATES AFTER FLOODS

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Extensive flooding occurred in the Red River Valley during the first part of July this past summer. In Clay and Norman counties several hundred thousand acres of farm ground were subjected to excess water with some fields being under water for a week or more.

Most of the affected fields were fine-textured, relatively high in organic matter and were sufficiently warm to support active microbial activity. These conditions satisfy the requirements for denitrification--a microbiological process which converts plant-available nitrate into nitrogen gases which are lost to the atmosphere.

Consequently, there was concern that the flooded soils would be very low in nitrate and would require large applications of nitrogen prior to the 1976 crop season. Soil nitrate tests taken during July through October, however, have not been unusually low for available nitrogen. Several explanations of these unexpectedly high nitrate values are offered.

The soils might not have been under water long enough for denitrification to have taken place. Assuming, however, that there were nitrogen losses and the soils were low in nitrate when the water receded, natural recharge of nitrate during the remainder of the summer when the soil was fallowed from mineralization of soil organic matter could account for much of the nitrate found by the soil tests. Fallowing has long been recognized as a method to increase available nitrogen in soils. The organic residue remaining from the crop growing prior to the flood provided an additional source of organic nitrogen available for mineralization into nitrate.

EFFECT OF DROUGHT AND FERTILITY ON CORN ROOTS

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We often hear the statement that corn roots are growing down after moisture, however, this is an old wives tale. Instead corn roots will grow where the environment is favorable for their growth.

Over the past ten years roots have been dug at the Southwest Experiment Station trying to look at the effect of a number of factors upon corn root growth. From the observations that have been made over this time, perhaps a few generalizations can be made.

I. SOIL DRAINAGE IS FIRST INSURANCE PREMIUM AGAINST DROUGHT.
Tile drainage of poorly drained soils is perhaps the first insurance premium against drought. When the excess water is drained from the soils this allows them to warm up earlier in the spring, makes tillage easier, and allows the roots to penetrate into the subsoil because of the better air water relationship.

II. NITROGEN FERTILITY IS A SECOND PREMIUM AGAINST DROUGHT.
Nitrogen fertilization in adequate amounts can increase the depth of corn rooting so that in dry years this may actually allow the plants to pick up an additional two inches of moisture during the critical July - August periods. In addition to this, some nitrates in the lower regions of the root zone may be a benefit in that the roots may be able to utilize this during this high demand period.

III. TILLAGE IS A THIRD PREMIUM AGAINST DROUGHT.
Tillage used to induce early root growth and by warmer temperatures and good surface drainage gets corn off to a quicker start. This allows plants to become established with a more prolific root system.

A cropping system that induces plants to be vigorous growing with a deep root system is the crop that will have the greatest advantage in utilizing all of the moisture available to it, and will be able to withstand short periods of drought with the least amount of damage.

FORAGES BENEFIT FARMERS (WHAT IS MFGC?)

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Grassland agriculture is a farming system which emphasizes the importance of grasses and legumes in livestock and land management. Farmers who plan row crop and livestock production around their grassland acres are grassland farmers. The main feature of grassland agriculture is its dependence on grasses, legumes, and other forage crops for proper land use to increase profitability of the livestock enterprise.

Nearly 1/3 or 9.5 million acres of Minnesota farmland is used for forage production, Table 1. Pasture acreage encompasses 62.8% of these forage acres, but only a small portion of these pasture acres have been improved. Alfalfa or alfalfa-grass mixtures dominate the remaining acres of forage crops which are used for winter feed.

Table 1. Forage Production in Minnesota.1/

Crop	Acres
Total Farmland	28,845,240 2/
Pasture	
Cropland pasture	2,100,812
Woodland pasture	1,668,330
Other pasture	1,440,335
Improved	336,991
Sub Total Pasture	5,952,878
Stored Feed (Commercial Farms 3/)	
Corn (silage and dry feed)	729,823
Sorghum (silage and dry feed)	9,995
Alfalfa and alfalfa mixtures	1,735,203
Clover and clover mixtures	416,471
Small grain hay	23,222
Other hay	189,519
Grass silage	94,531
Green chop	29,447
Sub Total	3,228,211
Sub Total 2/	3,524,561

1/ 1969 Census of Agriculture (1972).

2/ All farms, assuming same proportions as commercial farms.

3/ Class 1 - 5 farms (sales over $2,500)

FORAGE BENEFITS

However, acreage alone does not demonstrate the full contribution forages make to Minnesota's Agricultural Industry. Wedin, Hodgson, and Jacobson (1975) reported nationwide statistics which reflect the amount of feed units which are supplied by forages for the production of various livestock products, Table 2. Forages provided 63, 73, and 89 percent of the total feed units consumed by dairy cattle, beef cattle and sheep and goats, respectively.

Table 2. Consumption of feed units from various sources by class of ruminant livestock, 1972.

	Feed Units in Metric Tons[2/]			Forage as
	Concentrates	Forages	Total	% of total
	(000)	(000)	(000)	
Dairy cattle	25,602	43,739	69,340	63
Beef cattle	56,963	152,168	209,131	73
Sheep and goats	974	7,610	8,584	89

1/ Taken from Wedin et al. (1975) Table 8.

Over the past 10 years, 1964 to 1974, Minnesota's state alfalfa and alfalfa-grass hay yield has increased from 2.25 to 2.85 tons/acre (Crop and Livestock Reporting Service, 1975). Only once in the past ten years (1972 - 3.15 tons/acre) has Minnesota pushed its state alfalfa and alfalfa-grass hay yield average above 3 tons/acre. Although, total hay acres have dropped from nearly 4 million acres in 1955 to an estimated 3.2 million acres intended to be harvested in 1975, hay or hay crop silage remains as the dominant source of livestock feed for all ruminant livestock in Minnesota.

Livestock producers need to know the potential for increased profitability which can be gained in their livestock operation by changes in species and varieties, fertilization practices, crop management and utilization practices with forage crop. Forage crops also benefit the farming operation through providing nitrogen from legumes for row crops which follow alfalfa in the crop rotation, providing erosion control on steep sloping land, providing crops which help maintain soil organic matter, and provide flexibility in cropping programs by offering crops adapted to wide variations in soil conditions. Perhaps these benefits should be viewed as opportunities rather than benefits. Nevertheless emphasis on forage crops and their benefits and opportunities is long overdue. Yield of forage crops in Minnesota can double and forage quality increase if forage producers, agribusinessmen, University agricultural research and extension personnel, and other educators unite behind such a goal.

MINNESOTA FORAGE AND GRASSLAND COUNCIL (MFGC)

Hence, in April of 1975 a group of twenty leaders in the Agricultural Industry representing sectors of Agricultural Research; Agricultural Extension; Chemical, Fertilizer, and Seed Industry; Soil Conservation Service and the Agricultural Mass Media decided to organize the Minnesota Forage and Grassland Council (MFGC) to promote more efficient production and use of forage crops through livestock or other marketing channels in Minnesota. MFGC will provide the common bond under which forage and grassland activities in Minnesota can be united. MFGC has planned three main activities for its members. These are: 1) A two-day Winter Symposium and Annual Meeting--now scheduled for March 29 and 30, 1976 at the Radisson South in Bloomington, 2) Distribution of a quarterly Newsletter, and 3) Organize summer tours. This is the year of organization for MFGC which provides an opportunity for you, anyone interested in forage production and use, to help organize MFGC to best support forage and grassland activities in Minnesota.

MFGC has established two kinds of membership: individual memberships, costing $5 per person and associate memberships for agribusiness firms or trade associations, costing $25. Memberships are for a calendar year. Obtain a brochure to receive more information about MFGC. Forage crops help provide meat, milk, and fiber to a nation which has always liked milk and meat. Join Now, and help promote efficient production and use of forage for a more profitable livestock enterprise.

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LIME AND FERTILIZER FOR FORAGES

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INTRODUCTION

Land cropped to forages have often been referred to as the "forgotten acres". A cursory review of the statistics regarding forages indicates that such a title is appropriate. For example, average yields of alfalfa in the midwest have increased only 20% to 25% over the past three decades, whereas average corn yields have nearly doubled during the same period of time.

One of the principal reasons why forage production has lagged behind corn and other grains is that farmers have not used the technology available to them to increase forage yields. Fertilizer use statistics demonstrate this point very well. Over 95% of the corn grown in the midwest is fertilized as compared to less than 15% of the alfalfa acreage, even though use of recommended rates of fertilizer is very profitable on both crops. Our record on the use of agricultural limestone is not very good either, even though agricultural experiment stations have been advocating use of limestone to correct soil acidity for nearly 100 years. In Wisconsin, for instance, we have several important agricultural counties in which over one-third of the acreage needs two tons per acre or more of aglime. Such an observation is even more disconcerting when you consider that forages are the foundation of dairying, our most important livestock enterprise.

Why have farmers tended to neglect forages? I do not have time to discuss all the reasons but one important reason is that forages do not show dramatic visual responses to lime and fertilizer. As a result, farmers are unaware that significant and very profitable yield increases often occur when a sound soil fertility program is established. Historically, other reasons for the lack of interest in implementing new forage technology have been that alternate sources of protein were inexpensive (primarily soybean meal), additional forage production was not effectively utilized because farmers did not increase the size of their livestock enterprise, and excess forages were underpriced and difficult to sell because of the lack of a good forage marketing system. In the past three years we have seen dramatic increases occur in the value of livestock products, in the value of livestock feeds and forages, and in the cost of inputs to produce grain and forage. However, even though the price of aglime and fertilizer has increased, the value of the commodity sold by the farmers has increased even more. Therefore, use of recommended amounts of aglime and fertilizer on forages is more profitable today than ever before.

Given the fact that we are in this new "ballgame", how do we proceed to get farmers to treat forages like they should? In my estimation, the answer to this question is to develop sound educational and promotional programs which will clearly demonstrate the profitability of using recommended amounts of aglime and fertilizer. Once profitability is demonstrated, farmers will adopt the technology they should be using to produce forages more economically.

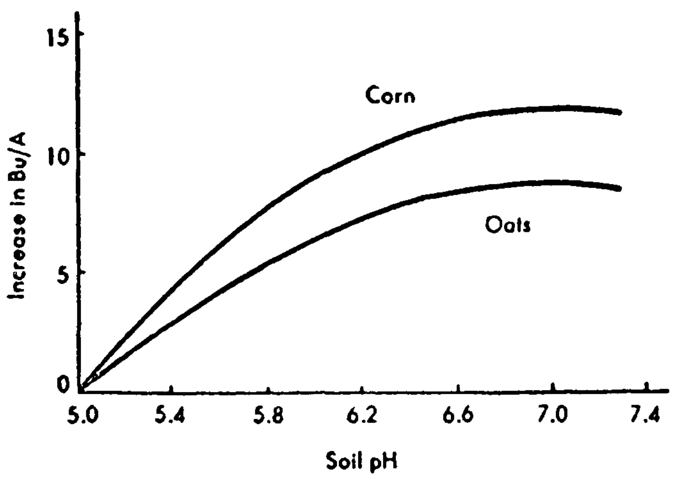
AGLIME

In recent years soil acidity has become a more serious problem throughout the North Central Region. Reduced emphasis on forages--crops that require an adequately limed soil--is part of the reason why we see more soil acidity problems. Also, soil acidity problems have been accentuated by the use of large amounts of nitrogen on our corn land. In research work conducted at Wisconsin, we have found that about five pounds of aglime are required to neutralize the residual acidity created by one pound of ammonium nitrogen.

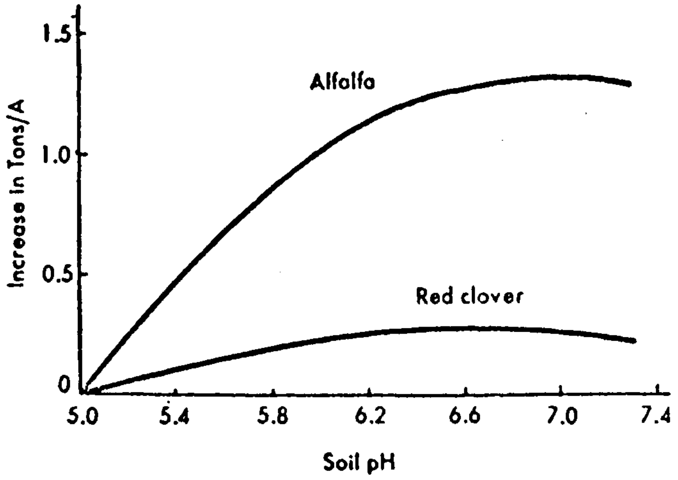
As I mentioned previously, plants do not exhibit any specific "lime deficiency" symptom. The only way to determine your lime needs is by soil testing. If the soil pH is below 6.5, aglime is required if you expect to produce optimum alfalfa yields.

Yield Response

Work at Wisconsin and elsewhere has shown that substantial yield increases can be expected when aglime is applied at recommended rates of application. The data presented in the figures below clearly show that liming acid soils markedly improves crop yield (4). These data also show that crops vary considerably in their response to increasing pH levels. The magnitude of the response is in the following order: alfalfa > corn > oats > red clover.



Effect of increasing the soil pH above 5.0 on the yield of corn and oats. (Iowa State University, Pamphlet 315).



Effect of increasing the soil pH above 5.0 on the yield of alfalfa and red clover. (Iowa State University, Pamphlet 315).

In Table 1, the results of long term trials show that maximum yields of alfalfa are achieved at a pH of 6.8 - 7.0. Consideration of these and other data convinced us that we should provide lime recommendations to raise the soil pH to either 6.6 or to 6.9. If alfalfa is in the rotation for only one or two years, a pH of 6.6 is adequate. However, if dairy farmers expect to maintain alfalfa over a long period of time, it will be profitable to lime the soil to a pH of 6.9.

Table 1. Influence of soil pH on the average yield of alfalfa over a 7 year period of time.

	Average Alfalfa Yields		
pH Range	Marshfield, Wisconsin	Spooner, Wisconsin	Guelph, Ontario
5.1 - 5.4	1.4	2.2	--
5.5 - 5.8	1.9	2.8	2.5
5.9 - 6.2	2.6	3.3	3.0
6.3 - 6.6	3.3	3.5	3.1
6.7 - 7.0	3.5	3.8	3.2

Economics

Hundreds of trials conducted in the midwest over the past 50 years show yield responses similar to those presented in Table 1. However, the most important consideration is whether these yield increases have been profitable. Therefore, I have used data from Wisconsin (1) and have assigned a reasonable cost for the aglime and value of the alfalfa produced in order to determine the economic returns from applying limestone.

Using modest prices for corn, oats and alfalfa hay of $2.25/bushel, $1.60/bushel, and $30.00/ton respectively, and a cost of lime of $8.00/ton, we find a total return of $87.10 from an investment of $32 in lime. This calculates out to a return of $2.72 per dollar invested in lime and a net profit per acre per year of $17.42. These data are summarized in Table 2.

Table 2. Returns from applying aglime to a soil with a pH of 5.5 (1).

	CORN	OATS	ALFALFA 3 years	
INCREASED YIELD BY RAISING pH FROM 5.5-6.5	10 bu/A	6 bu/A	2.9 T/A	
VALUE/UNIT	$2.25	$1.60	$30.00	5 YR. GROSS
INCREASED INCOME	$22.50	$9.60	$87.00	$119.10
	4 T AGLIME @ $8.00/T			$32.00
	NET PROFIT PER ACRE			$87.10
	NET PROFIT / Acre / Year			$17.42

Economic returns from liming a long term alfalfa stand are even more dramatic than those obtained when crops are being rotated. The data in Table 3 demonstrates this point. In this trial, higher rates of lime were being applied than normally would be required because the soil was very acid and highly buffered. Nevertheless, additional profits were being realized even at a rate of 12-1/2 tons/A.

The quality of alfalfa must be considered as well as the quantity when one determines its value in a livestock program. Additional experiments conducted in Wisconsin at the Marshfield Experiment Station show that crude protein increases as well as the yield when acid soils are limed. If increased yields and percentage of protein is evaluated on the basis of pounds of protein produced, gross value per acre increase due to lime is even greater than when calculations are based on yield alone. (See Table 4.)

Calcium-Magnesium Ratios

Some questions have been raised regarding the "balance" of calcium and magnesium in soils and the possible need to adjust the ratio of calcium to magnesium in Wisconsin and elsewhere in the midwest. Proponents of this theory have suggested that soils contain deficient levels of calcium and toxic levels of magnesium due to use of dolomitic limestone in the past, and that calcitic limestone or gypsum is needed to correct this situation. Two years ago trials were established to attempt to evaluate these claims. In this work, we applied one, two and four mil equivalents of calcium as calcium sulfate, and one, two and four mil equivalents of magnesium as magnesium sulfate, and combinations of each. The effect of these treatments on the soil calcium:magnesium ratios and the yields of alfalfa at two sites are presented in Table 5. These data show that calcium:magnesium ratios were markedly altered by the treatments but the yields of alfalfa were not influenced significantly. Therefore, our work shows that we do not have adverse calcium:magnesium ratios in soils where dolomitic limestone has been used in the past. Soils with a favorable pH (6.0 or above) will always contain adequate levels of available calcium. Similarly, there is no evidence to indicate that magnesium is toxic in any soil which has been treated with dolomitic limestone. In conclusion, therefore, addition of calcitic limestone or gypsum for the purpose of adding calcium, or for the purpose of changing the calcium:magnesium ratio, is not recommended.

FERTILIZATION

Fertilizing alfalfa to produce optimum yields of quality forage represents a major management decision. In many cases, farmers would realize additional net income if they purchased more fertilizer to produce additional better quality forage, rather than buying hay or protein supplement in order to balance their livestock ration. Grain, hay and protein supplement are much higher-priced now than they have been in the past so our livestock producers are under more economic pressure to do a good job of producing high quality forage today.

Table 3. Increased value of alfalfa from liming on acid soil over 7 years (U.W. Experimental Farm, Marshfield, WI)

Soil pH[1]	Rate of Limestone Application	Average Dry Matter Yield T/A	Increased gross[3] value/acre/yr.	Net return[4] each year	Net return[4] for 7 years
5.3	0	1.44	---	--	--
5.6	2 1/2	1.64	6.00	3.14	21.98
6.0	5	2.24	24.00	18.28	127.96
6.2	7 1/2	2.96	45.60	37.03	259.20
6.5	10	3.30	55.80	44.37	310.60
6.8	12 1/2	3.56	63.60	48.91	342.40

1/ Average pH values at the end of the experiment.

2/ The recommended rate, according to soil test, would have been 10 tons/A.

3/ Based on aglime costs of $8/ton. (Interest costs on the investment for aglime are not included).

4/ Based on alfalfa hay at $30.00/ton.

Table 4. Increased value of alfalfa crop from proper liming of acid soil.

Soil pH	Alfalfa dry matter yield T/A 1st cut	Alfalfa dry matter yield T/A 2nd cut	Gross value of increase in hay [1]	Crude Protein % 1st cut	Crude Protein % 2nd cut	Increased gross value/acre at 35¢/lb for protein 1st cut	Increased gross value/acre at 35¢/lb for protein 2nd cut
5.1	0.6	0.4	--	12.4	14.2	--	--
5.6	0.8	0.6	$12.00	14.4	17.1	28.56	32.06
6.0	1.1	0.8	27.00	14.8	18.6	61.88	64.40
6.5	1.3	1.0	39.00	16.5	20.9	98.07	106.54
6.9	1.5	1.1	48.00	16.2	20.0	118.02	114.24

1/ Calculated at $30/ton.

Table 5. Influence of $CaSO_4$ and $MgSO_4$ treatments on the calcium:magnesium ratio in the soil and the yield of alfalfa.

Rate of application		Soil Type: Plainfield soil			Theresa silt loam	
Calcium 1/ meq/100g	Magnesium 2/ meq/100g	Soil Ca:Mg ratio	Alfalfa yield 1974 tons/A	Alfalfa yield 1975 tons/A	Soil Ca:Mg ratio	Alfalfa yield 1974 tons/A
0	0	3.3	4.4	3.6	4.0	3.5
1	0	5.0	4.4	3.6	4.8	3.3
2	0	7.6	4.6	3.8	5.2	3.4
4	0	7.4	4.6	3.8	8.5	3.1
0	1	2.8	4.6	3.8	3.4	3.2
0	2	3.2	4.5	3.8	2.5	3.3
0	4	2.7	4.4	3.7	2.5	3.2
0.5	0.5	3.5	4.6	3.9	3.9	3.0
1	1	3.9	4.6	4.0	3.6	3.0
2	2	4.4	4.5	4.9	4.0	3.3

1/ One milequivalent of Ca = 1850 lbs/A of calcium sulfate.

2/ One milequivalent of Mg = 3840 lbs/A of magnesium sulfate.

Table 6. Influence of annual application of potassium on the yield and stand of Ranger alfalfa and on the economic returns.

Annual Rate of K_2O 1/	Average yield 2/ 3 cuttings	Average yield 2/ 4 cuttings	Remaining stand at the end of the experiment 3 cuttings	Remaining stand at the end of the experiment 4 cuttings	Net incremental increase, \$/A 3/ 3 cuttings	Net incremental increase, \$/A 3/ 4 cuttings
lbs/A	tons/A of dry matter		%	%	\$	\$
0	3.00	2.77	47	24	---	---
60	3.58	3.48	64	35	16.30	20.85
120	3.81	3.66	79	55	4.05	2.30
240	4.00	4.03	85	66	-1.35	4.95
480	4.31	4.17	93	81	-5.15	-11.10
720	4.48	4.34	95	84	-10.05	-10.05
960	4.38	4.24	92	89	-19.50	-19.50
1200	4.25	4.23	93	86	-20.55	-16.35
Lsd .05	0.19	0.19				

1/ The initial soil test was 127 lbs/A of exchangeable K.
2/ Average of three year's data (1970-1972).
3/ Calculated based on K_2O at 10¢/lb and alfalfa at $35/ton.

First, I think it is important that we dispell the notion that alfalfa is a crop that can be planted to rejuvenate a rundown, infertile soil. Alfalfa does supply nitrogen to subsequent crops, but it has higher phosphate and potash requirements than any other agronomic crop grown in the North Central Region. For example, our data (1) indicate that each ton of alfalfa will remove about 10 pounds of phosphate (P_2O_5) and 50 pounds of potash (K_2O). It is obvious, therefore, that many of our soils will require substantial amounts of maintenance fertilizer if we expect to produce optimum yields of high quality forage.

Again, hundreds of trials have been conducted in the midwest to indicate response that can be expected from the application of phosphate, potash, boron, and sulfur on alfalfa. It is far beyond the scope of this presentation to thoroughly review the literature on all these nutrients. Therefore, I wil concentrate primarily on the results of a potassium study which was recently completed at the University of Wisconsin Arlington Experimental Farm. The data in Table 6 indicate that 720 lbs/A of K_2O were required to achieve maximum yields under both the three-cutting and the four-cutting system. However, the optimum economic rate of fertilization was 120 lbs/A of K_2O for the 3-cutting system and 240 lbs/A of K_2O of the 4-cutting system.

The yield data from the Arlington study was used to prepare the information in Table 7 which shows the optimum rate of potassium fertilization as affected by varying fertilizer costs and by varying the value of the alfalfa produced. In this table, you will note that the optimum rate of fertilization increases markedly as the value of the alfalfa increases, or as the cost of the potassium decreases. If the value of alfalfa would increase from $35 to $50/ton the optimum rate of fertilization would nearly double--from 170 lbs/A of K_2O to 315 lbs/A of K_2O. In view of the data presented in Tables 6 and 7, it is obvious that very few livestock farmers are fertilizing their alfalfa crop at levels which approach the optimum rate.

Plant Uptake of Potassium

The percentage of potassium in the alfalfa tissue increased with each increment of added potassium. As shown in Table 8, the percent K in the plant tissue was about 2.8% when the maximum alfalfa yields were achieved. At the highest levels of applied potassium, some decrease in yields were observed. Since potassium chloride was the carrier used to supply the potassium in these trials, these yield depressions were likely due to the accumulation of excess salts in the soil or excess chloride in the plant tissue.

We should also point out that temperatures influence the growth and chemical composition of alfalfa. Surveys conducted in Wisconsin have shown that, at a given soil test level, the alfalfa herbage will contain a higher concentration of potassium in southern Wisconsin than in northern Wisconsin (See figure below) This suggests that higher levels of exchangeable soil potassium will have to be maintained in a cooler environment in order to maintain adequate levels of potassium in plant tissue and achieve maximum yields.

Table 7. Optimum rate of potassium fertilization as affected by fertilizer costs and value of alfalfa.[1/]

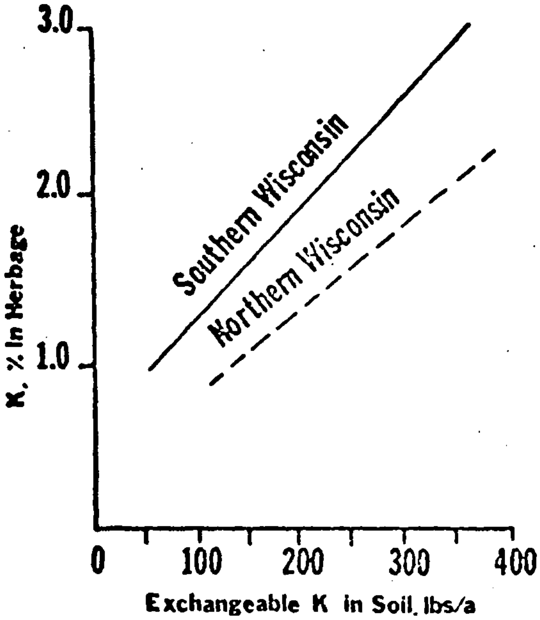
Cost of K_2O $/lb.	Value of alfalfa $/ton $30	$35	$40	$45	$50
	---------------optimum rate of K_2O, lb/A --------				
.06	315	360	400	425	445
.07	255	315	355	385	415
.08	200	265	315	350	380
.09	145	220	270	315	345
.10	90	170	230	275	315
.11	35	125	190	240	280
.12	0	75	145	200	245
.13	0	30	105	165	215
.14	0	0	63	130	180
.15	0	0	20	90	145

1/ Based on an average of 3- and 4- cutting systems from experiments conducted at the University of Wisconsin Arlington Experimental Farm (2,3).

Table 8. Average alfalfa yield, concentration of potassium (K) in the herbage and uptake of potash (K_2O) in the herbage as influenced by rate of applied potash (K_2O) in a 3-cutting system. [Adapted from Smith (2)].

Annual rate of K_2O	Average[1/] yield	Concentration[1/] of K	Uptake of[1/] K_2O
lbs/A	tons/A	%	lbs/A
0	3.00	0.9	58
60	3.58	1.1	79
120	3.81	1.4	106
240	4.00	1.7	135
480	4.31	2.3	200
720	4.48	2.8	254
960	4.38	3.1	277
1200	4.25	3.4	292

1/ Average of 3 years data.



Percentage of K in the herbage of Vernal alfalfa sampled at first flower of the spring crop of 1966 from several farm fields in the Madison and Ashland areas of Wisconsin. [Adapted from Smith (2)].

Maintenance Recommendations for Phosphate and Potash

After reviewing the results of research work conducted in Wisconsin and in other northcentral states, we recently revised our soil test recommendations for maintenance (topdressed) fertilizer on an established alfalfa. To give you an example of the kind of recommendations we have developed, I have included our suggestions for alfalfa grown on dark colored soils in southern, south central and south western Wisconsin in Tables 9 and 10. These soils are similar to some of the soils which occur in southern and south eastern Minnesota. The amount of phosphate and potash recommended varies with the expected yield level and soil test levels for phosphorus and potassium. If the farmer expects to achieve high yields year after year, it will be necessary to apply the higher levels of phosphate and potash in order to maintain these yields. Since forages are of more value than ever before, we strongly recommend that farmers soil test at least every two to three years in order to arrive at realistic fertilization rates for alfalfa.

Table 9. Phosphate recommendations for established alfalfa as affected by soil test phosphorus and expected yield.(5)

Expected yield Tons/A	Soil Test P. lbs/A	Recommended rate[1/] of P_2O_5 lbs/A
3-4	0 - 30	40
	over 30	0
4-5	0 - 40	50
	over 40	0
5-6	0 - 50	60
	over 50	0

1/ University of Wisconsin recommendation, 1975

Table 10. Potash recommendations for established alfalfa as affected by soil test potassium and expected yield (5)

Expected yield Tons/A	Soil Test K lbs/A	Recommended rate of K_2O, lbs/A 1/
	0 - 180	160
3-4	181 - 270	120
	over 270	0
	0 - 240	200
4-5	240 - 320	150
	over 320	0
	0 - 300	240
5-6	300 - 400	180
	over 400	0

1/ University of Wisconsin Recommendations, 1975

SUMMARY

The potential for additional use of lime and fertilizer on forages is great. Farmers have demonstrated time and time again that they will adopt practices which have proven to be profitable to them. Our job, therefore, is to develop programs to bring the agronomic and economic information to farmers which will allow them to make better management decisions in the future regarding the management of their forage crops.

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FERTILIZERS AND CROP QUALITY

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Potash Institute

We hear and know about the yield-increasing benefits of fertilizers. They are fantastic. A less told story, but equally exciting and interesting side of the benefits of fertilizer use, is their affect on crop quality.

The purpose of this paper will be to look at some of the measures of crop quality and provide examples as to how fertilizer nutrients influence quality.

HOW IS CROP QUALITY MEASURED?

Yield is the major factor, and usually the only factor, measured in most fertilizer trials. Grain, seed, forage, fiber, fruits, nuts, vegetables or flowers are harvested, but how does one measure these in terms of quality? Sometimes seed, bulbs, roots, tubers, stems, leaves or fruits are harvested for specific components such as protein, oil, starch, sugar or alkaloids, which are measures of quality. Mineral and/or vitamin composition maybe important measures of quality in feeding and for balancing rations. Size, shape, color, texture, and taste or flavor can be measures of quality in fruits, nuts and vegetables. Dry matter, soluble solids,juiciness, and acidity, as well as shelf-life may be used to measure and reflect quality. For forage crops, palatability, digestability and utilization are important measures of quality which may be related to protein, non-protein nitrogen (NPN), water soluble carbohydrates, alkaloids, mineral composition and fiber. Amino acid composition of the protein of grain or edible portions of crops are extremely important in determining how well protein is utilized. In comparing sources of protein in feeding and utilization trials, sources of protein can be ranked by protein efficiency ratio (PER), which indicates their effectiveness.

Crop quality can be expressed in terms of better seed from the standpoint of less disease, better germination and seedling vigor. Also, increased disease resistance during vegetative growth has a bearing on quality. In many crops quality is reflected in improved market value, such as increased yield of a higher market grade, or improved mineral and/or nutritional value.

GENERAL RELATIONSHIPS AMONG FERTILIZERS, YIELD AND CROP QUALITY

Fertilizers are added to soils or applied to crops to provide elements essential for growth. Soils may contain inadequate amounts of elements or forms that are unavailable, or they may be unable to supply nutrients at rates to meet the needs of a rapidly growing, high producing crop. Fertilizers help bridge the gap. Often, as a deficient nutrient or nutrients are applied, yield and quality of the crop are improved together until the point of maximum yield is approached.

In other cases, quality will remain fairly constant as yields are increased to maximum yield and only show quality gains when rates beyond those necessary for optimum yields are used.

MINERAL COMPOSITION AND QUALITY

Crops need certain concentrations of 16 essential elements in order to grow, develop and produce optimum crop yields. As supplies of essential elements are varied, the concentrations found in the entire crop or grain can vary, and yet not meet the requirements of livestock or humans. Unfortunately too, optimum concentrations needed by plants or crops may not coincide with those required by animals. In such cases, supplementations are needed to balance a diet or ration if feed sources are limited. Dietary standards have been set by the National Research Council in order to meet the recommended daily allowances (RDA) of man and classes of livestock.

The mineral composition of grains or seed, in general, change far less than do the vegetative portions of crops. Early research by Dowdy and others of Michigan using N, P and K variable rates indicate how mineral composition varied in corn grain at relatively low yield levels. (Table 1).

TABLE I. Range of plant nutrient concentrations in corn grain produced by combinations and rates of N, P, and K fertilizers (Dowdy, et al,MI).

Nutrient in Grain	Grain Yield	Range 41.5 - 76.2 bu/A
N		1.15 - 1.87%
P		0.13 - 0.28%
K		0.21 - 0.41%
Mg		0.08 - 0.28%
Ca		0.002 - 0.013%

Under much higher yield levels, Clapp, ARS, USDA, in Minnesota has provided an example for corn grain under moderate and good fertility (Table 2). Note that nitrogen (N) and zinc (Zn) are the two elements that increased the most. Phosphorus (P) and potassium concentrations in the grain appear to be under genetic control.

Table 2. The yield and elemental concentrations in corn grain under two levels of soil fertility (Clapp, ARS, USDA, MN.)

Yield or Element	Moderate Fertility	Good Fertility
Yield	103 bu/A	168 bu/A
N	1.38%	1.70%
P	.43	.48
K	.51	.54
Mg	.12	.14
Zn	26.2 ppm	46.0 ppm

Dumenil of Iowa has related P and K soil test levels to P and K concentrations in the grain and whole plant of corn, oats, soybeans and meadow or hay. The increased soil test should reflect increased nutrient availability, whether from soil and/or fertilizer application. The P and K soil tests and concentrations were independent of one another and should be considered as such. His corn and oats results are shown in Table 3, and represent a greater spread than would be anticipated if genetic control were as great as some studies would indicate. The important point to consider would be the concentrations that occurred at optimum yields, because supplementation can be provided to animals.

Table 3. The influence of independent soils test P and K levels upon the P and K concentrations found in corn and oat grain and soybeans (Dumenil, IA)

Soil Test Level		Corn Grain		Oats-Grain		Soybeans-Seed	
lb P/A	lb K/A	%P	%K	%P	%K	%P	%K
10	50	0.19	.30	0.25	.29	0.45	1.69
15	75	.22	.315	.29	.34	.495	1.79
20	100	.24	.33	.325	.38	.535	1.87
30	150	.28	.35	.37	.44	.60	1.99
40	200	.31	.37	.40	.49	.64	2.08
60	300	.34	.40	.43	.55	.69	2.20
80	500	.35	.46	.445	.67	.715	2.40
100	700	.36	.51	.45	.78	.73	2.53

From the standpoint of K, the mineral composition of the corn and oats is improved. On a high concentrate diet the K concentration in the ration should be between 0.6 and 0.8% for beef and dairy cattle. High concentrate diets may be deficient in K. High concentrate diets are also often low in calcium (Ca) and magnesium (Mg). Originally, in the upper Midwest cattle were very deficient in P. Phosphate fertilization has greatly improved the P concentrations in feed stuffs, but still phosphate supplementation is an important part of beef and dairy feeding programs.

We have the tools to analyze crops so that we can know the mineral composition. The important question revolves around seeing to it that the animal needs are met. In human nutrition the elements that have been added to the RDA most recently are Mg and Zn. It is only a matter of time until K will join the list.

PROTEIN CONTENT OF GRAIN

People are very interested in the protein content of grain and the quality of that protein in terms of essential amino acids, particularly lysine, tryptophan and methionine. Cereals have been traditionally low in lysine, so that was the reason why excitement was generated by the discovery of corn and sorghum lines containing above normal concentrations of lysine. Improved amino acid composition of the protein, especially for monogastric animals, including humans, increases the utilization or protein efficiency ratio (PER) of that consumed. That is one aspect of quality.

Another aspect involves the amount of protein in the crop. Grain exchanges now recognize and pay a higher price for spring wheat containing higher protein (Table 4).

Table 4. The average cash grain price of spring wheat varies with the protein content of the grain. (Oct. 1975).

Percent Grain Protein	Average Cash Price
	$/bu
17	5.36
16	5.26
15	5.00
14	4.77
12	4.33

Considerable data are available to indicate that we can increase the protein content of grain by proper fertilization. Let's examine some of the relationships.

CORN

Illinois researchers conducted a nitrogen rate-plant population study which illustrates the influence that varying these two factors can have on the grain yield, percent protein and yield of protein for one hybrid (Table 5).

Table 5. The influence of rates of N and plant population on corn grain yield, percent grain protein and yield of grain protein. (Funk's G-94, IL.)

Plant population	Grain yield N rate - lb/acre			Grain protein N rate- lb/acre			Grain protein yield N rate - lb/acre		
Plants/acre	0	80	160	0	80	160	0	80	160
	bu/acre			%			lb/acre		
11,761	113	135	139	8.4	9.8	10.3	449	626	677
15,682	108	149	156	7.8	9.2	10.0	399	649	738
23,522	117	155	184	8.0	8.5	9.5	443	623	827

Note that when population was limiting at a given level of N, percent protein decreased as population was increased. At a given population, as N increased, the percent protein concentration increased. The yield of grain was increased 71 bu or 63% and the protein yield was increased by 84%.

Elements other than N will increase the protein concentration of corn. For example, in a Wisconsin study, adding potash to an NP treatment, increased the concentration of protein by 2.2%, with only a relatively small increase in yield.

Early research indicated that N fertilized corn of a high percent protein had lower biological value. The reason for this was that most of the increase in grain protein takes place in the endosperm or zein fraction (prolamine) which is lower in lysine. However, researchers have found that high protein corn when fed in equal proportions is superior to low protein corn because it is deficient in fewer amino acids. Protein supplementation was most effective when added to the high protein corn.

Pierre and his co-workers at Iowa have come up with a unique measure relating the percent of maximum yield of corn to the percent N in the grain. Summarizing many experiments, their data indicate that when the N content of corn is

1.5% or 9.4% protein the corn crop was producing at maximum yield. This suggests that by knowing the percent N in the grain, one has an estimate of the yield loss due to the N deficiency.

WHEAT

Many have shown that the protein content of wheat can be increased by fertilization. Urea sprays at flowering are effective in boosting protein, but grain yields are increased most by spraying 5 to 7 weeks prior to flowering. Nitrogen topdressings are also effective in increasing grain protein, particularly as one surpasses the rate at which maximum yields are obtained. Illinois researchers have obtained data on two wheats (Table 6). Note that it takes different amounts of N to achieve maximum grain yields for the two varieties, and higher rates of N to achieve maximum protein yields than grain yields.

In these studies, amino acid profiles indicated that the proportion of lysine in the protein did not decrease as N increased protein and therefore, the quality of the protein was maintained or improved.

Table 6. The wheat grain yield, percent protein and grain protein yield as influenced by variety, rates of N as KNO_3(topdressed April 23, IL)

	Grain Yield		Grain Protein		Protein Yield	
N rate	Blueboy	Parker	Blueboy	Parker	Blueboy	Parker
kg/ha	kg/ha		%		kg/ha	
0	4,700	3,820	10.0	11.0	502	452
56	6,140	4,880	11.5	12.9	753	674
112	5,760	5,200	13.8	15.6	854	870
224	5,320	4,320	15.3	18.6	874	862

Lueschen and Randall in Minnesota have conducted N research on wheat varieties and found both yield and protein were increased. Amino acid profile were not determined.

Recent studies with high lysine barley indicate that the high lysine character increases lysine as percent protein increases with N fertilization. Therefore, protein quality would improve with the protein concentration. However, with this particular line there was a 10 percent yield sacrifice for the improved quality when compared to the non-mutant line.

SEED QUALITY

One of the real contributions of fertilizers has undoubtedly been the improved seed quality that results from proper fertilization. Healthy, vigorous seed is available to start the next crop. Results from some studies indicate that proper nutrition can induce genetic changes which are heritable. Benefits of larger, better germinating seed and more vigorous seedlings are obvious. Adequate nutrition may reduce seed diseases. Also, the minerals in the seed, such as adequate molybdenum (Mo) concentrations, can make the difference for a crop grown on a Mo deficient soil. Such relationships can be particularly important for such micronutrients.

Michigan has research that reflects the advantages of fertilizing one crop well, being passed on to a second crop through the seed, increasing the yields and seed quality through improved protein.

Virginia researchers found that P and K applications not only increased soybean yields, but increased seed size. Their results are shown in Table 7.

Table 7. Effect of P and K rates on the average yield and size of York soybeans grown on two soils (unpublished data, VA).

P	K	Soybean yield	Seed weight
lb/acre		bu/acre	g/100 seeds
0	0	31.0	14.0
0	99.6	45.0	15.9
51.6	0	29.5	13.0
51.6	99.6	57.9	16.1

Randall while conducting research on Mn in Wisconsin found that foliar sprays on Mn deficient soybeans was effective in boosting yields and increasing bean size (Table 8).

Table 8. Effect of Mn treatments on soybean yield (WI)

Mn applied ($MnSO_4$)	Soybean yield	Avg. bean weight	Number of beans
lb/acre	bu/acre	mg/bean	1,000/acre
0	44.5	185	5,784
0.5 (foliar 2X)	58.9	200	7,132
10 (row)	60.8	206	7,111

In order for soybean seed to germinate well, it needs to be free of disease, such as pod and stem blight which can drastically reduce bean quality. Delaware researchers found that some years, depending upon the season, K can greatly improve bean quality by reducing infection (Table 9). Muriate of potash and sulfate of potash were equally effective.

Table 9. Effect of applied K in reducing soybean seed infected with pod and stem blight (DE).

K Levels	Diseased seeds
	%
0	86.8
1	65.2
2	21.0
3	13.0

MALTING BARLEY

Malting barley is a rather special crop. If the protein content is too high (above 13.50% protein), it is unacceptable for malting. On the positive side from a fertilization standpoint, quality and price are improved as the percentage of plump kernels increase (Table 10).

Table 10. The price of top malting barley increased with the percent plump kernels.

Percent Plump Kernels	Top barley price
%	$ /bu
65	4.00
50	3.70
40	3.30
25	2.91

Potash applications usually increase the percentage plump kernels in barley on low K soils, and often on high K soils. Results from two sites in Manitoba indicate how treatments influenced the kernel plumpness (Table 11). Kernel plumpness may be enhanced at fertilizer rates above those giving a yield response.

Table 11. Fertilizer enhance barley kernel plumpness on low K soils.(Manitoba)

Broadest N	Drilled P_2O_5	K_2O	Plump Kernels Site 1 (62 pp2m Exch.K)	Site 2 (54 pp2m Exch.K)
--------lb/A-------			%	%
0	0	0	40.8	34.7
60	20	0	49.0	37.8
60	20	15	63.7	46.2
60	20	30	70.0	51.1

FORAGES

Bluegrass

Everyone know how N fertilization will cause grass to green up and grow when other nutrients are present in correct amounts. Research in Northeast Nebraska indicates that within 30 days after application, cattle, are not only grazing a much higher yielding but a higher quality forage. Nitrate-nitrogen values are well below the 2000 ppm which is the level considered to be excessive. (Table 12).

Table 12. Effect of N on protein and nitrate-nitrogen found in bluegrass in the spring thirty days after application (NE).

N rate	Protein	NO_3-N
lb/A	%	ppm
0	9.56	132
40	13.69	80
80	16.31	117
120	17.38	319
160	16.88	602

Earlier studies on orchardgrass in Indiana involving N and K indicated that K was important in converting the nitrogen taken up to true protein-N, thereby reducing nitrate-N accumulation in N fertilized grass.

Corn Silage

In corn silage you are after high grain yields to go along with the stover, because it is the grain that produces high total digestible nutrients. Some of the best corn silage quality-fertility research of recent years was conducted in Wisconsin. In this research large NP interactions occurred and phosphate with N markedly reduced nitrate-N in the silage. Grain yields of the silage were increased 33 percent by adding K with the N and P. In addition the NPK fertilized corn produced the silage with the highest carotene content, the highest protein yield and the lowest fermentation losses after ensiling. Not only did you grow more silage of higher quality, but you retain more to feed because of the lower dry matter losses during ensiling.

Table 13. The influence of N,P_2O_5 and K_2O combinations on silage corn grain yields, percent protein, protein yield, carotene composition and fermentation loss during ensiling (WI)

Treatment N P_2O_5 K_2O	Grain in Silage	Protein	Protein Yield	Carotene Content	Silage Fermentation Loss
----lb/A--	bu/A	%	lb/A	mg/lb D.M.	% D.M.
0 160 0	45.8	5.9	253	-	7.0
0 160 160	50.9	5.9	304	8.6	7.3
160 160 0	96.7	11.1	840	21.0	6.8
160 160 160	128.3	10.9	910	57.4	2.1

Alfalfa

A host of factors can influence alfalfa quality, not the least of which is fertilization. Research in Minnesota indicated that as yields are changed through fertilization, there was no appreciable change in amino acid composition. Phosphate, potash, sulfur(S) and boron (B) are the nutrients to which alfalfa is most responsive, in addition to soil pH. Providing adequate nutrients to alfalfa enables it to fix large amounts of N from the air, increasing alfalfa yields and providing substantial amounts of N to other crops through rotations. A high producing crop of alfalfa can fix 400 to 500 pounds of N. In a grass-legume mixture it will contribute a 150 to 200 pounds of N per acre.

In Wisconsin Powell conducted correlation studies to determine the factors that were contributing to alfalfa quality as measured by protein content through forage analysis. A summary of the results is shown in Table 14. Note that as the percentage of grass in alfalfa increases, the protein content of the hay decreases. High positive correlations were obtained with both soil test and fertilizer K.

Table 14. Correlations of alfalfa quality as reflected by protein content with other factors (WI)

Factor	Correlation Coefficient
% Grass in Forage	-0.93
Soil Test P	-0.06
Soil Test K	0.55
Fertilizer P	0.06
Fertilizer K	0.89

Had phosphorus been a more limiting factor, correlations involving it would have been higher.

Smith of Wisconsin applied rates of K two years and measured alfalfa yields for three years. Based on current alfalfa hay and potash price relationships, the most profitable rates of potash to use for the first two years would have been 750 lb K_2O/A. The three year average increase in yield was 1.79 tons of hay per acre. The amounts of N fixed in the crop were 224 lb/A on the control and 300 lb/A on the K treatment receiving 717 lb K_2O/A.

In Wisconsin Hoeft found that S applications on a deficient soil increased alfalfa yields, increased protein and lowered the N:S ratio of the hay. Lowering N:S ratios is assumed to improve quality. Yields more than doubled. Total N fixed and in the crop was increased 2.4 times. The results are in Table 15.

Table 15. Effect of S on alfalfa yield, protein, N yield and N:S ratios of Alfalfa (WI)

Sulfur[a] treatment	Alfalfa dry matter yield-tons/acre			Total
	1st cut	2nd cut	3rd cut	yield-t/A
S_o	1.01	0.75	0.31	2.07
S_1	1.57	1.68	1.20	4.46
	Percent protein			Total N lb/acre
S_o	16.4	16.2	15.8	107.5
S_1	20.9	18.0	16.2	264.4
	N:S ratio in forage			lb S/ton dry matter
S_o	10.1	16.2	18.1	4.1
S_1	8.6	11.5	17.3	5.4

[a]S source was K_2SO_4, Jacobson site, 1970.

CONCLUSIONS

Much more could be said about the influence of fertilizers on the quality of these and other crops, such as vegetables, fruits and sugar cane or sugar beets. Determining the proper amounts of nutrients to apply in balancing the yield benefits and quality benefits is extremely important.

Nutrient balance and amounts can be very important in quality considerations, particularly when a nutrient is in the deficiency range of availability. In that range, quality and yield increase together.

It is hoped that this discussion has aided in making people more aware of the quality benefits of fertilizers and encourage them to inquire into the subject more deeply. Much remains to be learned. But, one thing is certain. Because of the crop quality benefits of fertilizers, their true added value to crop production is well above that reflected only in yield.

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BRIEF DESCRIPTION OF MINNESOTA APPLICATOR CERTIFICATION PLAN

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Minnesota Department of Agriculture

The Congress has passed amendments extending implementation of FIFRA, as amended, until 1977. It has also provided for the certification of private applicators by a more practical and economic approach.

It is the intent of the Minnesota Department of Agriculture and the University of Minnesota Extension Service to proceed with the training of pesticide applicators and also the certification of pesticide applicators in accordance with time schedules established prior to the federal amendments.

The several Minnesota laws relating to pesticide registration, management and use are being consolidated into one proposed bill and this proposed legislation will be submitted to the 1976 Minnesota legislative session.

The training and licensing of commercial pesticide applicators and structural pest applicators will continue with minimal changes in the training and licensing provisions and procedures. The proposed training and certification plan for private applicators is outlined under the following heading: Brief Description of Minnesota Applicator Certification Plan, a copy of which is attached.

EXHIBIT "F"

BRIEF DESCRIPTION OF MINNESOTA APPLICATOR CERTIFICATION PLAN
NOVEMBER 1975

TRAINING

1. Cooperative Programs
   a) Extension Service
   b) MDA
   c) Other State Agencies
   d) Industry
2. Have had many types and kinds relating directly and indirectly to the management and use of pesticides, primarily for commercial, but open to dealers and private applicators.
3. Intra-agency agreement on training has been submitted and has preliminary approval.
4. All training programs are approved by MDA.
5. Training for "private" applicator has begun with the initiation of a training program for all County Extension agents.
6. The next step will be for the County Agent to hold training sessions in his respective county.
7. MDA will have time on all programs to cover regulatory aspects.
8. Extension at all levels may give examination for purpose of evaluating the training program
9. Extension plans to keep a roster of all those attending training sessions.

REGULATION

CERTIFICATION

1. All dealers wishing to sell "Restricted Use" pesticide must obtain a license from the MDA.
2. Dealers are examined before being issued a license. (This area is being improved.)
3. Many dealers participate in one or more of the programs relating to improving the management and use of pesticides.
4. Dealers must maintain a register of all purchases of "Restricted Use" pesticides. This register will be improved as to form and information requested.
5. All purchasers must sign this register and attest to certain conditions or facts.
6. Purchaser must sign register <u>each</u> time a "Restricted Use" pesticide is purchased.
7. Register must be submitted to Minnesota Dept. of Agriculture at designated times.
8. Dealers will be encouraged to attend training programs.

INSPECTION, SERVICE ENFORCEMENT

<u>Organizational Structure</u>

Commissioner of Agriculture
- Administrator
- Division Director (Agronomy)
- Supervisor (Pesticides) (3)
- Dist. Agric. Inspectors (a) (16)
- County Agric. Inspectors (b)
  (87 counties, 91 inspectors)

(a) Approx. 1/3 time on pesticides
(b) " 20% " " "
(Also have responsibility for weed control, seed inspection and other duties.)

1. (a) has responsibility for related areas that most dealers are also involved in, i.e., feed, fertilizer and seed.
2. (a) & (b) work together and with County Extension personnel on investigation of alleged damage claims.
3. Philosophy of regulatory work in Minnesota is to inspect and then to advise industry, firm or individual of problems, violations and give them an opportunity to make the necessary corrections within a reasonable time rather than taking legal action the first time. This generally results in greater compliance and is more cost and time effective for the party involved as well as for regulatory agency. It does not result in a large number of official enforcement actions, and to some this represents inefficiency. We do not support this latter view.

BRIEF DESCRIPTION OF MINNESOTA APPLICATOR CERTIFICATION PLAN
NOVEMBER 1975

TRAINING	REGULATION	
	INSPECTION SERVICE	ENFORCEMENT
	4. Either "b" or "a", or both, can call on a licensed dealer, check names of purchasers of "restricted use" pesticides on the register and call on these purchasers in a matter of hours. This area will be improved.	
	5. If violations are found, inspector can and will investigate individual as to training and then check this out with appropriate Extension Office.	
	6. MDA has authority to revoke or suspend license of dealer if he is found in violation.	

SUMMARY:

1. The basic thrust is to improve the management and use of pesticides.

2. This is a continuing type of program, both for the private and commercial user, not a one time certification for a period of 3 or 5 years.

3. It is, as stated, cost and time effective.

4. The register, in addition to providing effective information close to the label level, also provides a means to determine trends in the use of these "restricted" materials.

5. Commercial applicators must take an examination for two years in order to obtain a license. After that period they have an option of an examination or attending a MDA approved training program. Structural pest control applicators must attend a MDA approved training program each year in order to obtain a license.

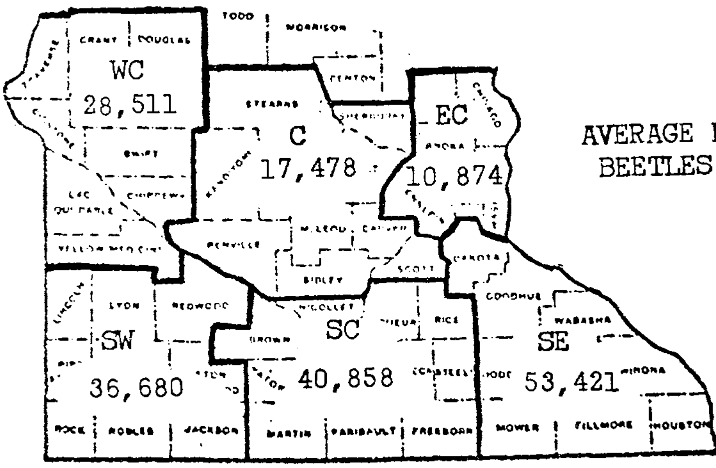
CROP INSECT SURVEYS, SITUATION & OUTLOOK FOR 1976

H. Hoger
Division of Plant Industry
Minnesota Department of Agriculture

ADULT CORN ROOTWORM SURVEY - 1975

Fifty-four counties of the principal corn growing areas were surveyed for corn rootworm adults. Five fields were chosen at random and beetles were counted in fields that were in corn the previous year. The survey revealed decreases in four districts and increases in two. The SC, SW, C, and EC districts had decreases and the SC and SE had substantial increases. Lodging levels were back to previous years. In spite of decreases, populations are high enough to cause losses.

POPULATION COUNTS - (Both northern & western species)



AVERAGE NUMBER OF BEETLES PER ACRE

Southwest District - Counts averaged 36,680 per acre. All counties, except Jackson and Lyon had increases. Rock county again had the highest number of beetles.

South Central District - Counts averaged 40,858. Seven counties had increases and four had decreases. Rice county had the highest number of beetles.

Southeast District - This district had the highest counts with 53,421 beetles per acre. Six counties had increases and three had decreases. Olmsted county was the highest with an average of 120,299 beetles per acre. This county had several corn fields that were lodged from 75-100%.

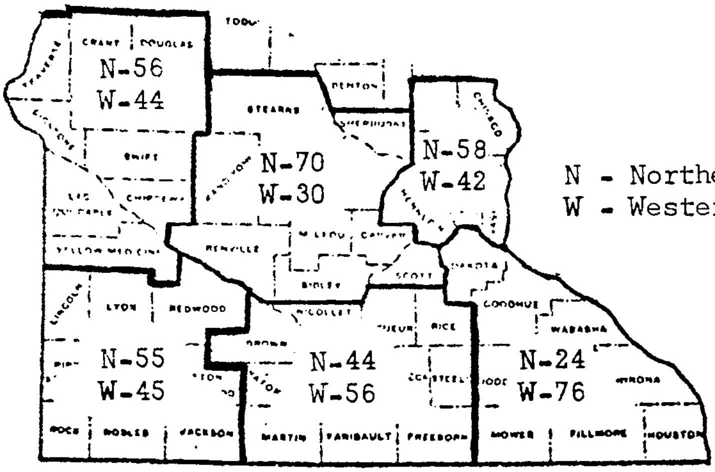
West Central District - Counts averaged 28,511 beetles per acre. One-half of the counties had decreases and one-half had increases. Stevens county had the highest average. This district had the highest amount of lodging at 5%.

Central District - Population counts were 17,478 beetles per acre. Scott county had the highest number of beetles.

East Central District - Counts averaged 10,874 beetles per acre, the lowest of all the districts. Hennepin county decreased in numbers from last year, but still had the highest populations.

The overall ratio of western to northern remains virtually unchanged at 50-50 with the edge returning to the northern at 51%.

The following map shows the percentage of Northern and Western corn rootworm beetles in each surveyed district.



N - Northern Corn Rootworm
W - Western Corn Rootworm

The average percentage of lodged plants for the last three years is as follows:

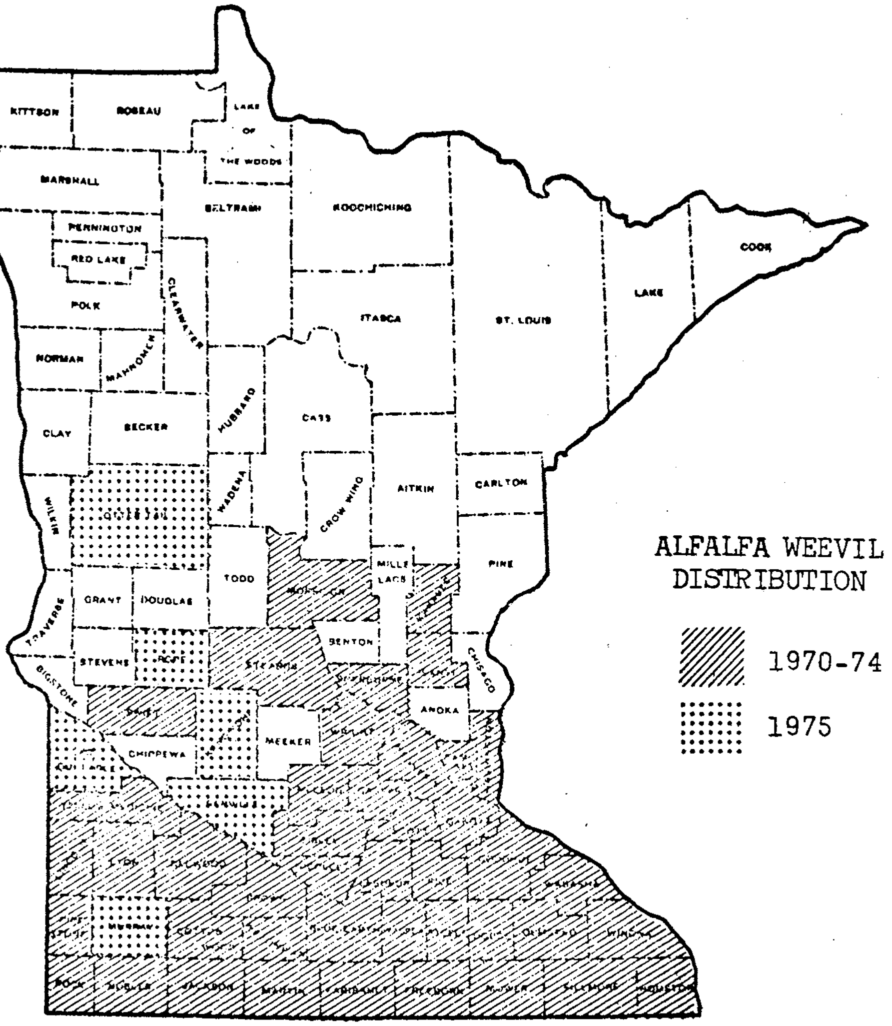
District	Average Percent Lodged 1973	1974	1975
SW	1.00	11.00	4.1
SC	7.00	8.00	.16
SE	3.70	13.00	5.0
WC	.40	5.00	.58
C	3.10	14.00	1.32
EC	1.50	9.00	0

1976 Outlook

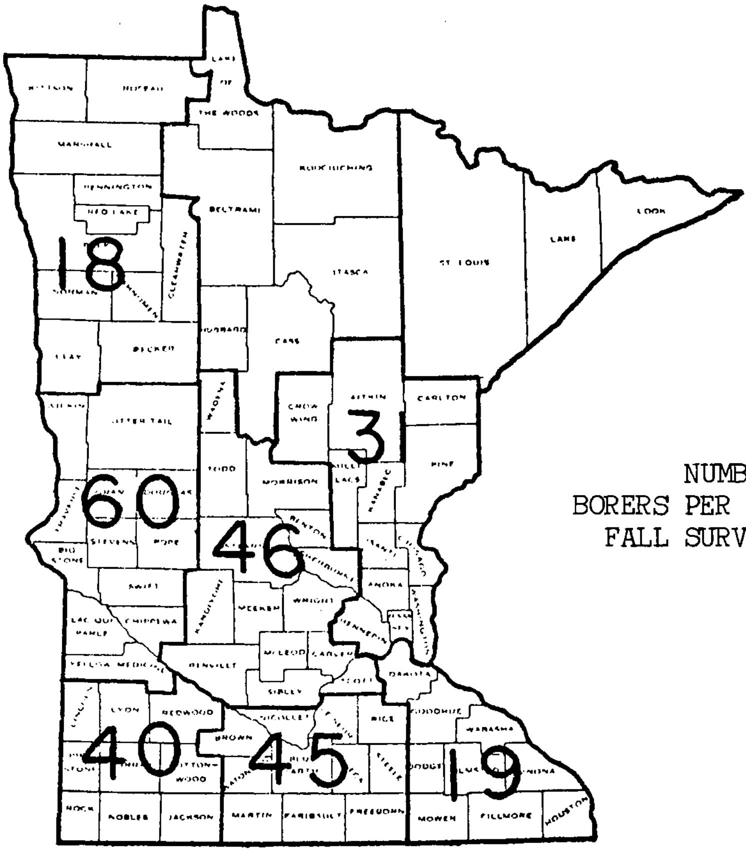
Although four of the reporting districts had population decreases, counts are still high enough to cause damage if corn following corn is not treated for rootworm.

ALFALFA WEEVIL SITUATION

Six new counties; Murray, Renville, Lac Qui Parle, Pope, Kandiyohi, and Ottertail were added to the list of counties where this pest can now be found. Approximately 80% of the alfalfa growing portion of the state is now infested. We still have had no reports of economic populations.



EUROPEAN CORN BORER INFESTATION - 1975

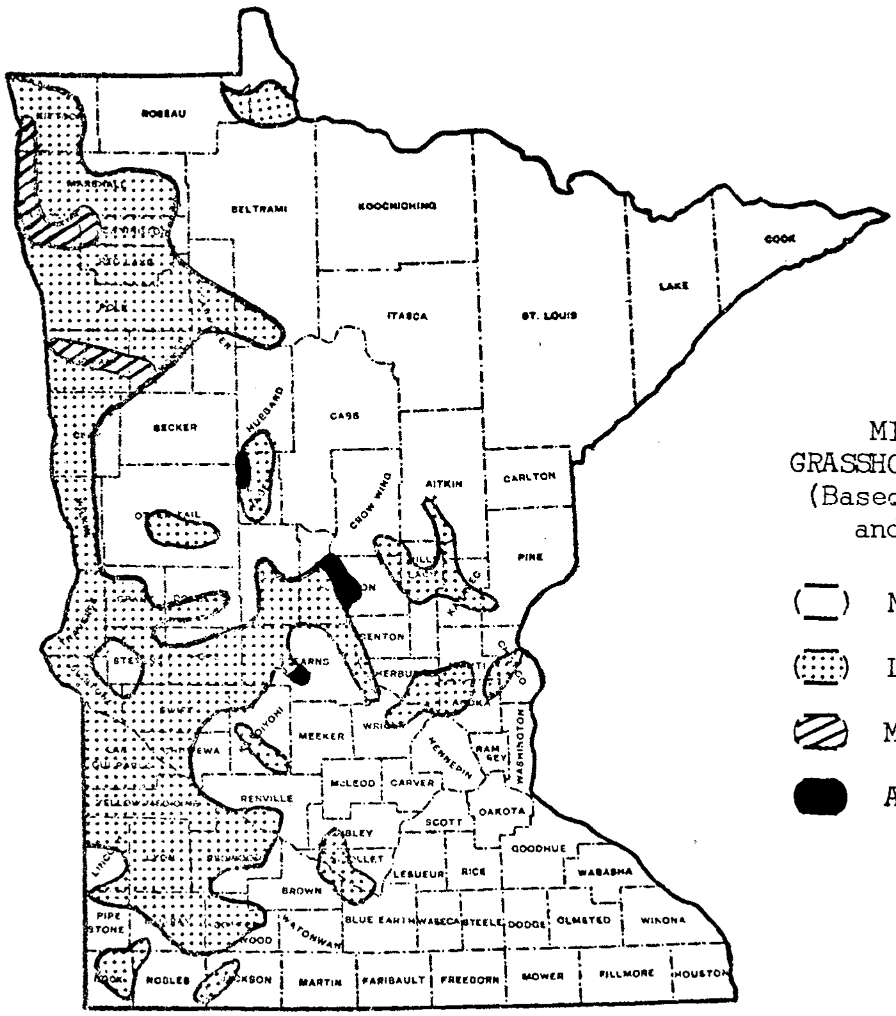


NUMBER
BORERS PER 100 PLANTS
FALL SURVEY 1975

Fall overwintering corn borer populations in 1974 were the lowest in the history of the survey in most districts. Near record rainfalls in June reduced egg laying somewhat and the 1st generation remained low. July and August weather, however, was very favorable and the 2nd generation made some increases. Heavy catches of moths began showing up in light traps particularly in the SW district and higher concentrations of overwintering larvae were expected in that area. Some increases have become evident but they were not as high as we had anticipated. With a better than three-fold average increase in the number of overwintering larvae, we can expect a higher 1st generation but populations will still be relatively low.

GRASSHOPPER SITUATION

The areas of economic populations of 8 or more grasshoppers per square yard remains virtually unchanged. An estimated 130,200 acres of forage crops had economic infestations in 1975. This was an increase of 200 acres over 1974. The redlegged and twostriped continue as the most important species.



MINNESOTA 1976
GRASSHOPPER INFESTATION
(Based on 1975 Adult and egg surveys)

Non-Economic

Light

Moderate

Abundant

1976 Outlook

Based on the adult survey, areas of abundant infestations will be found in Wadena, Stearns, and Morrison county. Moderate infestations may appear in Norman, Mahnomen, Polk, Pennington, Marshall, and Kittson counties in the Red River Valley. Grasshopper populations should be approximately the same in 1976 as they were in 1975. Roadsides and field margins will continue as primary sources of infestation, especially in the northern areas of the Red River Valley.

CORN ROOTWORM LABORATORY TESTS

L.K. Cutkomp

Field collected adults were obtained from the major corn growing areas of the state. Insecticides were tested by applying known doses to each individual with 60 adults usually comprising each set of determinations.

Lower LD 50's indicate greater effectiveness than higher LD 50's. Table 1 shows the comparison of the western corn rootworm and table 2 of northern corn rootworms. The arrangement is by districts to show variations that were occuring.

Table 3 gives the comparison by insecticide and comparable figures are given starting with 1972. The 1975 comparisons include 2 hours mortality and 24 hours mortality and also gives values for each sex tested.

Although variations are evident, there seems to be no indication of any resistance developing based upon this type of test procedure.

TABLE I

1975

MINNESOTA
Western Corn Rootworm

Insecticide susceptibility tests of field collected adults. Arrangement of data by counties and districts. Values are in micrograms per gram weight of beetle. A minimum of 60 beetles per determination. ca=approximately LD50= dose required to inactivate or kill 50 per cent.

District and County	Insecticide	Beetle Wt. in mg.	Sex	LD 50 2 hr.	LD 50 24 hr.
Southwest					
Cottonwood	Carbofuran	10.80	F	0.5	+
Cottonwood		13.54	F	-	>0.75
Cottonwood	Phorate	13.54	F	8.97	-
Jackson					
Lincoln	Carbofuran	11.55	F	0.40	0.39
Lincoln	Dyfonate	8.61	M	15.02	15-20
Murray	Dasanit	5.62	M	3.54	
Murray	Dyfonate	5.62	M	19.74	
Nobles	Dyfonate	13.52	F	-	
Nobles	Dasanit	6.39	M	6.97	-
Pipestone	Phorate	12.79	F		
Pipestone	Diazinon	9.34	M	5.80	5.0
Redwood	Carbofuran	10.80	F	ca 0.50	1.3
Redwood	Phorate	10.80	F	ca14.0	5.38
Redwood	Diazinon	10.80	F	7.78	
Rock	CGA 12223	12.10	F	-	ca 0.5
Rock	Counter	12.10	F	5.64	ca 3.0
Southcentral					
Brown	CGA 12223	15.13	F	0.79	-
Brown	Counter	15.13	F	5.14	ca 3.0
Rice	Diazinon	10.66	F	17.60	10.66
Rice	Carbofuran	10.66	F	0.36	
Rice	Carbofuran	7.20	M	0.73	
Rice	CGA 12223	10.66	F	1.5-1.6	ca 1.4
Scott	Carbofuran	10.89	F	0.4-0.5	0.67
Scott	CGA 12223	10.89	F	ca 1.4	0.66
Steele	Carbofuran	13.56	F	0.4-0.5	0.66
Steele	CGA 12223	13.56	F	ca 1.5	0.49
Southeast					
Dakota	Counter	6.67	M	23.76	ca 0.5
Olmsted	Counter	15.31	F	12-13	ca 5.0

TABLE 2

1975

MINNESOTA
Northern Corn Rootworm

Insecticide susceptibility tests of field collected adults. Arrangement of data by counties and districts. Values are in micrograms per gram weight of beetle. A minimum of 60 beetles per determination. ca= approximately LD 50= dose required to inactivate or kill 50 per cent.

District and County	Insecticide	Bettle Wt. in mg.	Sex	LD 50 2 hr.	LD 50 24 hr.
Southwest					
Jackson	Carbofuran	9.93	F	0.39	0.31
Jackson	Diazinon	9.93	F	ca 15.00	
Lyon	Dyfonate	5.44	F	37.57	18.0
Southcentral					
Blue Earth	CGA 12223	7.15	F	2.51	2.01
Blue Earth	Diazinon	7.15	F	21.83	ca 7.0
Blue Earth	Carbofuran	7.15	F	-	1.31
Rice	Diazinon	6.56	F	ca 11.00	ca 8.0
Rice	CGA 12223	6.56	F	ca 3.0	2.12
Rice	Carbofuran	6.56	F	0.69	0.86
Martin	Carbofuran	8.99	F	0.40	0.40
Martin	Phorate	8.99	F	12-15	3.64
Scott	CGA 12223	7.61	F	1.0	0.95
Scott	Diazinon	7.61	F	7.10	-
Scott	Carbofuran	7.61	F	0.74	0.50
Steele	CGA 12223	8.99	F	1.93	ca 0.8
Steele	Carbofuran	8.99	F	0.60	0.68
Watonwan	Carbofuran	9.02	F	0.46	0.30
Southeast					
Dakota	Counter	7.90	F	16.57	4.51
Dakota	Phorate	7.90	F	15.11	ca 3.80
Goodhue	Carbofuran	9.88	F	0.29	-
Olmsted	Counter	9.72	F	9.72	-
Olmsted	Phorate	10.92	F	13.64	ca 5.0

TABLE 3

1975

MINNESOTA
Corn Rootworms Tests

A comparison of several insecticides used for laboratory tests for adult corn rootworms with respect to LD 50 determinations of field collected adults. LD 50= dose required to inactivate or kill 50 per cent.

		Beetle weight (mg.)		LD 50 (mg/g)	
Insecticide	Year	No.	Western	No.	Western
Phorate	1972	8.2	9.6	11.5	13.2
	1973	7.1	11.4	14.9	13.1
	1974	5.8	7.8	23.8	20.6
	1975(F)	9.3	12.2	14.1	11.5
Diazinon	1972	8.6		23.3	14.2
	1973	7.7		12.4	10.4
	1974	6.4		35.0	15.5
	1975	8.1(F)	10.7(F)	11.0	10.4
			9.3(M)		
Dasanit	1972	8.1	10.1	5.6	3.9
	1973	7.2	11.0	4.7	3.3
	1974	7.0	7.8	3.9	2.4
	1975	3.9	6.0(M)	6.2	5.3
Dyfonate	1972	8.5	-	23.5	-
	1973	7.6	11.8	35.9	31.2
	1974	-	7.6	-	27.6
	1975	5.4(M)	7.1(M)	37.6	17.4
			13.5(F)		
Carbofuran	1972	8.0	10.2	0.5	0.7
	1973	7.9	11.7	0.6	0.5
	1974	8.5	9.8	0.7	0.6
	1975	9.9(F)	6.3(M)	0.5	0.7(M)
			11.8(F)		0.5(F)
Counter	1974	5.3		14.2	
	1975	9.4(F)	13.6(F)	8.8	7.8
		-	6.7(M)	-	23.8

Minnesota

1975 Corn Rootworm Control Summary

Root Ratings 1-6
John A. Lofgren
ST= Seed Treatment, B= Band at Plant, C= Cultivation Basal Treatment

Treatment (Al/A)	Lamberton Av.	Waseca Av.
Furadan 8 oz/Bu. ST	3.95	--
Furadan 16 oz/Bu. ST	3.95	--
Furadan 24 oz/Bu. ST	3.65	--
Furadan 15G 3/4 B	--	2.10
Furadan 15G 3 in furrow	--	2.65
Furadan 15G 1 B	2.30	2.20
Furadan 10G 1 B	2.10	2.20
Furadan 10G 1 C	2.85	--
Counter 15G 1 1/2 in Furrow	--	2.90
Counter 15G 1 B	2.73	2.30
Counter 15G 1 C	2.60	--
Counter 15G 1 1/2 B	2.48	2.60
Counter 15G 1 in furrow	--	2.75
CGA12223 15G 3/4 B	2.30	2.25
CGA12223 15G 1 B	2.45	2.00
CGA12223 20G 1 B	2.05	2.20
CGA12223 20G 1 C	2.58	--
CGA12223 20G 3/4 B	2.30	2.35
CGA12223 20G 1 in furrow	--	2.50
Lorsban 15G 1 B	2.68	2.90
Lorsban 15G 1 C	3.20	--
Lorsban 10G 1 B	2.55	3.45
Lorsban 10G 1 C	3.38	--
Dyfonate 20G 1 B	2.28	2.65
Dyfonate 20G 1 C	3.10	--
Dasanit 15G 1 B	2.58	2.80
Dasanit 15G 1 C	3.05	--
Dasanit 15G 1+1 B+C	2.50	--
Mocap 10G 1 B	2.18	2.20
Mocap 10G 1 C	2.85	--
Mocap 10G Coated 1 B	2.35	2.55
Dotan 10G 1 B	2.28	2.35
Dotan 10G 1 C	2.35	--
Dotan 10G 2 B	2.35	--
Diazinon 14G 1 C	3.35	--
SD 41706 10G 1 B	4.03	3.40
SD 41706 10G 2 B	4.10	--
Thimet 15G 1 B	2.80	2.65
Thimet 15G 1 C	3.38	--
Checks	4.39	4.48

4 Reps, 5 samples per Rep

Minnesota

1975 Corn Rootworm Control Summary

Waseca Expt. 2

Root Rating 1-6

Counter 15G 1 lb B	2.20
Counter 15G 1 1/2 lb B	2.17
Counter 15G 1/2 + 1/2 lb B+C	2.33
Counter 15G 1 lb C	2.83
Furadan 10G 1 lb B	2.92
Furadan 10G 1 1/2 B	3.00
Furadan 10G 1/2 + 1/2 lb B+C	2.83
Furadan 10G 1 lb C	2.67
Dasanit 15G 1 lb B	2.50
Dasanit 15G 1+1 lb B+C	2.17
Dasanit 15G 1 C	3.17
Checks	3.50

Report on the 1975

Armyworm, *Pseudaletia unipuncta*

Infestation in Minnesota

David Noetzel

The first suggestion that armyworms might become a problem was made by John Lofgren in the May 30, 1975 Plant Pest Control newsletter. Professor Lofgren based this on observations of mass movements of leafhoppers carried north on strong frontal weather movements at that time and the knowledge that high populations of armyworms had already been reported from southern states.

The first armyworm adults were reported by Mr. Hoger of the Minnesota Department of Agriculture on June 13th. Light trap collections from south central and southwestern Minnesota showed small numbers of adults on that date. Low numbers of adult armyworms were again reported on the 20th of June but were followed by massive movements on June 27, 1975. This information was transmitted to county agents.

The first reports of armyworm larvae were from Nobles, Redwood and Chippewa counties in early July. By mid-July agents in these three counties had prepared newspaper and radio releases and in at least one county evening meetings had been held.

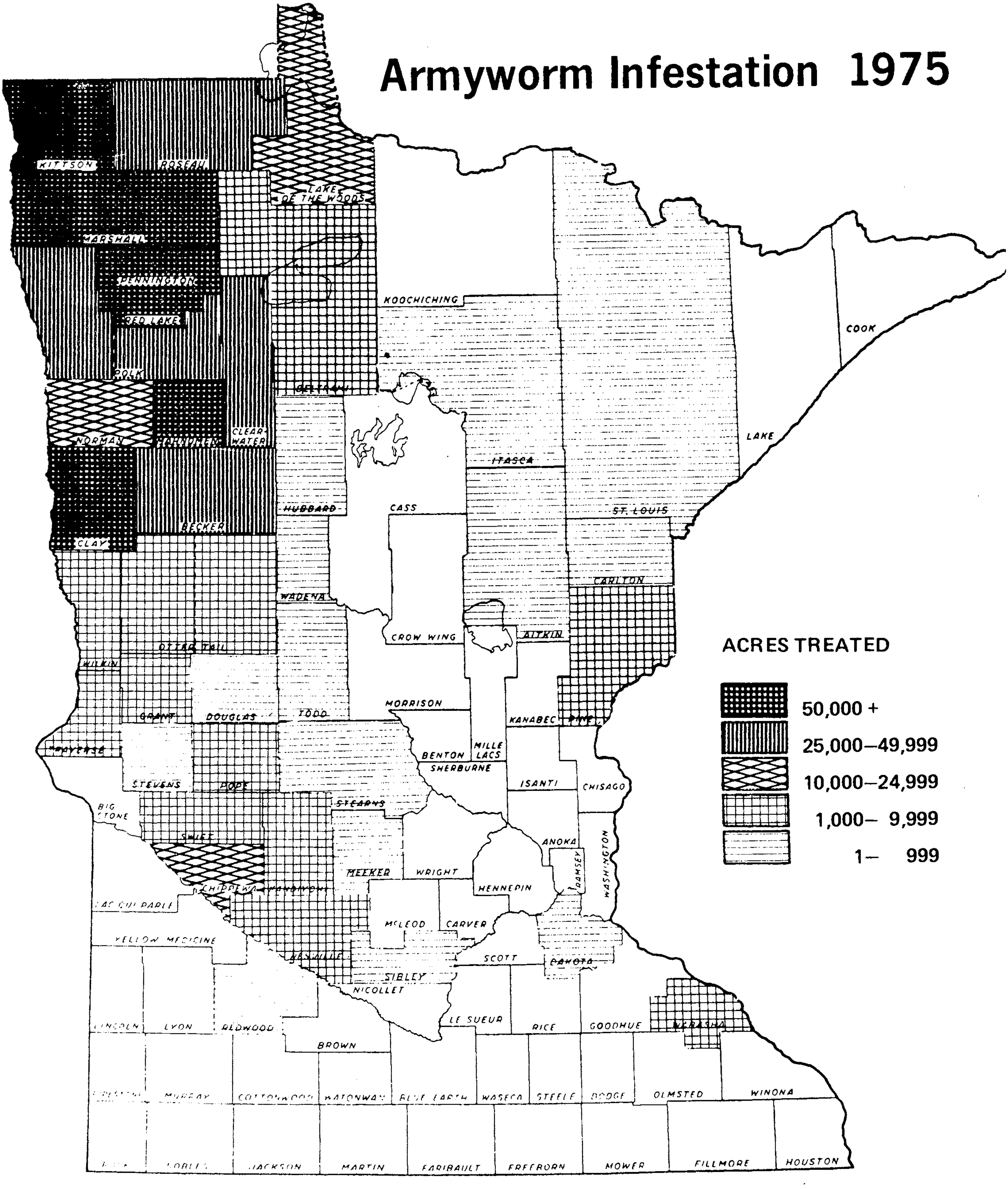
Initial economic damage was observed in field corn in Rock county. These infestations were quite localized, however, in contrast to more wide spread infestations in Chippewa County. Roger Larson, the Chippewa county extension agent, reported that between ten and fifteen thousand acres of cropland were treated following the series of meetings he held. He indicated that not only were Chippewa county growers made aware of the problem in an orderly manner but insecticide treatments were better limited to those areas requiring it.

The heaviest armyworm infestations (up to 32 per sq. ft.) however, were to occur a little later in the northwestern district. Marshall, Mahnomen, Pennington and Red Lake counties were particularly hard hit. The early awareness of the potential problem permitted adequate supplies of insecticide to be moved into the area. Also aerial applicators got an early jump on the problem. Thus no real "emergency" situation developed.

The estimated total acres treated for armyworm control was 637,605. The average cost of treatment per acre was five dollars. The cost to growers of chemical control was $3,188,025. In addition county agents estimated there was approximately one million dollars of armyworm damage where fields were not treated. The estimated loss to the state from armyworm including cost of controls and yield reductions was $4,177,525.

County	Estimated acres treated
Marshall	104,400
Mahnomen	80,000
Pennington	65,000
Red Lake	60,000
Clay	50,000
Kittson	50,000
East Polk	46,560
Roseau	40,000
Becker	28,000
West Polk	25,000
Norman	22,500
Lake of the Woods	12,100
Chippewa	12,000
Swift	8,000
Wabasha	4,000
Kandiyohi	4,000
Traverse	4,000
Clearwater	3,400
West Ottertail	3,000
Grant	3,000
Beltrami	2,640
Wilkin	2,000
Renville	1,100
Pine	1,050
Pope	1,000
Douglas	700
Stevens	700
Sibley	600
Aitkin	500
Todd	500
S. St. Louis	350
Meeker	300
Hubbard	200
Dakota	200
Redwood	200
Itasca	160
Stearns	150
Wadena	125
Carlton	120
	637,605 acres

Armyworm Infestation 1975



FIELD CROP INSECT CONTROL--1976

Crop	Insect	Insecticide	Dosage	Limitations, remarks (Days before harvest)
Alfalfa, Clover	Alfalfa weevil	azinphosmethyl (Guthion)	1/2-3/4 lb.	21 days, one application per cutting.
		carbofuran(Furadan)	¼ - ½ lbs.	7 days ¼ lb., 14 days ½ lbs.
		methyl parathion	¼ lb.	15 days
		Imidan	1 lb.	7 days, one application per cutting.
		diazinon plus methoxychlor	½ lb. + 1 lb.	10 days - available as a ready-to-use mixture.
		malathion plus methoxychlor	½ lb.	10 days - available as ready-to-use mixture.
		Supracide	1/2 lb.	10 days.
		Cut first crop early to avoid most losses. Treat when over 30% of plant tips show feeding. Treat stubble if there are more than 8 larvae per sq. ft. or when regrowth has 50% of the terminals with feeding or if larvae are delaying regrowth.		
	Aphids, leafhoppers	diazinon	½ lb.	7 days
		dimethoate(Cygon De-Fend, Rebelate, Dimex 267)	¼ - ½ lb.	10 days
		malathion	1 lb.	No time limitations
		parathion	¼ lb.	15 days
		Control aphids when thick enough to cause wilting, usually during drought. Spotted alfalfa aphids may severely damage new seedlings.		
	Armyworm, cutworms	carbaryl (Sevin)	1 ½ lb.	No time limitations, spray or bait
		malathion	1 lb.(or ULV)	No time limitations:
		trichlorfon(Dylox)	1 lb. spray or bait.	7 days - 1 lb. 14 days - bait.
		Treat when over 5 per sq. ft.		
	Leafhoppers	azinphosmethyl	¼ - ½ lb.	14 days.
		carbaryl	1 lb.	No time limitations
		diazinon	½ lb.	7 days
		methoxychlor	1 lb.	7 days
		malathion	1 lb.	No time limitations
		Apply when regrowth after first cutting is 8 to 12 inches and leafhoppers are over 2 per net sweep.		
	Grasshoppers	carbaryl	1 to 1½ lb.	No limitations
		diazinon	½ lb.	7 days
		malathion	1½ lb. or ½ lb. technical as ULV by air.	5 days, ULV No time limitations
		carbofuran	1/2 lb.	7 days. One application per season.
		Control when there are over 8 grasshoppers per sq. yd. in the field or treat margins after cutting at more than 20 per sq. yd.		

Crop	Insect	Insecticide	Dosage	Limitations, remarks (Days before harvest)
Alfalfa, clover (Cont'd.)				
	Spittlebug	methoxychlor	1 lb.	7 days
	Apply on first crop when spittle masses average more than one per stem.			
	Plant bugs	malathion+ methoxychlor	3/4 lb.+ 3/4 lb.	7 days
		trichlorfon	1 lb.	7 days
		diazinon+ methoxychlor	1/2 lb.+ 1 lb.	7 days
		Control seldom needed except on seed crop. Cut early to avoid injury.		
Corn	Armyworm	carbaryl (Sevin)	1½ to 2 lbs.	No limitations
		malathion	1 to 1½ lb.	5 days
		toxaphene	2 lb.	Do not feed stalks, leaves or husks. No limitation for grain.
		trichlorfon	1 lb.	No limitations
		Treat when over 10% of the plants are infested. Higher rates for large worms.		
	Corn rootworm larvae			
	Control with chemicals may not be satisfactory under conditions of extremely heavy infestations. In such cases it is advisable to rotate to another crop. It is also possible to encounter infestation in first year corn the year following drought, early freeze or other conditions which cause beetle movement from corn.			
		carbofuran (Furadan)	1 lb.	Planting time application of granules in 7-inch band over the row. Do not place in direct contact with the seed. Band of granules should be covered lightly. Some liquid formulations are registered but are suggested for trial use only
		Counter	1 lb.	
		Dasanit	1 lb.	
		Dyfonate	1 lb.	
		Lorsban	1 lb.	
		Mocap	1 lb.	
		phorate (Thimet)	1 lb.	
				Cultivation time application of materials registered for such use may be made after rootworm eggs hatch in June. Apply at base of stalks and cover with soil.
	Corn rootworm adults.	carbaryl	1 lb.	No time limitations. ULV or dilute.
		diazinon	1 lb.	No time limitations
		malathion	1 lb.	5 days.

Crop	Insect	Insecticide	Dosage	Limitations, remarks (Days before harvest)
Corn (Cont'd.)				
	Corn root-worm adults	malathion ULV	4 to 8 oz as technical by air	5 days
		EPN	$\frac{1}{4}$ - $\frac{1}{2}$ lb.	14 days
		Treat when beetles reach 10 per plant when pollen and fresh silks are present.		
	Cutworms	chlordane**	4 lb.)	Apply broadcast and disk in before planting.
		heptachlor*	2 lb.)	
		diazinon	1 to 2 lb.	Apply in 7-inch band as for rootworms at planting time.
		carbaryl spray or bait	1 to 2 lb.	Post emergence spray to cover approximately 12-inch band at base of plants in at least 15 gal. total spray per acre.
		trichlorfon(Dylox)	1 lb.	
		toxaphene	2 lb.	Carbaryl bait is more effective than sprays for cutworms.
		Apply when over 10% of the plants are infested.		
	European corn borer	carbaryl	$1\frac{1}{2}$ lb.	Spray or granules, no time limitations.
		carbofuran	1 lb.	Granules. No more than 2 applications.
		diazinon	1 lb.	Granules. No time limitations.
		Dyfonate	1 lb.	Granules. 45 days.
		EPN	$\frac{1}{2}$ lb.	As spray or granules 14 days.
		phorate	1 lb.	As granules
		toxaphene	2 lb.	As granules. Use on corn for grain only.
		Treat when 50% of whorl leaves show shot-holing for first brood.		
	Grasshoppers	carbaryl	$1\frac{1}{2}$ lb.	No time limitations
		diazinon	$\frac{1}{2}$ lb.	No time limitations
		malathion	1 lb. or $\frac{1}{2}$ lb. technical as ULV	5 days
		toxaphene	$1\frac{1}{2}$ lb.	For grain only, no time limitations.
		Treat field margins early when grasshoppers are small.		

* Restricted use pesticide.

** The EPA has announced an intent to cancel registrations of chlordane and heptachlor. Check legal status before use.

Crop	Insect	Insecticide	Dosage	Limitations, remarks (Days before harvest)
Corn (Cont'd.)				
	Seed-corn maggot, Seed-corn beetle, wireworms	heptachlor*, lindane*, or diazinon	1 oz.per bu.	Seed treatment only. Will not control heavy wireworm infestations.
	Wireworms, white grubs, webworms Seed-corn maggots Seed-corn beetles	chlordane heptachlor*	4 lb. 2 lb.	Broadcast application disked in before planting. A row treatment at half the indicated rate applied at planting time may be used.
	Seed-corn maggots, beetles, wireworm	Dasanit Dyfonate	1 lb.	Band in row at planting time as for rootworm.
	Wireworms	phorate	1 lb.	As for rootworm.
		Mocap	1 lb.	" " "
Small grains	Aphids	malathion	1 lb.	
		methyl parathion	4 oz.	No limitations
		parathion	4 oz.	15 days
		Treatment most economical before heading with over 100 aphids per ft. of row. Disulfoton may be used on wheat.		
	Armyworm, cutworms	malathion	1½ lb.	7 days
		toxaphene	2 lb.	Use for grain only
		Treat when number of worms exceeds 5 per sq. ft.		
	Grasshoppers	malathion	1 lb. of ½ lb. as technical by air.	
		toxaphene	1½ lb.	Use for grain only
		Treat when over 8 per sq. yd. in field or over 30 in margins.		
	Wireworms	heptachlor* or lindane*	1 oz. per bu.	Seed treatment only
Soybeans	Bean leaf beetle flea beetles, blister beetles	carbaryl (Sevin)	1 lb.	No limitations
	Treat when defoliation exceeds 25% during pod fill or seedling stage or when pod feeding is extensive.			

* Restricted use pesticide.

** The EPA has announced intent to cancel registrations of chlordane and heptachlor. Check legal status before use.

Crop	Insect	Insecticide	Dosage	Limitations, remarks (Days before harvest)
Soybeans (Cont'd/)				
	Cutworms, Armyworms	carbaryl	1½ lb.	No limitations
		toxaphene	1 1½ lb.	21 days. Do not feed treated plants.
	Grasshoppers	carbaryl	1½ lb.	No limitations
		malathion	½ lb. technical as ULV by air	7 days.
		toxaphene	1½ lb.	21 days. Do not feed treated plants.
	Green cloverworm	carbaryl	1 lb.	No limitations
		malathion	1 lb.	7 days
		Bacillus thuringkensis as labelled.		No limitations.
		Treat when defoliation exceeds 25% or when worms number more than 15 per foot of row during pod fill.		
	Leafhoppers	malathion	1 lb.	7 days
Sugar beets	Webworm	carbaryl(Sevin)	1½ lb.	14 days, tops
		endosulfan (Thiodan)	1 lb.	Do not feed tops.
		parathion	4 to 8 oz.	15 days
		trichlorfon (Dylox)	1 lb.	14 days, beets. 28 days, tops.
		Treat when worms exceed 5 per sq. ft.		
	Cutworms	carbaryl	2 lb. spray 1 to 2 lb. bait.	14 days, tops. Bait formulation preferred.
		trichlorfon	1 lb.	14 days, beets. 28 days, tops
	Root maggots	aldicarb (Temik)	1½ lb.	(Row treatment at seeding time.
		carbofuran	2 lb.	(Place granules above seed in
		Dasanit	1 to 2 lb.	(5 to 7-inch band or as furrow
		diazinon	2 lb.	(treatment above seed. Some
		disulfoton (Di-Syston)	1 lb.	(prducts may also be side- (dressed at time of fly emer-
		Dyfonate	1 lb.	(gence. Check labels.
		phorate (Thimet)	1 lb.	
	Wireworms	lindane*	1 oz.per bu.	Seed treatment only.

* Restricted use pesticide. Check legal status before use.

Crop	Insect	Insecticide	Dosage	Limitations, remarks (Days before harvest)
Sunflowers	Sunflower moth larvae	endosulfan (Thiodan)	1 lb.	Not more than 3 applications Do not feed treated plants. No limitations on use of see
		methyl parathion	1 lb.	No more than 3 applications. 5 day intervals 20 days befo harvest.
		methidathion (Supracide)	1/2 lb.	2 or 3 applications the last treatment 50 days prior to harvest. Supracide is highly toxic to honey bees.

POWDERY MILDEW - "ITS" NEW ON OUR SUGAR BEETS

Howard L. Bissonnette,
Extension Plant Pathologist
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The powdery mildew fungus Erysiphe polygoni has been known in the United States since 1937. Originally found sporadically in Washington, Oregon and in greenhouse-grown sugar beets in California.

Sugar beet powdery mildew was first reported as epiphytotic in parts of the Imperial Valley of California in 1974. Later that year it was found in the sugar beet growing areas of California, Arizona, Colorado, Idaho, Kansas, Montana, Nebraska, New Mexico, Oregon, Texas, Utah, Washington, and Wyoming. The rapid spread of the fungus, twenty-five years after its first occurrance is hard to explain. It would seem unlikely that 1974 provided the first set of environmental conditions conducive to the spread of fungus. The disease occurred in areas with very diverse environmental conditions. In the warmer beet growing areas the fungus survives in the conidial stage and as such allows for wind dissemination of the conidia spore. This same fungus has been identified on many weed hosts that are present in sugar beet growing areas. There is the possibility that a genetic change in the population of the fungus has occurred which now allows the fungus to infect most varieties of sugar beets. In the past few years we have seen the introduction of many new sugar beet varieties and the possibility exists that the fungus may have thus been introduced into new areas.

In 1975 powdery mildew reoccurred in the above mentioned areas and also occurred in epiphytatic proportion in Minnesota. It appears that the fungus was able to overwinter in some of the western sugar beet growing areas. At this time we do not know if the fungus can overwinter in Minnesota. If the fungus is successful in overwintering here, the inoculum is well dispersed for our next crop of sugar beets.

As for the 1975 crop, powdery mildew occurred rather late, first found September 4 in Renville County. The amount of disease observed at that time suggested that the fungus may have infected the sugar beet plants as early as August 15 plus or minus a few days. Within two weeks of the first find the disease was identified as far north as Grand Forks. In Renville and surrounding counties the disease was found in almost all sugar beet fields. By mid-September, the disease could be found on more than 25% of the best plants in any field. The disease did not become as prevalent in the sugar beet fields further north.

Disease control practices in the form of fungicide application started September 5 in the Renville area. The quick use of fungicides and the proper application accounted for minimal crop damage. Powdery mildew can cause measurable damage to a crop of sugar beets in about 30 days, if left unchecked. Because of the late occurrance in this area, at most we expected some loss of sugar, rather than a yield loss of roots. If this disease should start in late July or early August and left uncontrolled, then we could expect a loss of root yield and sugar.

The mildew fungus is dependent on high humidity conditions. Such conditions occur as the plant leaves enlarge and cover the rows, usually 2½ months after planting. Light rains and cool nights can provide the high humidity conditions in late July.

Early symptoms of the disease are difficult to detect. The first symptom will be a very slight fungal growth on the surface of the leaf. This surface mycelium will have a whitish or grey color and occur in very small patches. These symptoms occur first on the older, lower leaves. As the disease progresses, the mycelium will cover the leaf surface, spreading to the younger upper leaves. After 3 or 4 weeks, yellowing and dying of the leaves will become apparent. As the fungus grows across the leaf surface it produces conidia spores, that may be wind borne to other plants or areas thus causing the secondary spread of the disease.

The fungus survives the winter in a special structure (cleistothecium) on infected plant debris. In this structure the fungus forms ascospores, which will be released the following year and act as the primary inoculum.

Powdery mildew can be successfully controlled with fungicides. Early detection is important - data from tests in California show that once 50% of the plants in a field are infected, some crop loss can be expected. Fungicides can be applied by aircraft, high pressure ground sprayers and dusters.

A cercospora disease control program using such fungicides as Benomyl, Mertect or similar materials, will usually provide mildew protection. Sulfur fungicides are the most promising chemicals for control. Depending on time of the first occurrance of the disease, repeated application may be necessary.

In 1975, Sulfur was applied under a temporary emergency registration. Even though Sulfur is registered for use on sugar beets for might control, it does not have a label registration for powdery mildew use.

GROWTH REGULATORS FOR CROPS

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There is a continued interest in the use of plant growth regulators as a means to increase crop yields. As a result, a number of chemicals have been studied in attempts to identify materials which have a yield or quality enhancing effect on crop plants. Very few of these growth regulators have been found to be successful, that is cause a consistent and repeatable desirable plant change. One example of a growth regulator with a significant economic impact is the compound Glyphosine which is used as a sugarcane ripener.

Recent work at Purdue University, Lafayette, Indiana, suggests the compound dinoseb may have promise as a growth regulator for increasing grain yield of corn. Dinoseb is the common name for the active ingredient, 2-sec-butyl-4,6-dinitrophenol, which is also commonly referred to as DNBP or dinitro. The Dow Chemical Company trademark for a dinoseb formulation is 'Premerge'. 'Surge' is the trademark of the Helena Chemical Company for a dinoseb and surfactant formulation. 'Premerge' contains 3 pounds of dinoseb per gallon; 'Surge' contains 0.073 pounds of dinoseb per gallon.

Dinoseb is used for weed control and/or dessication in several crops. Applied foliarly to corn, dinoseb may be a growth regulator. When used as an herbicide or a dessicant, application rates are many times greater than when applied as a growth regulator.

PURDUE UNIVERSITY EXPERIMENTS

The effect of postemergence foliar application of dinoseb on corn grain yield has been studied at Purdue University, Lafayette, Indiana, since 1968. The experiments were conducted at several locations using several hybrids, chemical rates, and times of application. Results of these studies identified the rate of 1/4 to 1/2 fluid ounce of 'Premerge' formulation per acre applied two to three weeks before tasseling as the rate and time of application for increasing corn grain yield 5 to 10 percent. Yield increases were thought to be due to growth regulation and fungicidal activity on smut spores.

Use of 'Premerge' as a postemergence spray on corn was approved for 1974 in the state of Indiana by the Indiana State Pesticide Administrator. On-farm strip tests were conducted at seven Indiana locations in 1974. Conclusions from the Purdue tests are:

"1. Premerge as a biostimulant for corn is effective over a wide range of yield levels.

2. When applied in recommended fashion, increases in grain yield of 5 to 10 percent are highly probable.
3. Grain yield increases result from decreased barrenness, resulting in more harvestable ears. On the average, the biostimulant also increases the size of the ears".

UNIVERSITY OF MINNESOTA EXPERIMENTS

Trials were conducted at Lamberton and Waseca during 1974 and 1975 to determine the effect of postemergence application of dinoseb on corn grain yield. Dinoseb was applied using the 'Premerge' formulation with 1/2 pint of surfactant per 100 gallons of spray solution.

1974 Trials - Dinoseb was applied with 20 to 25 gallons water per acre over the top of corn 13 days prior to tasseling. The rates of dinoseb in this experiment are higher than now recommended. Hybrids were different at the two stations. The dinoseb treatments did not give statistically significant grain yield effects at either location. Results are given in Table 1. The yield for the 14 grams/A rate at Waseca was 2 bu/A greater than the check plot yield; however, the same rate caused a 1 bu/A decrease at Lamberton.

Table 1. Effect of postemergence application of dinoseb on corn grain yield, 1974.

Dinoseb Rate*		Yield (bu/A)		
ounces/acre	grams/acre	Lamberton	Waseca	Location Average
0	0	78	100	89
.25	7.1	79	99	89
.50	14.2	77	102	90
1.00	28.4	80	99	90
Least Significant Differences (bu/A)		8	5	
Application Date		July 13	July 12	
Tassel Date		July 26	July 25	

*Active ingredient per acre

1975 Trials - Results from 1975 trials at both locations are given in Table 2. Yield differences are not statistically significant as indicated by Least Significant Difference values of 10 and 20 bu/A for Lamberton and Waseca, respectively. At Lamberton, 2 grams/A increased yield 4 bu/A compared to check yield. However, yields were lower with 4 and 8 grams/A of dinoseb. At Waseca, both 2 and 4 grams/A increased yield while the yields decreased with 8 grams/A compared to the check yield. This yield change was consistent for both hybrids. Tasseling and silking dates, barrenness, and lodging were recorded at Waseca. Application of dinoseb did not affect these traits.

Table 2. Effect of postemergence application of dinoseb on corn grain yield, 1975.

Rate			Waseca			
'Premerge'* (ounces/acre)	Dinoseb** (grams/acre)	Lamberton	Hybrid 1	Hybrid 2	Hybrid Mean	Mean over Locations
		Yield (bu/A)				
0	0	73	138	132	135	104
.2	2.1	77	145	134	140	108
.4	4.3	67	146	140	143	105
.8	8.5	72	125	124	124	98
Least Significant Differences (bu/A)		10			20	
Application Date		July 9			July 7	
Tassel Date		July 16			July 23	

*Volume of commercial formulation per acre

**Weight of active ingredient per acre

LEGAL USE OF FOLIAR APPLICATION OF DINOSEB ON CORN IN MINNESOTA.

As of November 1975, it is not legal to apply dinoseb postemergence on corn in Minnesota.

WEED CONTROL IN CROPS

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Controlling weeds in crops continues to require a well planned, multi-faceted system including crop selection, productive cultural practices, proper selection and application of chemicals, and cultivation. The planning of a 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 soil texture, the organic matter content in the soil, crop variety and crop tolerance to the herbicides. Proper analysis of these factors makes it possible to intelligently select a 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. Several new chemicals provide new possibilities for using chemical systems of multiple applications to control most weeds in crops and permit new innovations in cropping practices.

Herbicides are now used on about 90 percent of Minnesota's corn and soybean acreage, on about 80 percent of the small grain acreage, and on all the sugar-beets. Multiple applications have come into wide use on these crops in recent years. The returns for herbicide use have been excellent in terms of increased yields, higher quality crops and reduced labor and fuel requirements.

Suggestions for herbicides to use in crops are listed in Tables 1 to 7. Tables 2 and 4 show the expected crop tolerance and control of common weeds for each herbicide suggested for corn and soybeans.

Information such as that in Tables 2 and 4 illustrates the need for properly identifying the weeds in a field before selecting the herbicide. In many fields, it is necessary to use mixtures or multiple treatments to attain broad spectrum weed control. Several mixtures are now labelled for use. The Environmental Protection Agency does not consider it illegal to use mixtures that are not labelled, however, the user is considered responsible for the results of using unlabelled mixtures. Postemergence treatments of 2,4-D, atrazine and oil, or dicamba (Banvel) are commonly used in corn following the use of preplanting or preemergence herbicides. In soybeans, preemergence applications of chloramben (Amiben), linuron (Lorox) or metribuzin (Lexone, Sencor) are being used after preplanting applications of chemicals such as trifluralin (Treflan).

These herbicide mixtures and multiple treatments are economically practical where the weed problems warrant their use. They should help prevent the build-up of resistant types of weeds as has occurred in past years when we relied too much on a single herbicide. Some areas of the state have experienced a build-up in corn of certain grasses including crabgrass, witchgrass, fall panicum, wild proso millet, woolly cupgrass and certain strains of giant and green foxtail. In soybeans several annual broadleafs have become problems in some fields. These include common cocklebur, velvetleaf, venice mallow, wild mustard, black nightshade, buffalo bur, common ragweed, giant ragweed, and wild sunflower. Use of the information in Tables 2 and 4 should help in selecting herbicides that will control most of these weeds.

Bentazon(Basagran), a new postemergence chemical for annual broadleaf control in soybeans, received full clearance for 1975. Bentazon has given good control of most annual broadleafs and soybean tolerance is good. Early application when weeds are less than 2 inches tall and soybeans are in the first trifoliolate leaf stage (4 to 6 inches tall) has been the ideal time for application. Recent research indicates that bentazon applications during the evening, night, and early morning hours may be less effective on some weeds than applications from mid morning to about 6 p.m. Application made when dew is on plants may also be less effective than when the plant foliage is dry.

Bentazon has proven to be effective for controlling Canada thistle, perennial sowthistle, and yellow nutsedge in soybeans. Bentazon may be applied as a single application of 1 to 1 1/2 pounds per acre or in two applications of 3/4 pound per acre each time. The double application has controlled these weeds better. If a single application is used, bentazon should be applied when the tallest thistles or nutsedge are 6 to 8 inches tall. The timing of the first of a double application should be related to the size of annual broadleafs if these are also present and application should be made when the soybeans are in the first trifoliolate leaf stage and the annual weeds are less than 2 inches tall. If only thistles and/or nutsedge are present, the first application should be when these weeds are 3 to 6 inches tall. The second application should be made 10 to 14 days after the first. Broadcast applications are necessary to control these perennial weeds.

Soil texture and the amount of organic matter in the soil are major considerations in selecting preplanting or preemergence herbicides and in determining the proper rate of application. Generally, linuron (Lorox) and chlorbromuron (Maloran) are recommended only on soils with less than 4 percent organic matter. Atrazine and cyanazine (Bladex) perform more consistently than linuron or chlorbromuron on soils with higher organic matter, but rates of these compounds must be increased for finer textured soils and soils higher in organic matter. Alachlor (Lasso), butylate (Sutan$^+$), EPTC (Eradicane), dinitramine (Cobex), profluralin (Tolban), trifluralin (Treflan), vernolate (Vernam), and chloramben (Amiben) perform well on most soils, but some adjustment in rate is necessary for different soils. Propachlor (Bexton, Ramrod) works well on soils higher in organic matter, but generally is less effective than alachlor on sandy soils and soils low in organic matter. Metribuzin (Lexone, Sencor) shows good activity against weeds on most soils, but because of the potential for crop injury, it is not suggested for use on sandy soils with less than 2 percent organic matter nor on alkaline soils with a pH of more than 7.4. Chlorbromuron, linuron, cyanazine, and dicamba also are not suggested for preemergence use on sandy soils because of potential crop injury. EPTC (Eradicane) and butylate (Sutan$^+$) are now formulated with an antidote that protects corn from injury, thus making these chemicals relatively safe to use over a wide range of soils. Labels give specific information regarding use on different soils and this information should be followed carefully.

The differential response of crop varieties to herbicides has been observed for several years. Corn hybrids respond differently to 2,4-D and dalapon; there is some indication of flax varietal response to dalapon and EPTC. Some varieties of soybeans show insufficient tolerance to metribuzin (Lexone, Sencor). It is suggested that metribuzin not be used on Altona or Steele varieties of soybeans.

Difenzoquat (Avenge) is a new chemical that looks promising for wild oat control in wheat and barley. Barley has good tolerance, but some wheat varieties are susceptible to injury. Tolerant varieties are Era spring wheat and the durum varieties of Leeds, Wells, Hercules, Rolette, Ward, and Botno. Difenzoquat is now cleared only for experimental use, but may be fully cleared for the 1976 season.

Several other new chemicals are in the process of obtaining label approval and may be available under full clearance labels or experimental labels for 1976. Fluchloralin (Basalin) is chemically similar to trifluralin (Treflan). These chemicals control annual grasses, pigweed sp., and common lambsquarters, but they do not control other annual broadleafs or perennials. Fluchloralin is less active than trifluralin, thus higher rates are used to obtain comparable weed control. Soybean tolerance to fluchloralin is comparable or slightly greater than to trifluralin. Fluchloralin has been cleared for experimental use, but may receive full clearance for 1976.

Asulam (Asulox) has been evaluated and shows some potential for controlling wild oat, annual grasses and wild mustard and for suppressing wild buckwheat and annual smartweed in flax. However, considerable lodging or injury to flax occurred at some locations. Asulam is not yet cleared for use on flax.

Penoxalin (Prowl) was recently cleared for use in corn. It may be used at 1 to 2 pounds per acre for preemergence control of most annual grasses and some broadleafs such as common lambsquarters, pigweed, annual smartweed, and velvetleaf in corn. In Minnesota trials, penoxalin has been somewhat less effective on grasses, but more effective on broadleafs than has alachlor. Tank mixes with atrazine or cyanazine (Bladex) are labelled and would usually be preferred to using penoxalin along to provide more consistent and broader spectrum weed control. Penoxalin should not be used on soils that contain less than 1 1/2 percent organic matter, nor on sands, loamy sands, peat, muck, or clay soils.

Procyazine (Cycle), chemically similar to cyanazine (Bladex) and atrazine is expected to be cleared in 1976 for preemergence and postemergence use in corn. Procyazine controls most annual grasses and annual broadleafs. Pigweed and common lambsquarters are somewhat tolerant. Weed control has not been as good under dry conditions as under moderate to high rainfall. There has been no residue carryover of procyazine the year after use. Corn tolerance is limited. Do not use on sandy soils or soils with less than 1 percent organic matter. Apply postemergence treatments before corn passes the 5-leaf stage and before weeds are 1 1/2 inches tall. No additives should be used with procyazine.

Bifenox (Modown) was recently cleared for preemergence use alone or over trifluralin. It may be cleared in the future to use in a mixture with alachlor. In Minnesota trials, bifenox has given fair to good annual broadleaf control and inconsistent grass control. Soybean tolerance is limited. Malformation and stunting of young soybeans has frequently occurred.

Glyphosate (Roundup) is a new herbicide that has given excellent control of quackgrass and other perennial weeds when applied at 1 to 1 1/2 pounds per acre. This chemical also looks promising for weed control in "no tillage" systems, for killing old vegetation to renovate permanent pastures, and for many noncropland total vegetation control practices.

Glyphosate is applied as a spray to the foliage of actively growing quackgrass in the fall or spring before plowing. The field may be plowed three or more days later. By this time, the chemical will have translocated into the rhizomes and roots giving kill of these underground parts as well as the above ground portions of the plant. Glyphosate also kills or severely injures practically all actively growing plants, so it cannot be sprayed in growing crops. However, glyphosate is not active through the soil and leaves no soil residue, so practically any crop will grow in the soil in treated fields. But, only those crops which are cleared on the label may be planted legally. Glyphosate is not effective when applied to bare soil or to dormant quackgrass. Since glyphosate is not persistent nor active in the soil, other chemicals and cultivation will be needed to control annual weeds in crops grown after glyphosate treatments.

As of December, 1975, glyphosate is not cleared by EPA for use in cropland. Clearance is expected by the spring of 1976 for use before planting several major crops including corn, soybeans and wheat.

Other recently cleared uses include dinitramine (Cobex), profluralin (Tolban) and alachlor (Lasso) on dry beans; trifluralin (Treflan) on tame mustard; profluralin on sunflowers; and desmedipham (Betanex) on sugarbeets.

Drift control spray additives, 'Lo-Drift' and 'Nalco-trol' were recently cleared for use in crop sprays. These additives appear to be effective for reducing drift. Label instructions should be followed precisely as to rates and proper mixing procedures to assure satisfactory results.

More information on weed control in crops is given in "Cultural and Chemical Weed Control in Field Crops--1976", Extension Folder 212, Agricultural Extension Service, University of Minnesota, St. Paul, Minnesota, 55108. Labels should also be read carefully for specific use instructions.

Table 1. Suggestions for chemical control of weeds in corn[1/].

Chemical	Pounds per acre of active ingredient or acid equivalent broadcast	Remarks[2/]
Preplanting incorporated		
Alachlor (Lasso)	4	For nutsedge control
(Lasso II)	3.9	For nutsedge control
Atrazine	2-3	May injure some crops following year.
Butylate (Sutan+)	4	Controls annual grasses only.
EPTC + protectant (Eradicane)	3-4	For nutsedge and annual grass control.
Atrazine + butylate	1 to 1 1/2 + 3 to 4	For grasses and broad-leafs.
Cyanazine (Bladex) + butylate	1 to 2 + 3 to 4	For grasses and broad-leafs.
Preemergence		
Alachlor (Lasso)	2 - 3 1/2	Controls annual grasses primarily.
(Lasso II)	2.4 - 3.9	
Atrazine	1-3	May injure some crops following year.
Cyanazine (Bladex)	2-4	Do not use on sandy soils.
Propachlor (Ramrod, Bexton)	4-5	Controls annual grasses only.
Atrazine + alachlor	1 to 2 + 1 1/2 to 2 1/2	
Atrazine + propachlor	1 to 1 1/2 + 2 to 3 3/4	
Cyanazine + alachlor	1 to 2.2 + 2 to 2 1/2	Do not use on sandy soils.
Dicamba (Banvel) + alachlor	1/2 + 2 to 2 1/2	Do not use on sandy soils.
Linuron (Lorox) + alachlor	1/2 to 1 1/2 + 1 to 3	Do not use on sandy soils.
Linuron + propachlor	1 to 1 1/2 + 2 to 3	Do not use on sandy soils.
Postemergence		
Atrazine + oil	1.2-2	Apply when weeds less than 1 1/2 inches tall.
Cyanazine (Bladex)	2	Apply when weeds less than 1 1/2 inches tall and before corn has more than 4 leaves.

Table 1 (Continued)

Chemical	Pounds per acre of active ingredient or acid equivalent broadcast	Remarks[2/]
Dicamba (Banvel) Dicamba + 2,4-D amine	1/8 - 1/4 1/8 + 1/4	Controls broadleafs only. Apply before corn is 2 feet tall and not within 15 days of tasseling. Follow drift control precautions on the label.
2,4-D amine 2,4-D ester	1/4 - 1/2 1/6 - 1/3	Corn 4 inches to 3 feet tall. Use drop nozzles after corn is 8 inches tall. 2,4-D controls broadleafs only.
2,4-D amine 2,4-D ester	1/2 - 1 1/3 - 2/3	After corn is 3 feet tall. Use drop nozzles so only base of stalk is sprayed. Do not apply between tasseling and dough stage.

1/ From Cultural and Chemical Weed Control in Field Crops - 1976. Extension Folder 212. Agricultural Extension Service. University of Minnesota. St. Paul, Minnesota, 55108.

2/ Check label for detailed use instructions and restrictions on crop use.

Table 2. Effectiveness of Herbicides on Major Weeds in Corn

	Preplanting					Preemergence						Postemergence			
	Alachlor (Lasso)	Butylate (Sutan^{+})	EPTC (Eradicane)	Cyanazine (Bladex)	Atrazine	Alachlor (Lasso)	Atrazine	Dicamba (Banvel)	Propachlor (Ramrod, Bexton)	Linuron (Lorox)	Cyanazine (Bladex)	2,4-D	Dicamba (Banvel)	Atrazine and oil	Cyanazine (Bladex)
Corn tolerance	G	G	G	F	G	G	G	F	G	F	F	G	G	G	F
Grasses															
Giant and robust foxtail	G	G	G	F	F	G	F	P	G	F	F	N	N	F	G
Green foxtail	G	G	G	G	G	G	G	P	G	F	G	N	N	G	G
Yellow foxtail	G	G	G	G	G	G	G	P	G	F	G	N	N	G	G
Barnyardgrass	F	G	G	F	F	F	F	P	F	F	F	N	N	F	F
Crabgrass	G	G	G	F	P	G	P	P	G	G	F	N	N	P	F
Panicum	G	G	G	F	P	G	P	P	F	G	F	N	N	P	F
Nutsedge	G	G	G	P	P	F	P	N	F	P	P	N	N	F	P
Quackgrass	N	N	F	P	G	N	G	N	N	N	P	N	N	G	P
Woolly cupgrass	G	F	G	P	P	G	P	P	F	P	P	N	N	F	F
Wild proso millet	G	F	G	P	P	G	P	P	F	P	P	N	N	P	P
Broadleafs															
Cocklebur	N	P	P	F	F	N	F	F	P	P	F	G	G	G	F
Lambsquarters	F	P	F	G	G	F	G	G	P	G	G	G	G	G	G
Mustard	P	P	P	G	G	P	G	G	P	G	G	G	F	G	G
Pigweed	G	F	F	F	G	G	G	G	F	G	F	G	G	G	F
Ragweed	P	P	F	G	G	P	G	G	P	G	G	G	G	G	G
Smartweed	P	P	P	G	G	P	G	G	P	F	G	P	G	G	G
Velvetleaf	P	F	F	F	F	P	F	F	P	F	F	G	G	F	F
Wild sunflower	P	P	P	F	F	P	F	F	P	P	F	F	G	G	F
Canada thistle	N	N	N	P	P	N	P	N	N	N	P	F	G	F	P
Buffalo bur	P	F	G	P	P	P	P	P	P	P	P	P	P	G	P
Kochia	P	P	F	G	G	P	G	F	P	F	G	F	G	G	G
Jerusalem artichoke	N	N	N	P	P	N	P	P	N	P	P	G	G	P	P

G - Good; F - Fair; P - Poor; N - None

Table 3. Suggestions for chemical control of weeds in soybeans[1].

Chemical	Pounds per acre of active ingredient or acid equivalent	Remarks[2]
Preplanting incorporated		
Alachlor (Lasso)	4	For nutsedge control.
(Lasso II)	3.9	For nutsedge control.
Dinitramine (Cobex)	1/3 - 2/3	Primarily annual grass control.
Profluralin (Tolban)	1/2 - 1	
Trifluralin (Treflan)	1/2 - 1	
Vernolate (Vernam)	3	Controls annual grasses and some broadleafs. Incorporate immediately.
Preemergence		
Alachlor (Lasso)	2 - 3 1/2	Controls annual grasses primarily.
(Lasso II)	2.4 - 3.9	
Chloramben (Amiben)	3	Controls annual grasses and broadleafs. Apply same day soybeans are planted.
Chloramben + alachlor	2 + 2	
Chlorbromuron (Maloran) + alachlor	3/4 - 2 1/4 + 1 1/2 - 2 1/2	For medium textured soils with less than 4% organic matter. Do not use on sandy soils.
Chlorpropham (Furloe Chloro-IPC)	2-3	For annual smartweeds only.
Linuron (Lorox) + alachlor	1/2 - 1 1/2 + 1 - 3	For medium textured soils with less than 4% organic matter. Do not use on sandy soils.
Metribuzin (Lexone, Sencor) + alachlor	1/4 - 1/2 + 2 - 2 1/2	Do not use on soils low in organic matter or on sandy soils. Soybean injury may be more severe on alkaline soils or on soils with atrazine residues.

Table 3. (Continued)

Chemical	Pounds per acre of active ingredient or acid equivalent	Remarks[2/]
Postemergence		
Bentazon (Basagran)	3/4 - 1 1/2	Apply when soybeans are in first trifoliolate leaf stage. Controls most annual broadleaved weeds, Canada thistle, and nutsedge. Apply second treatment to Canada thistle and nutsedge 10 days after first application.
Chloroxuron (Norex, Tenoran)	1 - 1 1/2	Apply when soybeans are in first trifoliolate leaf stage and weeds are less than 2 inches tall. Controls certain broadleafs only.
2,4-DB amine	1/5	Controls only cocklebur. Apply 10 days before bloom up to midbloom or as a directed spray when soybeans are 8 to 12 inches tall.

1/ From Cultural and Chemical Weed Control in Field Crops-1976. Extension Folder 212. Agricultural Extension Service. University of Minnesota, St. Paul, Minnesota, 55108.

2/ Check label for detailed use instructions and restrictions on crop use.

Table 4. Effectiveness of Herbicides on Major Weeds in Soybeans.

	Preemergence						Preplanting					Post-emergence		
	Alachlor (Lasso)	Chloramben (Amiben)	Chlorpropham (Furloe)	Chlorbromuron (Maloran)	Linuron (Lorox)	Metribuzin (Sencor, Lexone)	Alachlor (Lasso)	Trifluralin (Treflan)	Dinitramine (Cobex)	Profluralin (Tolban)	Vernolate (Vernam)	Chloroxuron (Tenoran, Norex)	2,4-DB	Bentazon (Basagran)
Soybean tolerance	G	G	G	F	F	F	G	F	F	F	F	F	P	G
Grasses														
Giant foxtail	G	G	P	F	F	F	G	G	G	G	G	P	N	N
Green foxtail	G	G	P	F	F	F	G	G	G	G	G	P	N	N
Yellow foxtail	G	G	P	F	F	F	G	G	G	G	G	P	N	N
Barnyardgrass	F	G	P	F	F	F	F	G	G	G	G	P	N	N
Nutsedge	F	P	N	P	P	P	G	P	N	N	F	N	N	F
Broadleafs														
Black nightshade	G	F	P	P	P	P	G	P	P	P	P	-	-	G
Cocklebur	P	P	P	P	P	F	P	P	N	N	P	F	F	G
Kochia	P	G	P	F	F	G	P	G	G	G	-	-	-	-
Lambsquarters	F	G	P	G	G	G	F	G	G	G	G	F	P	F
Mustard	P	F	F	G	G	G	P	P	N	N	F	G	P	G
Pigweed	G	G	P	G	G	G	G	G	G	G	G	F	P	F
Common ragweed	P	G	P	G	G	G	P	N	P	N	P	P	P	G
Smartweed	P	G	G	F	F	G	P	P	F	P	P	P	P	G
Velvetleaf	P	F	P	F	F	F	P	P	P	N	F	P	P	G
Venice mallow	P	G	P	G	G	G	P	P	P	P	G	-	P	G
Wild sunflower	P	P	P	P	P	F	P	N	N	N	P	F	P	G

G - Good; F - Fair; P - Poor; N - None

Table 5. Suggestions for chemical control of weeds in small grains.

Crop	Chemical	Rate - Pounds per acre of active ingredient or acid equivalent broadcast	Time of application - crop stage
Wheat or barley	2,4-D amine	1/4 - 2/3	Fifth leaf to early boot.
	2,4-D ester	1/6 - 1/2	
	MCPA amine	1/4 - 2/3	Two leaf to early boot.
	MCPA ester	1/6 - 1/2	
	Bromoxynil + MCPA ester	1/4 + 1/4	Two leaf to early boot.
	Bromoxynil (Brominal, Buctril)	1/4 - 1/2	Two leaf to early boot.
Wheat or oats	Dicamba + MCPA amine	1/8 + 1/4	Two- to five-leaf stage.
Oats	2,4-D amine	1/4 - 1/2	Sixth leaf to early boot.
	MCPA amine	1/4 - 2/3	Two leaf to early boot.
	MCPA ester	1/6 - 1/2	
	Bromoxynil	1/4 - 3/8	
Winter wheat	2,4-D amine	1/4 - 3/4	Fully tillered to boot stage.
	2,4-D ester	1/4 - 1/2	
	MCPA	1/4 - 3/4	
	Dicamba + MCPA amine	1/8 + 1/4 - 3/8	After dormancy until wheat begins to joint.
	Dicamba + 2,4-D amine	1/8 + 1/4 - 3/8	
	Bromoxynil	1/4 - 1/2	Fully tillered to boot stage.
	Bromoxynil + MCPA ester	1/4 + 1/4	
Flax	MCPA	1/4	2- to 6-inch flax.
	Dalapon (Dowpon, Radapon)	3/4	2- to 6-inch flax.
	EPTC (Eptam)	3	Preplanting incorporated
	Bromoxynil	1/4 - 1/2	2- to 8-inch flax.

Table 6. Suggestions for chemical control of weeds in dry beans, sugarbeets, and sunflowers[1/]

Crop	Chemical	Rate - pounds per acre of active ingredient or acid equivalent broadcast	Remarks
Dry beans	Preplanting incorporated		
	Alachlor (Lasso)	2 1/2 - 3	Controls annual grasses, nutsedge, pigweed black nightshade.
	EPTC (Eptam)	3	Controls annual grasses, some broadleafs.
	Dinitramine (Cobex)	1/3 - 2/3	Controls annual grasses, pigweed, common lambsquarters.
	Profluralin (Tolban)	3/4 - 1	
	Trifluralin (Treflan)	1/2 - 1	
	Preemergence		
	Alachlor (Lasso)	2 1/2 - 3	Controls annual grasses, pigweed, black nightshade.
	Chloramben (Amiben)	3	Controls annual grasses and most annual broadleafs.
Sugarbeets	Preplanting incorporated		
	Diallate (Avadex)	1 1/2 - 2	Controls wild oat.
	EPTC (Eptam)	2 - 2 1/2	Controls annual grasses and some broadleafs.
	Preemergence		
	TCA	6 - 8	Controls annual grasses except wild oat.
	Early postemergence		
	Dalapon (Dowpon, Radapon)	2-3	Apply when sugarbeets are up to 6-leaf stage for controlling annual grasses except wild oat.
	Dalapon	2 1/2 - 3 1/2	Apply as directed spray when sugarbeets are 7-leaf stage to 14 inches.

Table 6. (Continued)

Crop	Chemical	Rate - pounds per acre of active ingredient or acid equivalent broadcast	Remarks
	Barban (Carbyne)	5/8 - 3/4	For wild oat control when wild oat has two leaves.
	Phenmedipham (Betanal)	1 - 1 1/2	Controls some annual grasses and most annual broadleafs except pigweed. Apply after sugarbeets have four leaves.
	Desmedipham (Betanex)	1 - 1 1/2	Controls most annual broadleafs. Apply after sugarbeets have four leaves.
	Endothall (Herbicide 273)	3/4 - 1 1/2	Controls wild buckwheat and annual smartweed. Apply when sugarbeets have 4 to 6 leaves.
	Pyrazon + dalapon (Pyramin Plus)	3.8 + 2.2	Controls annual grasses and annual broadleafs. Apply when weeds have no more than 2 leaves.
Sunflowers	Preplanting incorporated		
	EPTC (Eptam)	3	Controls annual grasses and some broadleafs.
	Profluralin (Tolban)	3/4 - 1	Controls annual grasses, pigweed, common lambsquarters
	Trifluralin (Treflan)	1/2 - 1	
	Preemergence		
	Chloramben (Amiben)	2 - 3	Controls annual grasses and most annual broadleafs.

1/ From Cultural and Chemical Weed Control in Field Crops-1976. Extension Folder 212. Agricultural Extension Service, University of Minnesota, St. Paul, Minnesota 55108. Check label for detailed use instructions and restrictions on crop use.

Table 7. Suggestions for wild oat control.[1/]

Chemical	Pounds per acre of active ingredient or acid equivalent broadcast	Time of application	Crop
Barban (Carbyne)	1/4 - 3/8	wild oat in 2-leaf stage	Wheat, barley flax, soybeans, sunflowers.
Barban (Carbyne)	3/4 - 1	Wild oat in 2-leaf stage	Sugarbeets
Diallate (Avadex liquid)	1 1/2 - 2	Preplanting or pre-emergence, fall or spring	Flax, sugarbeets
Diallate (Avadex granules)	1 1/2 - 2	Preplanting, fall or spring	Sugarbeets
Triallate (Far- go)	1 - 1 1/4 1 1/4 - 1 1/2	Preplanting or preemergence, fall or spring	Wheat Barley

[1/] From Cultural and Chemical Weed Control in Field Crops-1976. Extension Folder 212, Agricultural Extension Service, University of Minnesota, St. Paul, Minnesota 55108. Check label for detailed use instructions and restrictions on crop use.

UREA*

Urea is a white crystalline solid containing 45-46 percent nitrogen and is highly soluble in water. As the synthetic acid amide of carbonic acid, urea is an organic nitrogen carrier. Urea is used widely in the agricultural industry as a feed additive in ruminant rations and as a fertilizer. This paper will be confined to a discussion of urea as a nitrogen fertilizer.

Manufacture

The two ingredients for the manufacture of urea are carbon dioxide and ammonia. The simplified general reaction for urea production is:

$$\underset{\text{carbon dioxide}}{CO_2} + \underset{\text{ammonia}}{2NH_3} \longrightarrow \underset{\text{urea}}{CO\,(NH_2)_2} + \underset{\text{water}}{H_2O}$$

Carbon dioxide gas and ammonia are reacted at elevated pressure and temperature. A solution containing 70 to 75 percent urea is obtained. With further processing, including water removal, either granules or prills are produced.

Biuret: Biuret is formed during the manufacture of urea. Biuret basically is a coupling of two urea molecules with a release of one molecule of ammonia.

$$\underset{\text{urea}}{2(NH_2\text{-}CO\text{-}NH_2)} \longrightarrow \underset{\text{biuret}}{NH_2\text{-}CO\text{-}NH\text{-}CO\text{-}NH_2} + \underset{\text{ammonia}}{NH_3}$$

Normally the biuret content of fertilizer-grade urea is held below one-half percent. High levels of biuret are toxic to plants, as will be discussed later.

Urea in the Fertilizer Blending Plant

Understanding Critical Relative Humidity: Hygroscopicity is the tendency of a material to absorb moisture. It is an extremely important characteristic of fertilizer mixtures. Critical relative humidity (CRH) is an excellent measure of

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*To be presented by Harvey L. Meredith, TVA Area Representative, at the Combined Soils, Fertilizer, and Agricultural Pesticides Shortcourse, Minneapolis, Minnesota, December 9, 1975.

the hygroscopic nature of a fertilizer. CRH is the relative humidity of the atmosphere above which a given material will begin to absorb moisture from the atmosphere. Therefore the higher the CRH of a fertilizer, the less likely it is that the fertilizer will absorb moisture from the atmosphere.

Mixtures of Urea and Ammonium Nitrate: Mixtures of urea and ammonium nitrate are more hygroscopic than either material separately. The mixture has a CRH of only 18 percent and absorbs water rapidly. Urea blends containing small amounts of ammonium nitrate may absorb sufficient moisture from the atmosphere to cause problems in handling. When blenders switch from ammonium nitrate to urea, some definite precautions must be employed. Generally the plant should be thoroughly cleaned of all remnants of ammonium nitrate. It is imperative that urea and ammonium nitrate are kept separated in storage.

Mixtures of Urea and Superphosphate: Caution should be exercised when urea and triple superphosphate are blended because the water of hydration of monocalcium phosphate monohydrate is released. The reaction is as follows:

$$\underset{\text{triple superphosphate}}{Ca(H_2PO_4)_2 \cdot H_2O} + \underset{\text{urea}}{4CO(NH_2)_2} \longrightarrow \underset{\text{adduct}}{Ca(H_2PO_4)_2 \cdot 4CO(NH_2)_2} + \underset{\text{free water}}{H_2O}$$

The free water is sufficient to form a saturated solution (3).[1/] The potential exists for sufficient liquid phase to be formed to cause caking and stickiness. Bridging, uneven flow, and plugging of fertilizer application equipment may result. There is no concomitant problem when 18-46-0 is blended with urea.

Mixtures of Urea and Potash: Urea and potassium chloride blends will react in the presence of an ammonium salt to form an adduct of urea-ammonium chloride. This causes caking during storage.

$$\underset{\text{urea}}{CO(NH_2)_2} + \underset{\text{potash}}{KCl} \xrightarrow{NH_4^+} \underset{\text{adduct}}{CO(NH_2)_2 \cdot NH_4Cl}$$

1/ Numbers in parentheses refer to literature cited.

Hydrolysis in Storage: Jensen (4) reported urea in compound fertilizers stored at 110° F hydrolyzed at a rate of 5 percent per month. Urea undergoes hydrolysis through the addition of a molecule of water from the atmosphere as follows:

$$\underset{\text{urea}}{CO(NH_2)_2} + H_2O \longrightarrow \underset{\text{ammonia}}{2NH_3\uparrow} + \underset{\text{carbon dioxide}}{CO_2\uparrow}$$

Since both ammonia and carbon dioxide are gases, ammonia may be lost to the atmosphere. Little or no loss of urea due to hydrolysis has been observed when storage temperatures do not exceed 85-90° F.

Particle Size: In the past most urea was produced via prilling towers. Prills were often smaller than many of the other ingredients used in blending. Hence, segregation of blended materials posed a constant threat. Currently considerable urea is granulated. The granules are larger, harder, and more resistant to abrasion than prills. The larger granular urea more nearly fits the size distribution of other fertilizers such as DAP, MAP, and KCl used in blending, and segregation is reduced. Moisture pickup from the atmosphere and resultant caking also are reduced as urea particle size is increased.

Handling in the Plant: Augers should not be used to move granular fertilizers because of abrasion and breaking of the granules. This is especially true with urea because the particles are relatively soft. Belt conveyors should be used whenever possible.

Transportation and Storage: Urea is neither combustible nor explosive. It is free from crystal phase changes and does not tend to break down with changes in temperature. Hence it can be transported and stored safely with no loss in quality under normal circumstances. This, plus its high analysis, makes urea more economical to handle and store than lower-analysis, less stable ammonium nitrate.

Spreading: Urea has a lower density than most companion materials used in fertilizer blends. Special attention should be given to spreading width with fan-type spreaders to avoid segregation of the urea. For greatest success, a spreading width of 40-50 feet should not be exceeded.

Agronomic Properties

When urea is applied to the soil, it is hydrolyzed to ammonium carbonate by the enzyme urease as follows:

$$CO(NH_2)_2 + 2H_2O \longrightarrow (NH_4)_2CO_3$$

urea water ammonium carbonate

The formation of ammonium carbonate increases soil pH. As ammonium carbonate is unstable, it volatilizes to form ammonia and carbon dioxide gases as follows:

$$(NH_4)_2CO_3 \longrightarrow NH_3\uparrow + H_2O\uparrow + CO_2\uparrow$$

ammonium carbonate ammonia water carbon dioxide

One of the more serious drawbacks of surface-applied urea lies in the potential loss of ammonia due to hydrolysis. Highest N efficiency from urea is achieved when urea is incorporated with the soil. Due to the high solubility of urea, as little as 0.1 inch of rainfall is sufficient to move urea into the soil to sufficient depth to prevent ammonia loss (4). When urea is covered with soil or comes in contact with the soil by wetting, ammonium released by hydrolysis of urea is adsorbed on soil surfaces or organic matter and is retained in the soil as the ammonium cation.

Urea in the Soil System: Ammonium forms of nitrogen as urea undergo biological oxidation to nitrate ions as follows:

$$CO(NH_2)_2 + 2H_2O \longrightarrow 2NH_4^+ + CO_3^=$$

urea water ammonium carbonate

$$2NH_4^+ + \text{oxygen} \xrightarrow[\text{bacteria}]{\text{nitrosomonas}} 2NO_2^-$$

ammonium nitrite

$$\underset{\text{nitrite}}{2NO_2^-} + \text{oxygen} \xrightarrow[\text{bacteria}]{\text{nitrobacter}} \underset{\text{nitrate}}{2NO_3^-}$$

Each molecule of urea ultimately produces two molecules of the highly soluble nitrate ion, NO_3^-. This form of nitrogen is readily available to plants and is a form of nitrogen commonly taken up by agricultural crops.

Effect of Placement of Urea: Placement of urea with seeds sensitive to ammonia should be avoided. Serious injury to seed or germinating seedlings may result. Caution should be exercised especially on sandy soils and where soil moisture is marginal. Corn yields were shown to be severely reduced when as little as 5 pounds per acre of N were placed with the seed as urea (6). Placement of urea 2 inches to one side and 2 inches below the seed did not reduce yields even at rates of 100 pounds N per acre as urea. Placement of urea down the seed spout with spring wheat appears to be less risky. Twenty pounds per acre of N as urea have been applied to spring wheat without yield reduction; higher rates significantly reduced yields (1). On high pH soils under conditions of marginal soil moisture, as little as 10 pounds N per acre as urea reduced spring wheat stands and yields when urea was placed directly with the seed (2).

Effect of Biuret on Plants: Biuret is absorbed by plants through the roots and leaves. Once absorbed, biuret is seemingly metabolized slowly, if at all. Biuret toxicity symptoms may persist for long periods. Urea containing biuret banded near the seed or placed with the seed may inhibit germination and injure or kill seedlings. Foliar applications of urea should not exceed 0.25-0.50 percent biuret. When the biuret content of urea does not exceed 2 percent, little or no problems are encountered when urea is broadcast. Biuret is relatively mobile and readily mineralized in soil systems (8).

Agronomic Efficiency of Urea as an N Source

Field results of urea are variable owing to the many factors which can contribute to losses of NH_3. Urea generally is most effective when incorporated with the soil either through tillage or by a rain shower following application. Surface-applied urea usually is hydrolyzed to ammonia and the pH consequently is increased locally. Under these conditions, considerable ammonia may be volatilized and lost as a gas to the air.

Factors which tend to influence the loss of urea when surface applied include temperature, soil pH, cation exchange capacity, soil moisture, and vegetation.

Soil Temperature: Most urea will be applied in Minnesota in the fall prior to plowing or in early spring prior to planting. The average ambient temperature normally will be around 50° F or less. Losses of ammonia from urea would not be expected to be appreciable at this temperature. However, applying urea to the soil surface without incorporation in midsummer likely would result in considerable ammonia loss.

Soil pH: Studies have shown that ammonia volatilization from surface-applied urea increases as soil pH increases. Ammonia may be lost from surface-applied urea on acid soils as the zone surrounding a dissolving urea granule will be alkaline.

Cation Exchange Capacity: Soils with high cation exchange capacity (CEC) will likely lose less ammonia from surface-applied urea than soils with low exchange capacity due to higher adsorption of the ammonium ion. Soils with low CEC, such as sandy soils low in organic matter, tend to lose more ammonia than soils of medium to high CEC.

Soil Moisture: Moist soils readily dissolve urea and adsorb the hydrolyzed ammonium ion. Soils undergoing extensive drying may lose appreciable ammonia due to volatilization.

Vegetation: Vegetation influences ammonia loss from surface-applied urea apparently by affecting temperature and moisture. A vegetation canopy will be cooler than a dry surface and the probability of condensation of dew to trap ammonia will be enhanced.

Amended Urea to Effect Slow Release: Urea and most other nitrogen fertilizers are highly water soluble. After being applied to the soil, they usually are dissolved very rapidly. Under certain conditions this can be advantageous, but under many conditions nitrogen is made available faster than plants can use it and much of the nitrogen can be lost by leaching, volatilization or excessive consumption over that required for efficient growth. Sulfur coating of urea delays nitrogen release which, under certain conditions, results in more efficient use by growing plants.

Other coatings for urea have been tested. Urea reacts with a number of aldehydes to form compounds with low solubility in water. These slow-release materials have gained popularity as nitrogen fertilizers for golf courses and other specialty uses.

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Table 1. Physical Properties of Fertilizers Used in Blending

Fertilizer Material	Formula	Molecular Weight	%N	Apparent Specific Gravity	Lbs Per Ft^3
Urea	$CO(NH_2)_2$	60	46	1.33	46
Amm. nitrate	NH_4NH_3	80	34	1.73	62
Diammonium phosphate	$(NH_4)_2HPO_4$	132	18	1.62	56
Monoammonium phosphate	$NH_4H_2PO_4$	115	11	1.80	65
Potassium chloride	KCl	75	-	1.98	65
Concentrated Superphosphate	$Ca(H_2PO_4)\cdot H_2O$	252	-	2.22	62
Amm. sulfate	$(NH_2)_2SO_4$	132	21	1.77	54

Table 2. Solubility and Percent Concentration of Urea and Ammonium Nitrate

	Urea		Ammonium Nitrate	
°F	Lbs/100 lbs water	%N in solution	Lbs/100 lbs water	%N in solution
32	66.7	18.4	118.3	18.4
50	85.2	21.2	158.0	20.8
68	108.2	23.9	192.0	22.4
86	135.3	26.4	241.8	24.0

Source: Sanchelli, Vincent. Manual on Fertilizer Manufacture. 3rd Ed. Industry Publications, Inc. Caldwell, N. Jersey 1963, p. 158.

Table 3. Critical Relative Humidities (CRH) of Fertilizer Salts and Mixtures at 86°F.

Material	CRH
Urea	75.2
Ammonium nitrate (A.N.)	59.4
Urea + ammonium nitrate	18.1
Potassium chloride (KCl)	84.0
KCl + urea	60.3
Diammonium phosphate (DAP)	82.8
DAP + urea	62
Monoammonium phosphate (MAP)	91.6
MAP + urea	65.2
Monocalcium phosphate (Triple superphosphate)	97.7

Table 4. Estimated Energy Required for Various N Sources

Fertilizer Material	kcal/lb N for[1/] production	transportation	kcal/A for application	Total kcal/Ac[2/]
Anhydrous ammonia	6,250	277	25,386	980,000
Urea, solid	8,120	505	10,433	1,300,000
Ammonium nitrate	8,485	669	10,433	1,380,000

1/ kilocalories
2/ Based on 150 lbs N/Ac storage???

Source: White, W.C. Fertilizer - Food - Energy Relationships. Ill. Fert. Conf. Proc. pp. 37-43. 1974.

Table 5. Bacterial Oxidation of Selected Nitrogen Carriers

Fertilizer	Nitrification Reactions
Urea	$CO(NH_2)_2 + H_2O = CO_2 + 2NH_3$
	$2NH_3 + 4O_2 = 2HNO_3 + 2H_2O$
Ammonium nitrate	$NH_4NO_3 + 2O_2 = 2HNO_3 + H_2O$
Aqua ammonia	$2NH_4OH + 4O_2 = 2HNO_3 + 4H_2O$
Ammonium sulfate	$(NH_4)_2SO_4 + 4O_2 = 2HNO_3 + H_2SO_4 + 2H_2O$
Anhydrous ammonia	$2NH_3 + 4O_2 = 2HNO_3 + 2H_2O$

Table 6. Effect of Broadcast Nitrogen Carriers and Biuret Level on Stand of Barley and Milo, South Dakota

Crop	Carrier	Lbs N Per Acre	Lbs Biuret Per Acre	Stand % of Control
Barley	AN[1/]	180	0	93
	Urea	180	20	99
Milo	AN	180	0	104
	Urea	180	20	102

1/ Ammonium nitrate

Source: Brage et al. SSSAP 24: 294-96. 1960

Table 7. Relative Compatibility of Selected Fertilizers Blended with Urea

Mixture	Remarks
Urea-ammonium nitrate	Incompatible
Urea-triple superphosphate	Limited compatibility
Urea-single superphosphate	Limited compatibility
Urea-potassium chloride	Compatible
Urea-diammonium phosphate	Compatible
Urea-monoammonium phosphate	Compatible
Urea-potassium sulfate	Compatible
Urea-ammonium sulfate	Compatible
DAP - TSP	Limited compatibility

Table 8. Effect of Urea and Ammonium Nitrate Placed in Contact with Seed Upon Spring Wheat Yield

	Grain Yield, Bu/Ac	
Lbs N/Ac[1/]	Urea	Ammonium Nitrate
0	28	27
10	28	28
20	28	28
30	26	26
40	25	28

1/ Sufficient N broadcast prior to Seeding

Source: Adams & Carson. Garden City, S. Dak. 1973

Table 9. Effect of Source and Placement of Urea and Ammonium Nitrate on Corn Yields. Lamberton, Minn. Exp. Sta. 1960-74.

Lbs N/Ac	Treatment	Source	Yield, Bu/Ac
0	-	-	66
40	Plow down - fall	AN[1/]	83
40	" " "	Urea	90
40	Surface - fall	AN	88
40	" "	Urea	91
80	Plow down - fall	AN	105
80	" " "	Urea	104
160	" " "	AN	110
160	" " "	Urea	111
40	Topdress-spring	AN	95
40	" "	Urea	94
80	" "	AN	108
80	" "	Urea	110

1/ Ammonium Nitrate

Table 10. Effect of Urea and Ammonium Nitrate Placed with Seed on Corn Grain Yield, Wisconsin. 1973.

	Yield, Bu/Ac	
Lbs N/Ac[1/]	Urea	Ammonium Nitrate
0	137	137
5	60	142
10	36	143
20	33	92

1/ Sufficient N broadcast prior to planting

Source: Liegel & Walsh Plainfield Sand, Hancock, Wisc.

Table 11. Effect of Urea and Ammonium Nitrate Side-Placed on Corn Grain Yield, Wisconsin, 1973

Lbs N/Ac 1/	Yield, Bu/Ac Urea	Ammonium Nitrate
0	142	142
25	145	145
50	146	146
100	150	141

1/ Sufficient N broadcast prior to planting

Source: Liegel & Walsh Plainfield Sand, Hancock, Wisc.

Table 12. Evaluation of Urea and Ammonium Nitrate Surface Applied to Bahiagrass and Bermudagrass. 1967-1969, Alabama.

Bahiagrass

Lbs N/Ac	Yield, Lbs/A A.N.	Urea	% 1/ Urea Efficiency
0	1600		-
100	4,900	4,800	98
200	8,500	7,900	93
400	13,400	12,600	94

Bermudagrass

Lbs N/Ac	Yield, Lbs/Ac A.N.	Urea	% 1/ Urea Efficiency
0	2400		
100	6,500	6,000	92
200	10,300	8,700	84
400	16,100	12,200	76

1/ Urea efficiency compared to ammonium nitrate

Source: Agron J. 62: 618-620. 1970

Table 13. Continuous Corn Study of Source and Time of Application of N, Waseca 1972-1975.

Source	Yield, Bu/Ac 1/			
Fall Application	'72	'73	'74	'75
Anhydrous ammonia	145	145	103	52
Urea	154	137	80	52
Am. nitrate	154	123	76	35
Aqua ammonia	147	135	84 2/	33 2/
Spring Application	'72	'73	'74	'75
Anhydrous ammonia	142	143	101	53
Urea	160	127	95	53
Am. nitrate	153	129	96	51
Aqua ammonia	151	134	103 2/	51 2/

Randall et. al.

1/ 75 lbs/Ac

2/ 28% UAN

Table 14. U.S. Fertilizer Consumption

Year	N	P_2O_5	K_2O	Total
1850	3	4	1	8
1870	14	31	4	49
1890	38	132	31	201
1910	146	499	211	856
1930	378	794	354	1526
1950	1,005	1,950	1,103	4,058
1960	2,738	2,572	2,153	7,464
1964	4,353	3,378	2,730	10,460
1968	6,787	4,453	3,792	15,033
1970	7,459	4,574	4,036	16,068
1972	8,016	4,873	4,332	17,221
1974	9,157	5,099	5,083	19,339
1975	8,593	4,494	4,415	17,502

Table 15. Minnesota Fertilizer Use

Year	N	P_2O_5	K_2O
	1000 tons		
1958	49	93	55
1959	64	109	71
1960	54	114	68
1961	65	116	72
1962	66	115	75
1963	86	124	83
1964	94	166	103
1965	104	187	106
1966	114	197	115
1967	188	212	175
1968	251	214	196
1969	344	292	212
1970	284	223	214
1971	411	295	270
1972	374	261	259
1973	424	280	289
1974	413	268	323
1975	449	290	328

Source: Consumption of Commercial Fertilizers in the United States. USDA Stat. Rept. Service - Crop Reporting Board, SpCr 7, Washington, D.C.

Table 16. Selected Sources of N Used for Direct Application - Minnesota, 1965-1974.

Year	NH_3	A.N.	N Soln.	Urea	Total DA-N
	1000 tons N				
1965 1/	16	11	13	1.1	52.2
1966	24	13	11	1.3	60.5
1967	84	17	18	2.2	128.7
1968	138	24	17	1.5	186.6
1969	194	31	22	1.2	258.5
1970	164	24	17	1.6	215.9
1971	244	44	23	4.0	320.4
1972	205	41	24	14	293.0
1973	228	46	29	18	328.6
1974	229	40	25	18	322.3
1975	241	43	29	31	351.5

1/ Fiscal Year, July 1-June 30

Table 17. Direct Application N and N Applied in Mixtures in Minnesota 1965-75 with Percentage Contribution of Each.

Year	DA (1000 tons N)	% of Total	Mixtures (1000 tons N)	% of Total	Total (1000 tons N)
1965	52.2	50.4	51.4	49.6	103.6
1966	60.5	52.8	54.0	47.2	114.5
1967	128.7	68.4	59.4	31.6	188.1
1968	186.6	74.3	64.6	25.7	251.2
1969	258.5	75.2	85.1	24.8	343.6
1970	215.9	76.0	68.1	24.0	283.9
1971	320.4	77.9	90.9	22.1	411.3
1972	293.0	78.6	79.8	21.4	372.8
1973	328.6	77.5	95.4	22.5	424.0
1974	322.3	78.1	90.5	21.9	412.8
1975	351.5	78.3	97.6	21.7	449.1

Table 18. Direct Application (DA) Sources of N and Percent of Each, Minn., 1975

Source	Tons N	% of Total DA-N
Anhydrous ammonia	241,451	69
Ammonium nitrate	42,806	12
Urea	30,812	9
N Solution	28,979	8.5
Aqua	2,155	.6
Ammonium sulfate	743	.2

Table 19. Fertilizer Consumption, 1974-75

U.S.	1974	1975	% Change
	(1000 tons)		
N	9,157	8,593	-6.2
P_2O_5	5,099	4,494	-11.9
K_2O	5,083	4,415	-13.1
Overall			-9.5
Minn.			
N	413	449	+8.7
P_2O_5	268	290	+8.2
K_2O	323	328	+1.5
Overall			+6.7

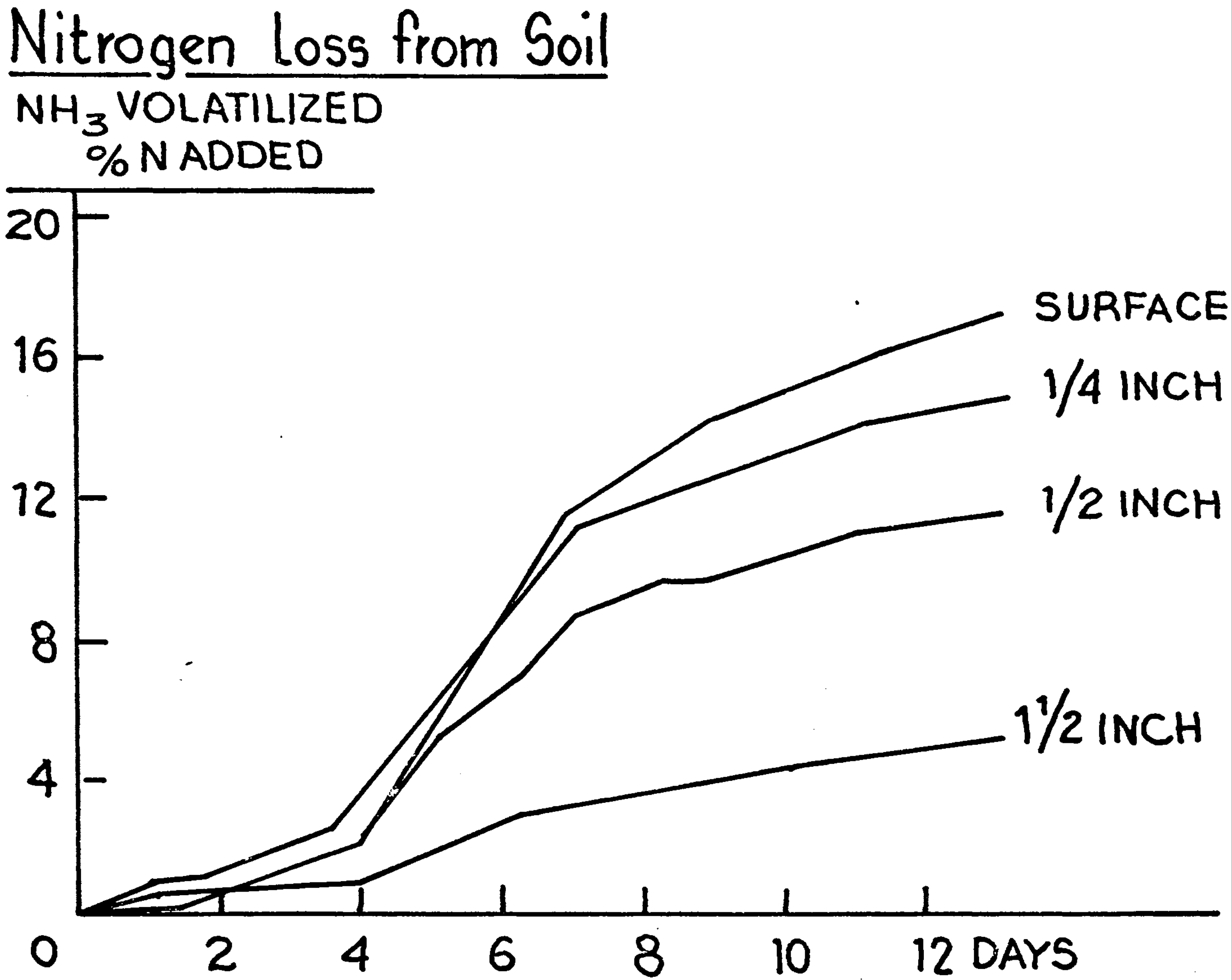

Figure 1. Cumulative loss of added N from urea mixed with soil layers of different thickness, Dickson silt loam; pH 6.5 at 75°F, rate of application: 100 lbs. N/A. Source: Ernst, J.W. and H.F. Massey. 1960. SSSAP 24: 87-90.

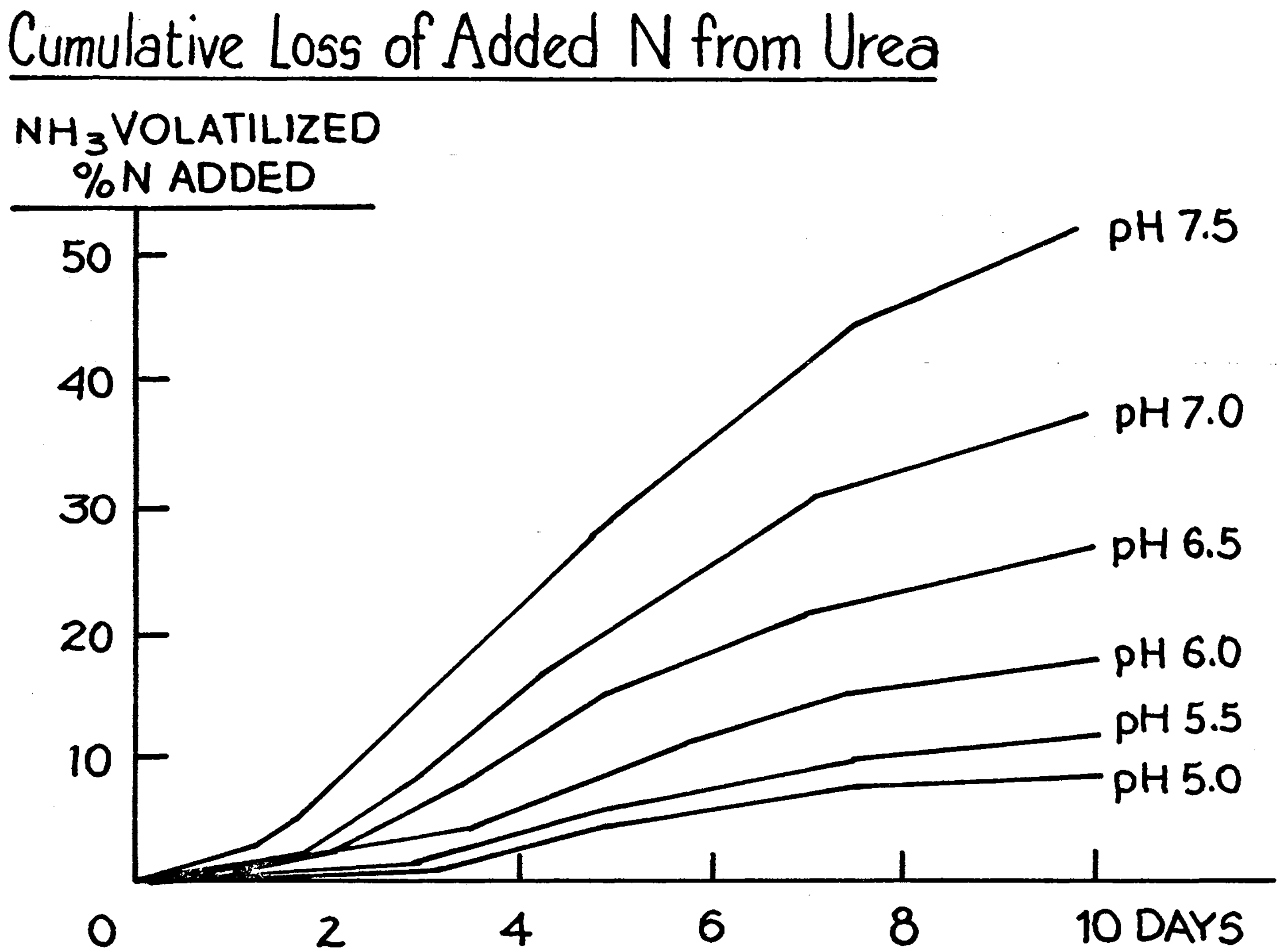

Figure 2. Loss of N from topdressed urea as influenced by soil pH, Dickson silt loam aerated at room temperature, rate of application: 100 lbs/Ac. SSSAP 24: 87-90. 1960.

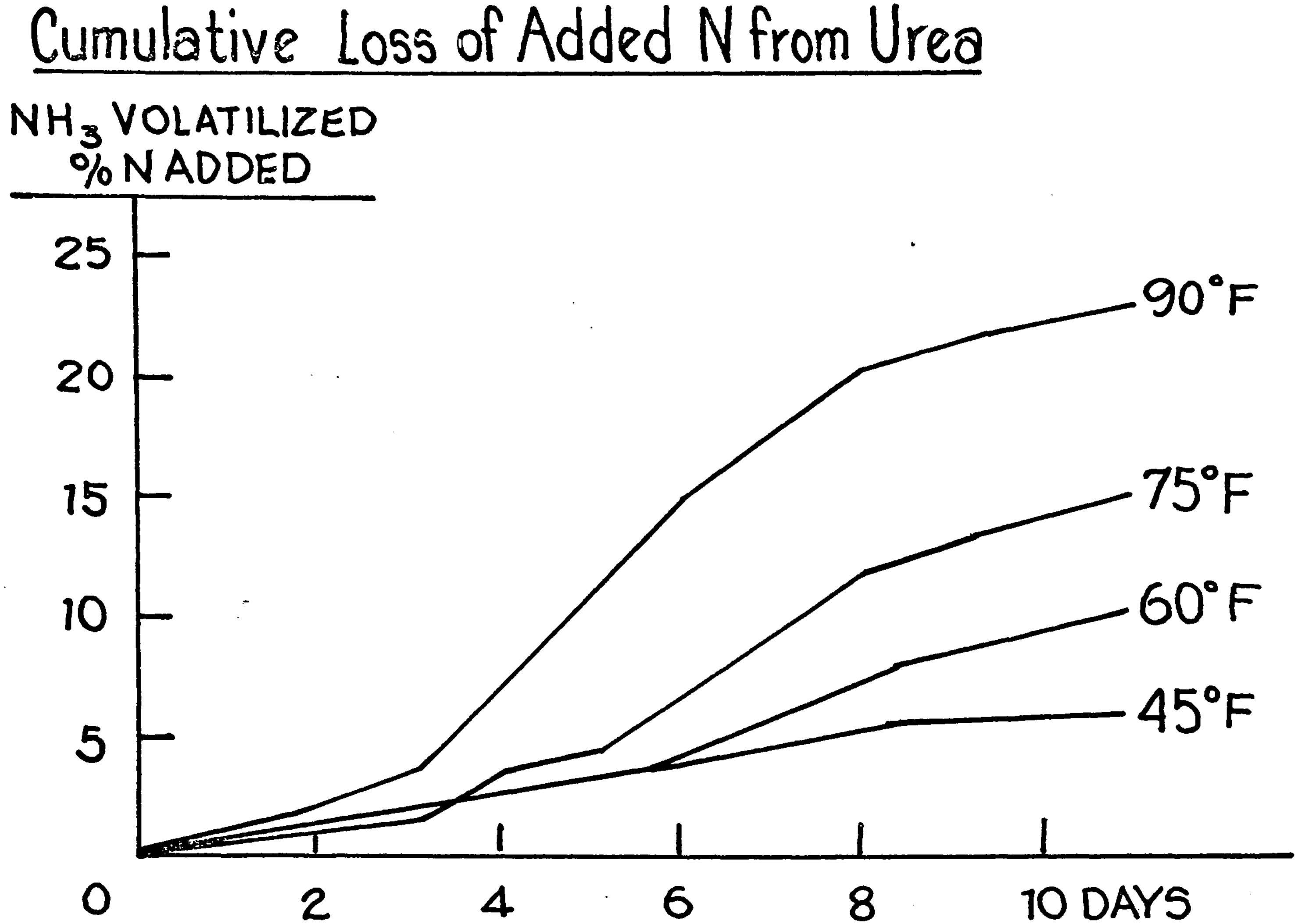

Figure 3. Loss of N from topdressed urea as influenced by temperature, Dickson silt loam, pH 6.5, rate of application: 100 lbs N/A. SSSAP 24: 87-90. 1960.

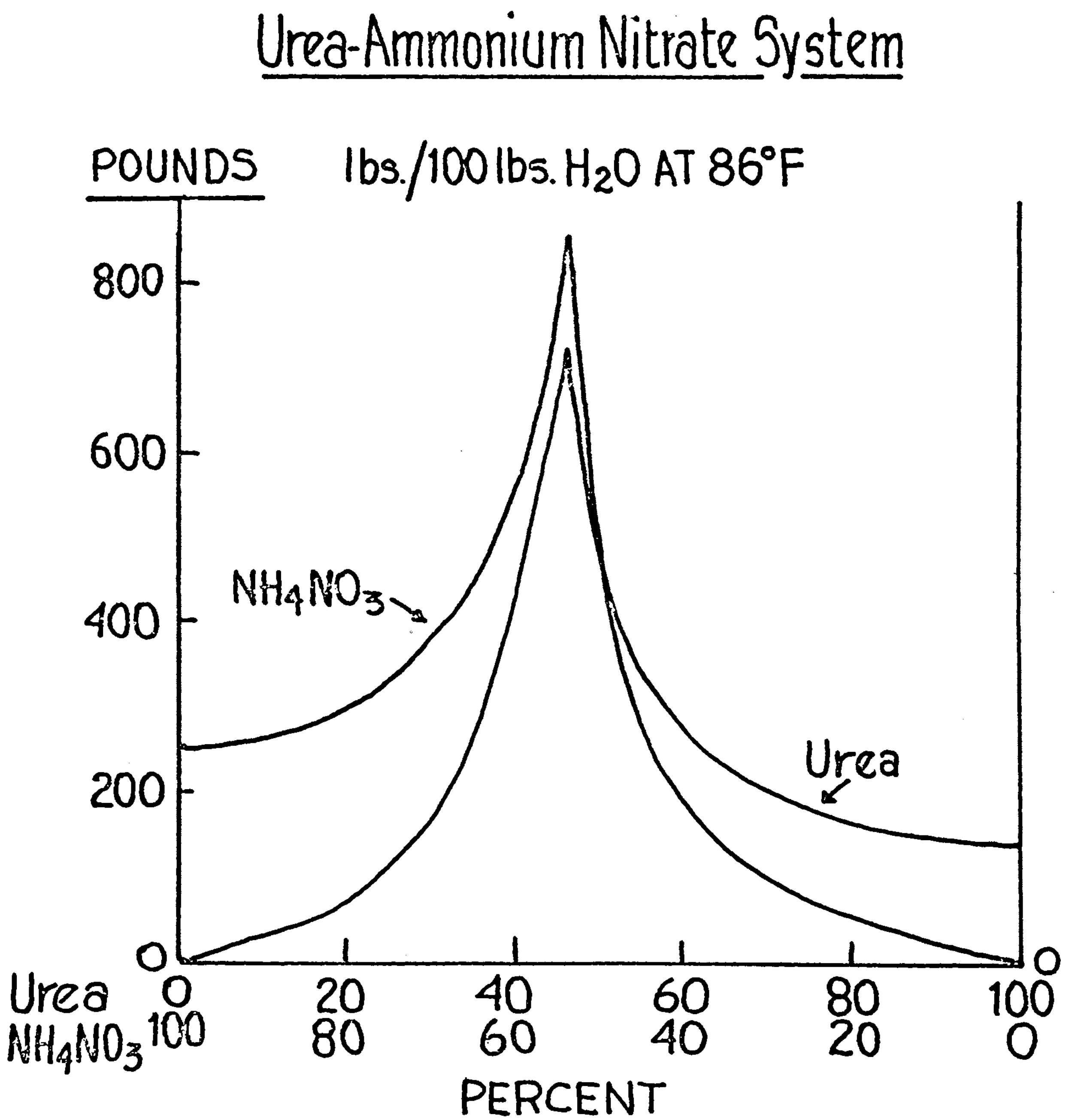

Figure 4. Solubility of urea-ammonium nitrate system maximized at 54% ammonium nitrate and 46% urea.