COMBINED SOILS, FERTILIZER & AGRICULTURAL PESTICIDES

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PRODUCTION RESEARCH IN THE FUTURE

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I am assuming that the term "production research" has meaning for a group such as represented at this meeting today. In our definition, production research are those types of activities carried on at the Minnesota Agricultural Experiment Station with respect to increasing the efficiency of an agricultural production enterprise. This may require very fundamental types of research in order to find solution to some problems or it may be the applied types of activities conducted at St. Paul and our several branch experiment stations that effect change in existing production practices. Presently, about 75 percent of the total research effort of the Minnesota Agricultural Experiment Station comes under this broad category of production research in the plant and animal sciences, and social sciences.

Looking to the decade ahead, the question must be raised as to whether this will be the continuing direction? This will probably not be the continuing direction in terms of percentage of time or effort but we will see an increase in the amount of dollar resources placed in the area. This is brought about by several factors.

The major factor is the shift in emphasis on the part of those making funds available whether they be public or private sources. There has been a major shift to more people-oriented types of research and the Agricultural Experiment Station is in excellent position to provide expertise.

We still have the burden of surplus, real or imagined, with selected commodities. This does have an effect on the attitude of Congressmen and State Legislators. This means that we must do a better job in defining the areas of work that have significance to the state.

During the past 18 to 24 months we have seen excessive pressures from "ecological groups". They are not hindered by limited facts and their approach is highly emotional. Production research in agriculture comes in for its share of criticism on use of pesticides, animal wastes, and fertilizer.

There are fewer farm units each year. Those who do not have close association with agriculture think of agriculture as only the basic producing units.

We have defined some of the problems in terms of production research for the future. Now it is a good idea to look at the facts.

The problems of surpluses are real in some commodities, but most crops grown in Minnesota do not come in this category. However, when we have a Congress that argues the size of payment for not producing rather than the fundamental economic issue of the program, and faced with the tremendous demands in urban areas for improving the quality of life of the disadvantaged, agriculture does not look too good. Within the State of Minnesota most of the legislators who will make decisions on funds for our research program have no close background to production agriculture. I hasten to add that we *have had excellent support from the entire legislative body, but we do have a continuing responsibility to point out the relationship of the agricultural sector to the total economy of the State of Minnesota.*

The problem of undue pressure and emotional approaches is one that has always confronted agriculture. We essentially sold the conservation movement by emotionalism and now someone else is playing it back to us on broader issues of our environment. We have better facts to present to the public and I am encouraged by what has happened when accurate facts are presented,as example, with the Minnesota Pollution Control Agency and the feedlot regulations.

The matter of fewer farms is really not a cogent issue. The generation of total wealth from agriculture which is constantly increasing, and the quality of life in rural America is the cogent issue. The numbers of units that you individually deal with will be less, but the volume of business with each of these units will be increasingly greater. It is our collective responsibility to point out that 30 percent of the total economy in Minnesota is generated from broad agriculture, from the producer to the consumer. This is the input-output industry that you people are directly involved with. It is the $3.5 billion income to Minnesota in 1969 from agribusiness.

HOW DO WE ADJUST?

We do have to research with greater diligence the interactions with environment, with rural development, with the human aspects and work toward a higher quality of life for all citizens. I believe this has been the mission of the Minnesota Agricultural Experiment Station since it was started in 1885. Reading through some of the old documents about the program of the Minnesota Agricultural Experiment Station indicates the impact that this program has had on the total development of the State of Minnesota. But we do need to be concerned with these interactions and perhaps a few examples will help to illustrate.

In the area of technical developments and their impact on income and need for services, we see some very serious discrepancy. The major push for irrigation agriculture in the Bonanza Valley through the enthusiasm of local individuals and the various agricultural services has made irriation a fact. This has been a low income agriculture area for many decades. This fall, with a very large corn crop, there were no commercial drying facilities in all of the area known as the Bonanza Valley. What are the implications of this type of technological development in terms of expenditures, in terms of services that need to be provided and eventual income or return to investment? We believe this is an area in which the Experiment Station and the Extension Service working cooperatively can provide solutions useful to other areas wishing to adopt the total technology if production technology is to have full impact.

We are stepping up research on the effect of pesticides in the environment. Greater consideration is being given to the secondary and even tertiary effects. We must design our research programs to not only look at the specific problem but anticipate the possible problems down the road. Un-

fortunately, we hear too little about the past benefits of DDT, but we do hear about the bad effects. However, on close scrutiny of data from the World Health Organization, we see that where the use of DDT has been minimized or completely eliminated, the incidence of malaria is again on the increase. But we should have anticipated the side effects of DDT. Perhaps present experiences will guide us in new approaches to pesticide research.

We need to do more research on the social cost of research. Essentially what is the impact of increased use of fertilizers, the conglomeration of large purchasing and marketing organizations, the opportunities for bargaining, and the varied numbers of activities that are of major concern to agriculturalists today.

The Minnesota Agricultural Experiment Station has just completed a year of self-study, known as Research 1980. Essentially this is a blue print for direction of the research program in the decades ahead. We are encouraged by the response of our staff, who essentially carried out the task force studies and have reported to us. We see a keen desire to move into some of the areas that we have already discussed.

We are asking the 1971 Legislature to increase the funding of the Experiment Station program in the amount of $2 million. About two-thirds will be used to strengthen existing programs. The remaining one-third on new programs in the areas represented above. Of the total increase requested, $1.3 million is in the broad production research areas; another $320,000 is in the area of environmental quality. All of these have implications for your activity and we encourage your support.

In summary, I believe that the production research programs of the Minnesota Agricultural Experiment Station will remain strong. It will remain strong by support primarily from the State of Minnesota, but hopefully increasing dollar support from private industry. We can best attack our problems in the State of Minnesota. Therefore we should put primary emphasis on home resources. By having flexibility in our program we will be able to provide leadership and solution to problems that we are facing now and anticipate in the decades ahead.

THE SULFUR PICTURE IN MINNESOTA

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The University of Minnesota Soil Testing Laboratory initiated a soil test for sulfur in 1968. Since then over 3000 sulfur tests have been made.

TESTING PROCEDURE

The laboratory uses a calcium-phosphate solution containing 500 parts per million of phosphorus as the extracting solution. It extracts two main forms of sulfur: soluble sulfate and adsorbed sulfate. The calcium-phosphate solution appears to be ideal for this purpose, because the mono-phosphate ion ($H_2PO_4^-$) displaces the adsorbed sulfate ($SO_4^=$), and the calcium depresses the extraction of soil organic matter, thus eliminating contamination from extractable organic S (2). Sulfur extracted from a soil is then determined by the turbidimetric method. In this method, sulfate is precipitated by adding barium chloride to the filtered solution. Barium and sulfate form crystals which remain suspended in the solution, thus making the solution turbid or "muddy". The amount of sulfate extracted from a soil is determined with a spectrophotometer by measuring the light intensity that passes through the solution containing the suspended particles of barium sulfate.

Generally, the turbidimetric method is rapid and sensitive but it has some shortcomings. It is essential that the same uniform conditions be used each time in order to obtain reproducible results. Quantity and size of barium chloride crystals, time and speed of stirring, and temperature are factors that influence the turbidimetric measurement of sulfates.

TEST RESULTS AND RECOMMENDATIONS

The sulfur test results are printed on the Computerized Soil Test Report. A Soils Fact Sheet, "Sulfur for Minnesota Soils" (4), contains the interpretation of results and recommendations, and is attached to this report.

Based on research work conducted at the Department of Soil Science, the state is divided into two areas according to sulfur needs. The majority of soils in north-central and east-central Minnesota have low sulfur-supplying capacities. Deficiencies occur mainly on sandy, low organic matter soils that were originally covered by forests. Most soils in this area contain less than 500 pounds of total S per acre plow depth. Soils of western and southern Minnesota have relatively high sulfur-supplying capacities. They may contain from 600 to 1400 pounds of total sulfur per acre.

Sulfur test results are reported as parts per million (ppm) of sulfur in the soil. A test reading below 7 ppm in the sulfur deficient area is considered low and yield responses to sulfur applications are highly possible. In this area sulfur is recommended for alfalfa and clovers as well as for corn and small grain. On soils, with test readings of 7 to 12 ppm S, it is suggested that sulfur be applied to alfalfa and clovers on a trial basis only. No S is recommended for corn and small grain at these test levels. On soils showing more than 12 ppm extractable S, sulfur is not recommended for either crop.

Outside of the sulfur deficient area, sulfur is recommeded for alfalfa and clovers on trial basis only, when the test shows less than 7 ppm S. Sulfur is not recommended for corn or small grain in this area even at soil test readings of less than 7 ppm.

SULFUR SOIL TEST SUMMARIES

The sulfur test results of samples processed during the last three years have been summarized. The percentage distribution of test results is given in tables 1 and 2.

Table 1. Percentage distribution of sulfur soil test results by area.

Area*	Number of samples	Extractable sulfur, ppm		
		0-6	7-12	12+
		percent of samples		
All samples	3072	48	35	17
Area 1**	1169	51	39	10
Area 2	115	35	49	16
Area 3	581	37	43	20
Area 4	338	35	32	33
Out of state and research samples	869	58	23	19

*Area	Location and soil description
1	North-Central and East-Central forest soils, North-Central forest soils from glacial outwash and organic soils.
2	Southeastern silty forest and prairie soils.
3	South-Central prairie soils, Southeastern and Central prairie and prairie border soils, Southwestern silty prairie soils.
4	Soils of the northwestern glacial plains, Western prairie and prairie border soils.

(See H. F. Arneman, 1963. Soils of Minnesota. Ext. Bull 278, Univ. of Minn. for further information on soil characteristics.)

** Corresponds to the shaded area on map shown in Soils Fact Sheet No. 5.

Table 2. Percentage distribution of sulfur soil test results by area, soil texture and organic matter content.

Extractable Sulfur, ppm.	Sandy loam and sand		Loam, silt loam, clay loam and organic soils	
	Organic matter low	Organic matter medium, high and very high	Organic matter low	Organic matter medium high and very high
		percent of samples		
		AREA 1		
0-6	24	18	7	2
7 and above	16	12	14	7
		AREA 2, 3, 4		
0-6	3	15	2	16
7 and above	1	11	4	48

Approximately 50 percent of the samples from the North-Central and East-Central forest soil area (area 1, table 1) had S test readings of less than 7 ppm. This indicates a need for sulfur applications to alfalfa, clovers as well as corn and small grain. Only 10 percent of samples from this area had more than 12 ppm S. At this level no sulfur is recommended. A greater proportion of those samples received from areas 2, 3 and 4 showed sulfur readings of 7 to 12 and above 12 ppm. Farmers who submitted these samples were advised not to use sulfur. The summaries show, however, that roughly one-third of samples received from the three southern and western areas had extractable S readings of less than 7 ppm. This level is considered to be low. It is recommended, in this instance, that sulfur for alfalfa and clovers be used only on a trial basis. No S is recommended for corn and small grain. What is the reason for this?

SULFUR FORMS NOT MEASURED BY THE SOIL TEST

Rehm and Caldwell (5) concluded that calcium-phosphate extractable S is a satisfactory estimate of the so-called available plant sulfur and that the test should be particularly well suited for soils that are relatively low in sulfur or are located in an area where the contribution of "fallout" S is small. The soluble and adsorbed sulfates, measured by soil test, however, represent only 2 to 4 percent of the total sulfur found in Minnesota soils (5). Other forms of sulfur include: organic sulfur, insoluble sulfate, and reduced inorganic sulfur compounds.

The bulk of sulfur in soils is organic. Evans and Rost (3) found that the percentage of total sulfur as organic sulfur ranged from about 50 percent in the soils of northcentral and northeastern Minnesota to 75 percent in the southern and western parts of the state. Organic forms of S predominantly present in soil cannot be directly taken up by plants but must be converted first to inorganic sulfate ($SO_4^=$). This conversion takes place when organic matter is decomposed by microorganisms. Annually about 2 percent of the organic S is converted to available plant sulfate.

Another inportant source of soil S is that brought down in rain and snow (sulfur fallout). Large industrial areas create an adequate S supply for soils in the immediate vicinity. At St. Paul, the annual fallout contribution is about 15 pounds of S per acre (4). At Lamberton, rain and snow add about 8 pounds of S per acre to the soil while at Park Rapids only 4 pounds per acre are added. Small additions of sulfur to the sulfate pool can come from the weathering of S containing minerals, and S containing fertilizers. The sulfate pool is depleted by withdrawals through plant uptake and leaching.

Based on this information it appears that the organic and the "fallout" sulfur are the two main contributors to the sulfate pool, and neither form is measured by the sulfur test. Table 3 shows the estimated amounts of sulfur released from organic matter and the fallout contribution of S for four different soils. The Milaca loam and the Dorset sandy loam soils are from northcentral Minnesota where sulfur deficiency is most likely to occur. The S released from organic matter of these two soils was estimated to be about 3 to 4 pounds per acre per year. The fallout may contribute an additional 4 to 5 pounds of sulfur per acre annually. Generally, about 8 pounds of sulfur may be added to the soils of area 1 by these two sources. This is in addition to the sulfate measured by soil test.

Table 3. Estimated amounts of sulfur from organic matter and fallout sulfur for different soils in Minnesota.

Soil type	Organic matter %	Estimated total N Lbs/Acre	Estimated organic S* Lbs/Acre	Estimated S release Lbs/Acre	Fallout S Lbs/Acre
Milaca loam	2.2	2200	122	3	5
Dorset sandy loam	3.4	3400	189	4	4
Nicollet clay loam	5.0	5000	556	11	8
Barnes silt loam	5.5	5500	611	12	8

* Calculated by using the following nitrogen to sulfur (N:S) ratios in organic matter of Minnesota soils as reported by Evans and Rost (2):
18:1 for the two first soils from northern Minnesota, and
9:1 for the two southern and western Minnesota soils.

Alfalfa contains about twice the amount of S found in corn and small grain (table 4). Cabbage has even higher requirements for S than legumes. It is apparent now that many soils in area 1 cannot supply sufficient amounts of S to alfalfa or clovers, and even corn and small grain may often benefit from S applications.

Table 4. Sulfur contained in various crops.

Crop	Yield	Sulfur, Lbs.
Cabbage	15 tons	19-38
Alfalfa	5 tons	20-24
Corn	150 bushels	12-15
Wheat	50 bushels	11-15

Source: Beaton, J. D., 1966. Soil Sci. 101:267-282 (1).

The Nicollet clay loam is a typical prairie soil in southcentral Minnesota, while the Barnes silt loam represents the soils of the western part of state. Both soils have about 5 to 5.5 percent organic matter. The estimated S release from organic sulfur is 11 to 12 pounds per acre. With the fallout contributing about 8 pounds of sulfur per acre annually, about 20 pounds per acre of sulfur may become available to crops. This amount, in addition to the S forms measured by soil test, should be sufficient for production of high yields of corn or wheat. Since the estimated annual sulfur contribution of 20 pounds per acre from organic and fallout forms is equal or slightly below the S requirement of the legumes, farmers are advised to apply sulfur on trial basis to soils with low test levels. Sulfur applications to corn or small grain are not recommended on these and simmilar soils in areas 2, 3 and 4 because much of the crop requirement can be satisfied by the S that becomes available upon organic matter decomposition and by sulfur from precipitation.

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RESPONSE OF ALFALFA AND CORN TO SULFUR

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Sulfur was demonstrated to be an essential plant nutrient many years ago. In fact, response to gypsum was observed in the United States as early as 1800. However, significant areas of sulfur deficiency have been noted in the North Central States only during the past couple of decades. The recent increase in the observation of sulfur deficiency is due to a combination of the following factors: (1) increased use of sulfur-free fertilizer, (2) increased crop yields, (3) decreased use of manure, (4) decreased use of sulfur-containing pesticides, and (5) decreased atmospheric sulfur.

ALFALFA RESPONSE

Research work in Northwestern Wisconsin.

Sulfur deficiency was first observed in Wisconsin in survey trials in the northwestern part of the state in 1968. In 1969 a comprehensive research study was initiated on nine established alfalfa fields to more precisely define the deficient soils and to evaluate various carriers of sulfur. The criteria used for selecting these sites in Buffalo and Dunn counties were as follows: (1) well drained soils relatively low in organic matter, (2) concentration of less than 0.2% sulfur in the alfalfa tissue in 1968, (3) lack of response to topdressed potassium and boron, and (4) yellow, thin-stemmed alfalfa plants. In addition, the sites were located in areas where the contribution of sulfur from the atmosphere was felt to be a minimum, and in fields which had not been manured recently.

Potassium sulfate and prilled elemental sulfur (88% S) were applied at rates of 25, 50 and 100 lbs/A of sulfur as a topdress treatment in the fall of 1968. Four replicates of each treatment were established. No sulfur was applied in 1969 or 1970. All plots annually received a total of 210 lbs/A of potassium (K).

Yields. Two cuttings were made in 1969 and three harvests were made in 1970. The yield results are presented in Table 1. In both years dry weather limited the yield at some of the sites. Significant yield response from one or more treatments was noted at six of the nine sites in 1969 and in 1970. During the first year, response was noted only to potassium sulfate, except for the 100 lb/A rate of elemental sulfur at site no. 4. Evidently the elemental sulfur was not microbially oxidized to sulfate-sulfur fast enough to take care of the needs of the crop. However, by 1970 the elemental sulfur treatments were equal to potassium sulfate. Hence, it appears that about a year is required for topdressed prilled elemental sulfur to become effective. Also, we can conclude from this study that 25 lbs/A of sulfur as potassium sulfate is sufficient on an annual basis, but that the carry-over from this treatment possibly will not be satisfactory the second year. Higher rates of sulfate-sulfur--50 and 100 lbs/A as compared to 25 lbs/A--resulted in more yield increase in 1970 than in 1969. The detailed yield results (Table 2) from one of the experimental sites (site no. 6) in northern Dunn County, shows that elemental sulfur was ineffective the first year, but the high rates of elemental sulfur were somewhat more effective than the lower rates of potassium sulfate the second year. Another interesting observation is that the magnitude of response to sulfur was always greater in the second or third cutting, presumably because the first crop benefited from some accumulation of atmospheric sulfur or mineralized organic sulfur in the soil during the late fall, winter and early spring.

Table 1. Yield of alfalfa as affected by rate and carrier of sulfur at nine locations in northwestern Wisconsin.

Site No.	Year	No S Applied	K_2SO_4, lbs/A of S 25	K_2SO_4, lbs/A of S 50	K_2SO_4, lbs/A of S 100	elemental S, lbs/A of S 25	elemental S, lbs/A of S 50	elemental S, lbs/A of S 100
			Yield, tons/A at 15% moisture					
1	1969	4.15	4.10	4.14	4.50	4.24	4.17	4.38
	1970	2.98	2.80	2.67	2.88	3.46*	3.73*	3.56*
2	1969	3.98	4.06	3.81	4.28	3.93	4.15	4.16
	1970	3.06	2.76	3.85*	3.04	2.85	2.96	2.65
3	1969	4.51	4.48	4.85	4.86	4.52	4.48	4.47
	1970	4.49	4.44	4.68	4.69	4.72	4.98*	4.70
4	1969	2.42	2.96*	3.11*	3.00*	2.50	2.79	2.91*
	1970	2.21	2.47	2.60*	2.61*	2.35	2.44	2.63*
5	1969 a/	2.65	2.82	2.95	3.13*	2.43	2.66	2.70
	1970	4.45	4.04	4.21	4.44	4.02	4.35	4.40
6	1969	2.34	3.17*	3.23*	3.15*	2.31	2.26	2.89
	1970	2.45	3.83*	3.35*	5.06*	3.49*	4.30*	4.54*
7	1969	2.68	3.59*	4.05*	3.52*	2.84	3.03	2.92
	1970	1.55	1.98*	1.99*	2.07*	1.76	1.83*	1.82*
8	1969	3.52	3.57	3.84	3.66	3.14	3.45	3.02
	1970	3.29	3.22	3.51	3.36	3.34	3.50	3.30
9	1969	2.61	2.80	2.77	2.96*	2.52	2.50	2.86
	1970	3.96	4.05	4.20	4.21	3.88	4.28	4.25
Average	1969	3.16	3.51	3.63	3.68	3.16	3.28	3.37
	1970	3.21	3.28	3.45	3.60	3.32	3.60	3.54

* Significant response (10% level) to sulfur over the check treatment.

a/ Sulfur was applied to the entire plot area in the fall of 1969.

Table 2. Effect of sulfur carrier and rate of application on the yield of alfalfa grown on a Norden loam (site no. 6, Ridgeland, Wis.)

Treatment	1969			1970			
	1st crop	2nd crop	Total	1st crop	2nd crop	3rd crop	Total
	Yield T/A at 15% moisture						
Check	1.36	.98	2.34	1.19	.89	.37	2.45
Potassium sulfate							
25 lbs/A of S	1.76	1.41	3.17	1.69	1.39	.76	3.83
50 lbs/A of S	1.85	1.38	3.23	1.53	1.26	.56	3.35
100 lbs/A of S	1.67	1.48	3.15	1.82	1.85	1.36	5.06
Elemental sulfur							
25 lbs/A of S	1.36	1.00	2.36	1.55	1.27	.67	3.49
50 lbs/A of S	1.20	1.06	2.26	1.70	1.66	.94	4.30
100 lbs/A of S	1.57	1.32	2.89	1.72	1.68	1.13	4.54

Sulfur and crude protein content. The sulfur and crude protein content was determined for each cutting at each site. The results of these analyses for Site No. 6 in 1969 are presented in Table 3. These results and those from other sites which are not reported in this paper indicate the critical level of sulfur in alfalfa tissue is about 0.20%. In other words, response to sulfur fertilizer generally can be expected if the level of sulfur in plant tissue is below 0.20%.

Table 3. Effect of sulfur carrier and rate of application on the sulfur and crude protein content of alfalfa grown on a Norden loam in 1969 (Site No. 6, Ridgeland, Wis.)

Treatment	% S		% crude protein	
	1st crop	2nd crop	1st crop	2nd crop
Check	.13	.16	12.6	15.4
Potassium sulfate				
25 lbs/A of S	.20	.20	15.2	16.1
50 lbs/A of S	.22	.27	14.8	16.9
100 lbs/A of S	.21	.33	14.4	17.1
Elemental sulfur				
25 lbs/A of S	.12	.16	12.4	15.6
50 lbs/A of S	.13	.16	13.6	15.9
100 lbs/A of S	.14	.14	12.9	15.1

Sulfur is a constituent of amino acids--the building blocks of protein--and, therefore, has an effect on the protein content of the plant. As shown in Table 3, application of potassium sulfate on sulfur-deficient alfalfa resulted in a 1.5 - 2.5% increase in protein in the alfalfa. Therefore, use of sulfur can improve the quality of alfalfa as well as increase the yield.

In 1970 strip trials were established throughout Wisconsin to survey the need for sulfur. The average results of three replicates at each site are presented in Table 4. Potassium sulfate was applied at a rate of 300 lbs/A on the +Sulfur strips and potassium chloride was applied at a rate of 210 lbs/A on the -Sulfur strips.

Table 4. Effect of S application on the yield of alfalfa at 47 locations in Wisconsin in 1970.

Site No.	County	Soil Type	No. of cuttings	Yield -S 1/	Yield +S 2/
				Tons/A at 15% moisture	
		LIGHT TEXTURED SOILS			
1	Iowa	Hixton sl	3	4.26	4.06
2	Marinette	Omega s	3	2.32	3.12*
3	Marinette	Omega s	2	1.76	1.70
4	Dane	Miami sl	2	2.88	2.84
5	Waukesha	Fox sl	2	3.53	3.26
6	Winnebago	Kewaunee fsl	2	2.90	3.12*
7	Winnebago	Austin ls	2	3.09	2.97
8	Langlade	Kennon sl	2	2.17	2.19
9	Juneau	Plainfield s	2	2.32	2.15
10	Juneau	Plainfield s	1	1.86	1.92
11	Juneau	Plainfield s	1	2.00	1.99
12	Green	Plainfield s	3	2.08	1.89
13	Grant	Sparta sl	3	2.42	2.96*
14	Grant	Sparta sl	2	1.16	1.09
15	LaCrosse	Dakota sl	1	2.17	2.46*
16	LaCrosse	Plainfield s	1	2.40	2.28
17	Iron	Vilas ls	2	1.69	1.69
18	Washburn	Pence sl	2	2.59	2.91*
19	Washburn	Omega sl	2	.85	1.51*
20	Burnette	Omega sl	2	1.64	3.03*
21	Waushara	Plainfield s	2	1.44	1.57
22	Waushara	Plainfield s	2	1.89	2.14*
		MEDIUM TO HEAVY TEXTURED SOILS			
23	Marinette	Onaway sil	2	1.99	2.01
24	Door	Onaway sil	3	5.44	5.30
25	Door	Longrie sil	2	1.26	2.24*
26	Door	Longrie sil	1	1.94	2.05
27	Door	Longrie sil	2	2.22	2.28
28	Dane	Fayette sil	2	1.93	1.83
29	Waukesha	Hochheim l	2	3.29	3.20
30	Waukesha	Fox si	2	3.32	3.20
31	Winnebago	Kewaunee sicl	2	2.56	2.35
32	Langlade	Kennon sil	2	3.04	2.74
33	Langlade	Kennon sil	2	2.23	2.14
34	Langlade	Spencer sil	2	2.87	2.95
35	Green	Dubuque sil	2	2.48	2.49
36	Green	Dubuque sil	1	1.48	1.73*
37	Grant	Tama sil	3	3.65	3.99
38	Grant	Dubuque sil	3	3.20	3.02
39	Buffalo	Fayette sil	2	4.03	3.84
40	Buffalo	Fayette sil	3	5.14	4.87
41	Ashland	Gogebic l	2	2.74	2.46
42	Washburn	Santiago sil	2	2.78	2.52
43	Burnette	Santiago l	2	2.73	3.14*
44	Burnette	Santiago sil	2	1.79	1.86
45	Wood	Withee sil	2	2.89	3.18
46	Wood	Withee sil	1	1.26	1.15
47	Wood	Withee sil	2	3.62	3.68

1/ Treated with 210 lbs/A of potassium chloride
2/ Treated with 300 lbs/A of potassium sulfate (54 lbs/A of sulfur)
* Significant response to sulfur

Based on observation of deficiency symptoms and yield data (Table 4) it appears sulfur response occurred at 11 of the 47 locations. Eight of the 11 responsive soils were light textured, and 1 of the 3 responsive medium textured soils was very shallow (site No. 25, Table 4). On the basis of this survey it appears that sulfur deficiency can occur throughout the state, but deficiencies appear to be primarily limited to non-manured sandy or shallow soils.

Conclusions

1. Sulfur deficiency appears to be widespread in westcentral and northwestern Wisconsin, and it has been observed in localized areas in other parts of the state. Most deficient soils are sandy or shallow, low in organic matter, and have not been manured in recent years.

2. Twenty-five lbs/A of sulfur as potassium sulfate is sufficient to correct sulfur deficiency of alfalfa in the year of application.

3. Elemental sulfur does not correct sulfur deficiency on alfalfa the year of application, but it is equal to potassium sulfate the second year after sulfur application.

4. Alfalfa containing less than 0.20% sulfur likely will respond to sulfur fertilization.

5. Use of sulfur on sulfur-deficient alfalfa results in a significant increase in protein content of the alfalfa.

CORN RESPONSE

A sulfur trial on corn was established on an irrigated Plainfield loamy sand in Dunn County in 1969. Sulfur deficiency was expected at this site because tissue analysis in 1968 revealed that the corn leaves contained less than 0.12% S.

Prilled elemental sulfur (88% S), potassium sulfate, and ammonium sulfate were applied at rates of 25, 50 and 100 lbs/A of sulfur just prior to planting in 1969. Four replicates of each treatment were established. No additional sulfur was added in 1970. All plots received 210 lbs/A of potassium in 1969 and 150 lbs/A of N in 1969 and 1970.

The results from this trial presented in Table 5 show that corn responded to sulfate-sulfur in 1969. As with alfalfa, response was not obtained from elemental sulfur the year of application. The difference in effectiveness is due to the fact that sulfate sulfur is immediately available, while elemental sulfur must be microbially converted to the sulfate form. In 1970 all three carriers of sulfur tended to increase corn yields. However, optimum yields were obtained only when 50 or 100 lbs/A of sulfur were applied.

In 1969 leaf analysis showed an increase from 0.15% sulfur in the check to about 0.20% sulfur in the corn treated with sulfate-sulfur. However, the percent nitrogen in corn was not significantly influenced by the application of sulfur.

Conclusions

1. Application of 25 lbs/A of sulfur as potassium sulfate or ammonium sulfate will correct sulfur deficiency the year of application, but more than 25 lbs/A appears to be needed for optimum yields the second year after application.

2. Elemental sulfur does not correct sulfur deficiency the year of application, but it is equal to sulfate-sulfur the second year after application.

3. Corn containing less than 0.15% sulfur in the ear leaf likely will respond to sulfur fertilization.

SULFUR SOIL TEST

Research is presently underway to correlate and calibrate various procedures for determining available sulfur with demonstrated crop response. This research will be completed by the fall of 1971. In the meantime a tentative test for available sulfur is being used by the University Extension Soil Testing Laboratory. This test, based on some preliminary greenhouse work, requires the analysis of the soil for organic matter and sulfate-sulfur (extracted with 0.025 N $CaCl_2$). A sulfur availability index is calculated as follows:

Sulfur availability index = 0.1 (organic matter in tons/A) + 0.2 (sulfate sulfur in lbs/A)

At present the sulfur availability index is calibrated as follows:

Sulfur availability index	Interpretation
less than 6.0	low
6.0 - 9.0	adequate
above 9.0	high

It should be pointed out, however, that this is only a tentative procedure and interpretation. It is very likely that changes will be made in the near future based on the research work currently being conducted.

Table 5. Effect of S carriers and rate of S on the yield, % S, and % N of corn.

	Ear leaf analysis - 1969		Yield bu/A @ 15% moisture	
Treatment	% S	% N	1969	1970
Check	.15	2.10	133	116
Elemental sulfur				
25 lbs/A of S	.17	2.02	135	117
50 lbs/A of S	.14	2.07	134	131
100 lbs/A of S	.15	2.00	139	127
Potassium sulfate				
25 lbs/A of S	.18	2.11	143	118
50 lbs/A of S	.20	2.19	144	128
100 lbs/A of S	.20	2.15	142	128
Ammonium sulfate				
25 lbs/A of S	.19	2.16	142	121
50 lbs/A of S	.18	2.16	142	127
100 lbs/A of S	.20	2.20	147	129
$Lsd_{.10}$	.04	.22	13	27

SUMMARY

Lack of sulfur appears to be a problem on many light-colored sandy soils in Wisconsin, especially for alfalfa which has a high sulfur requirement. With increased crop yields, reduced application of manure, decreased atmospheric sulfur, and continued use of sulfur-free fertilizer, we can expect even more sulfur deficiency in the future. Therefore, farmers should periodically test their soil and analyze the crops they grow to determine whether lack of sulfur is limiting their crop yields. And if sulfur is found to be deficient, the recommendations of the College of Agriculture and the Extension Service should be followed to correct the problem.

SOIL pH

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A discussion on soil pH brings to mind entirely different problems in different areas of the state. To discuss pH as it pertains to soil acidity and liming, would tune out our audience from western Minnesota, and problems of high pH or excess lime wouldn't concern many of those who come from eastern Minnesota. But to discuss pH across the scale from its highest to lowest values involves everybody.

Those who have had chemistry and remember any of it know that defining chemical terms to lay people is not easy. But since most people have had logarithms in high school, defining pH really isn't as difficult as it first sounds.

MEASURING SOIL pH

Nearly everyone knows the chemical formula for water -- H_2O. H is the symbol for hydrogen, the main culprit in causing soils to be acid. The hydrogen ion (H^+) is an altered form of hydrogen. Since it is positive, it is called a cation. Elements carrying negative charges are called anions. Only minute quantities of the water particles (H_2O) actually separate to form such ions. For the pH of water, it is this very small amount of H_2O that has separated into H^+ and OH^- that we are interested in. Only .0000001 expressed as mols per liter is in the ionic form. With other solutions, the separation is much greater. Concentrated hydrochloric acid, for example, is so highly ionized that it has a pH at zero or slightly below.

If we tried to express the small amounts of the water molecules (H_2O) that actually break up into H and OH ions, their concentration in actual numbers would result in awkward figures for the H ion measurement.

In order to avoid these cumbersome numbers, we use the idea of pH. This scale is based on logarithms. A few simple examples of hydrogen ion concentrations may be helpful.

.0000001 or $\frac{1}{10,000,000}$ is a neutral soil with pH 7

.000001 or $\frac{1}{1,000,000}$ has a pH of 6

.00001 or $\frac{1}{100,000}$ has a pH of 5

Note that the hydrogen ion concentration at pH 6 is 10 times more than at pH 7, and that pH 5 is 100 times larger than pH 7. (Remember when working with fractions that if the number below the line is smaller, the fraction is larger.) At pH 4, the hydrogen ion concentration is 1,000 times greater than at pH 7.

You can see that as the pH lowers the hydrogen ion concentration increases much more rapidly than the simple pH numbers appear to indicate. Actually, as the pH drops 0.3, the acidity of a soil is doubled. Therefore, a soil with pH 5.7 is twice as acid as a soil with pH 6. It is obvious then why we must understand that pH is measured by the use of logarithms, since a drop of .3 in simple arithmetic doesn't look like very much.

WHY SOILS BECOME ACID

Through the centuries, water from rains moves downward through a soil and the free H ions gradually replace calcium and magnesium ions carried away in drainage waters. The more water moving through the soil profile, the faster the soil becomes acid. That is why soils in areas of high rainfall are more acid than soils in drier regions. Also, sandy soils hold fewer calcium and magnesium ions because their low clay and organic matter content offers ions fewer places to hang on. Therefore, sandy soils become acid more rapidly than do fine-textured soils. Crops, particularly legumes, remove large amounts of calcium and tend to hasten the lime depletion. High nitrogen rates because of the H ions introduced, also reduces pH.

THE EFFECT OF pH ON THE CROP

Excess or insufficient supplies of lime can have an adverse effect on a crop. These effects, however, are indirect.

D. I. Arnon and his associates in California, conducted a classic experiment to demonstrate that the harmful effect of pH was not direct. They grew plants in water solutions containing a liberal (but not excess) supply of all the important plant nutrients. The solutions were prepared at a wide range of pH values. The plants all grew well in the pH range from 4 to 9. This was in a solution not affected by the complexities of soil. In a soil, it is therefore, the indirect effect of nutrient tie-up, adverse relationship with soil organisms, and other factors that makes the need for measurements of pH so important.

Most micronutrients become less soluble as lime increases the pH of an acid soil. In acid soils, some of these elements are so soluble that they can be toxic to plants. When a soil is neutral, no toxicities occur and essential elements are soluble enough to be absorbed by plants. As the pH is increased further, the solubility of these elements becomes so low that deficiencies can occur.

PROBLEMS OF TOO HIGH A pH

High lime means large quantities of calcium and magnesium. These react with phosphate compounds to make these less soluble.

Monocalcium phosphate is a form of phosphate that is water soluble and its phosphate is available to plants. But excess calcium or magnesium makes less monocalcium and more dicalcium and tricalcium phosphates, which makes P absorption from this source nearly impossible. Thus areas of excess lime and very high pH may have soils with considerable amounts of phosphorus in total present, but plants usually need the addition of available phosphorus fertilizers.

Some soils have such a high pH (at least 8.3 and higher) that their problem is that of excess sodium and soluble salts. These are the alkali soils. Few problems of this nature are encountered in Minnesota. Some high lime rims are frequently called alkali, but should be referred to as "alkali like", since they are seldom true alkali. These areas present the same low phosphorus and low micronutrient problems described earlier and also have low potassium uptake. It is known that plants take up nutrients in about equal proportion to their occurrence in the soil. These rims have such an excess of calcium and magnesium that they simply outnumber potassium in gaining entrance to the plant. Therefore, even with relatively high K soil tests (perhaps up to 300 lbs/acre K) a potassium response is often observed on corn. Unfortunately, pH measurements are about all there is to depend upon to predict potassium needs on these trouble spots. Measuring cation exchange isn't the reliable answer either, since it is the excess calcium and magnesium carbonates (beyond what is exchangeable) that causes the trouble. Iowa experiments show that excess of 15 percent calcium and magnesium carbonates is where we would expect to encounter the K problems. These percentages aren't measured in routine soil tests. The usual recommendation for corn is 120 pounds per acre of K_2O where these problems are suspected to be a potassium deficiency, through observation, or otherwise simply by use of pH and K tests. There is no similar potash recommendation presently made for small grains or other crops.

In brief then, nutrients likely to become deficient with very high pH are:

- Phosphorus - because of high percentages of di and tri calcium phosphates
- Potassium - because calcium and magnesium compete too favorably for entrance to the plant
- Boron - because of unfavorable calcium to boron ratio in plants
- Iron - problems of imbalance within the plant and problems of absorption unless chelated
- Manganese - prefers pH from about 6.2 to 6.4
- Zinc - uptake is a function of pH, but deficiency can occur on acid soils
- Copper - deficiency has been related to high pH, but some researchers disagree

SUBSOILS WITH HIGH pH

The pH of the plow layer doesn't always accurately predict lime needs. There are many areas, especially in south central and southwest Minnesota, where soils have acid surfaces, but a high pH in the subsoil. Lime loving crops such as alfalfa and sweetclover, seldom respond to lime applications on these soils.

At the Lamberton Experiment Station, surface pH indicated a need for lime, but even though high lime rates did bring the pH to 6.7, no significant yield increases of alfalfa, corn or soybeans were noted.

The following data from Lamberton by Grava, Nelson, Fairchild and McCaslin, show original pH values of the soil profile to 30 inches:

Depth	Site 1	Site 2
0-6"	5.3	6.0
12-18"	6.0	7.6
24-30"	7.4	8.2

The surface pH (0-6") as affected by a 3 and 6 ton lime treatment in 1965 and an additional 4 and 10 ton treatment in 1968, were as follows:

Lime T/A			
1965	1968	1967	1969
0	0	5.7	5.7
3	0	5.8	-
3	4	-	6.1
6	0	6.1	-
6	10	-	6.7

In extreme southwestern Minnesota, the Moody-Kranzburg-Vienna soil association has an acid surface. Depth to lime varies. If the pH is not 6.5 or above within 3 1/2 to 4 feet, lime for alfalfa may be beneficial. If lime is found within 2 or 3 feet, however, responses are rare. The decision about lime needs must be based on past success in alfalfa or sweetclover stand establishment. If stands have been difficult to maintain, even with high P and K soil test levels, then liming may be beneficial. For greater details on liming, obtain Extension Folder 210, "Liming Minnesota Soils" by Grava, Overdahl and Fenster.

PROBLEMS OF TOO LOW A pH

Since plants in a water solution can grow well in a pH range of 4 to 9, what are the indirect factors of low pH that hurt plant growth?

Perhaps the most important factor is the effect of low pH on the livelihood of soil organisms. These organisms are about as unadapted to acid conditions as a "fish out of water". The following data show a relationship of bacteria population and the soil pH:

Soil pH	Bacteria Count in millions
4.4	1.5
5.2	7.8
6.4	12.3
7.0	14.9

Soil organisms require a pH in a reasonable range of 6.5 to 7.0 in order to do their most effective work in rotting residues or manufacturing nitrogen in the root nodules of legumes. If, for example, acid conditions prevent proper nodule development, then inadequate nitrogen is available, legume production is reduced and stands eventually become thin.

Under low pH conditions, iron, aluminum and manganese dissolve in amounts large enough to be toxic to plants. When these elements are soluble, they are ready to react with other elements. Soil and fertilizer phosphorus may react with the dissolved iron and aluminum to produce phosphorus compounds that are unavailable. When the pH is raised by liming from very acid to a neutral condition, phosphorus fertilizer needed at the low pH can be reduced.

Molybdenum is one of the micronutrients that has low availability under acid conditions.

HOW DOES LIME INCREASE pH?

Minnesota limestones are of the dolomitic type, that is, they are composed of a mixture of calcium and magnesium carbonates ($CaCO_3$ and $MgCO_3$). Applied to the soil, they dissolve slowly in the soil water where they separate into calcium (Ca^{++}) and magnesium (Mg^{++}) cations and carbonate ($CO_3^{=}$) anions. The calcium and magnesium ions replace the hydrogen ions, which are on the clay and humus particles. The hydrogen ions can join up with the carbonate ions from the lime to form carbonic acid (H_2CO_3), which could leach out with downward water movement or break down into carbon dioxide gas (CO_2) and water (H_2O).

CAN WE REDUCE pH WHEN IT'S TOO HIGH?

Fenster and Gunderson, Minnesota Agricultural Extension Service, applied elemental sulfur to a high lime soil in Chippewa County to observe the drop in pH. Their data are as follows:

	Pounds of elemental S/acre applied spring 1969				
	0	30	500	1000	2000
pH (Oct. 1969)	7.9	7.6	7.2	7.1	7.0
pH (July 1970)	7.8	7.7	7.4	7.3	7.2
pH (Oct. 1970)	8.0	7.8	7.6	7.7	7.9

These data show that they could tentatively reduce surface pH with sulfur. The pH doesn't appear to remain lowered for very long and there is considerable cost involved.

WHY IS IT SOMETIMES SO HARD TO RAISE pH BY LIMING?

The quality of limestone is important. This is determined by purity and particle size. Usually purity isn't much of a problem in Minnesota, but there are sometimes questions of particle size.

Minnesota ASCS regulations specify that limestone shall be ground finely enough to enable not less than 80 percent by weight to pass through an 8-mesh sieve. Perhaps more attention should be paid to the quantity that will pass a 40 to 60-mesh sieve.

The time to react with the soil for various mesh sizes may cause one to wonder about the value of the coarser material.

Mesh Size	Time to React
finer than 100	2 months
60 to 100	6 "
40 to 60	2 years
20 to 40	25 years
8 to 20	infinite

The soil itself will affect the rate at which the pH rises when lime is added. Equal rates added to a sand and a clay loam will show a more rapid pH increase on the sand because it has less reserve acidity. Reserve acidity is the H^+ held tightly to clay and humus of which sands have very little.

The SMP buffer was introduced to get a measure of reserve acidity. In many cases, with the buffer test we have found greater need for lime than we had formerly been recommending on fine textured soils. Two and three ton lime rates on these soils showed no pH change two years later. The reserve acidity was preventing the rise. Fact Sheet No. 10 by Fenster, Overdahl and Grava, explains the buffer method in measuring pH.

We sometimes observe difficulty in getting early lime benefits on sands too. The reason here might be that the plow layer is often totally dry, preventing organisms from becoming active, even though lime has been supplied. The lack of water, too, can often reduce the speed of reaction. In the spring of 1968, 8 tons per acre of lime was added to a loamy sand at the Elk River Experiment Field. The pH readings comparing irrigated alfalfa versus non-irrigated were as follows:

Time	Lime Applied		
	none	8 tons irrigated	8 tons non-irrigated
1968 April	5.4	-	-
1969 Sept.	5.2	6.2	5.4
1970 Sept.	5.5	6.8	6.0

It can be seen that under the non-irrigated conditions with a drouthy soil, that the lack of water made for a very slow pH change relative to the effect on the irrigated area. Another reason for slow pH rise is depth of plowing.

Recommendations are based on the 6-inch depth. For deeper plowing, lime rates must be increased proportionately to have the effect on pH expected at 6-inch depth plowing.

HOW DO NITROGEN FERTILIZERS REDUCE pH?

On sandy soils in the southeastern United States where nitrogen has been used a long time, it has been observed for many years that the pH drops quickly. On the heavy soils in our area though, we have not been much alarmed until recently when nitrogen application rates increased.

The reason nitrogen fertilizers reduce pH is because of ammonia nitrogen fertilizers, or the ammonia released from organic nitrogen forms.

$$2\,NH_4^+ + 3O_2 \xrightarrow{\text{bacteria}} 2\,NO_2^- + 2\,H_2O + 4\,H^+ + E$$

ammonium	oxygen		nitrite	water	hydrogen	energy

There is an additional step where the nitrite NO_2^- is converted to nitrate (NO_3^-), but we can already see how hydrogen ions come out of this reaction. It can be shown that ammonium nitrate or urea would produce the same quantity of hydrogen. For every atom of nitrogen added, one molecule of nitric acid is formed.

Ammonium sulfate produces twice as many hydrogen ions as the others because of the sulfate it contains. Not only is one molecule of nitric acid formed, as with the others, but a molecule of sulfuric acid is also formed for each atom of N.

Dr. W. H. Pierre, Iowa State University, calculated both the theoretical amount of lime needed to correct acidity caused by nitrogen fertilizers and also the actual, as obtained in field trials. Theoretically, 3.57 pounds of pure limestone (calcium carbonate) would be needed to offset the acidity of 1 pound of nitrogen. This, of course, assumes no N used by the plant or lost otherwise. Actually, it would take more lime when using agricultural lime, rather than pure lime. He found through several long time field experiments, however, that 1.15 pounds of pure lime was needed to counter the acidity of 1 pound of nitrogen in ammonium nitrate. This was only 32 percent of the theoretical. For average Minnesota limestone, it is estimated that 2 pounds is needed to counter the acidity of 1 pound of N where soil acidity is a problem.

The reason for the less than theoretical is explained by Pierre. Ash in plants is alkaline. It contains such bases as calcium, magnesium and potassium. These neutralize acidity the same as lime does. Corn removes more nitrogen in the grain than it does bases. There are excess bases in the stalks which are left in the soil to provide the ash containing the bases that counter soil acidity. Corn harvested as silage, however, causes 50 percent more acidity than when corn residue is returned to the soil.

Some measurements in Minnesota experiments show the effect of nitrogen on soil pH. (Stalks returned to soil.)

Waseca after 13 years

lbs. of N annually	lbs. of N total	pH 0-6"
check	0	6.7
80	1040	6.6
160	2080	6.2
320	4160	5.6

Morris after 11 years

lbs. of N annually	lbs. of N total	pH 0-6"
check	0	7.3
40	440	7.3
80	880	7.2
240	2640	6.5

Rosemount after 12 years

lbs. of N annually	lbs. of N total	pH 0-6"
check	0	6.1
100	1200	5.6

ORGANIC SOILS

Nutrient availability in organic soils is not the same as in mineral soils. Copper, for example, can be deficient in acid organic soils, but is rare in acid mineral soils. Lime recommendations are quite different. The pH is brought only to pH 5.5 on organic soils.

SUMMARY

Soil pH relationships are complex. In liquid solutions, pH is straightforward. In soils, we have the complication of the solution phase (soil water) and the solid phase (both mineral and organic). No matter how complex the relationship, however, the first step in diagnosing soil and plant nutrient problems should be a look at the pH.

LEAF FEEDING OF PLANT NUTRIENTS : FACT OR FANCY?

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Four of the 16 elements now considered essential for normal plant growth are absorbed as gases through the leaves to some degree (carbon, oxygen, nitrogen, hydrogen). Some others such as sulfur may also be taken into plants in this manner. However, since soil via plant roots is known to supply most of the necessary elements for growing plants, soil fertilization has received our major attention and research effort, even though it has long been known to be a comparatively inefficient exchanger of the applied fertilizer materials. Soils are extremely complex and variable, and all too frequently they withhold needed elements and water when these are badly needed by growing plants. Foliar fertilization, if possible, practical, and effective, would mean the elimination of the comparatively inefficient practice of soil fertilization in the plant growth cycle. Usually less than 20% of soil applied phosphorus is taken up by plants grown over several years, and the uptake of potassium is much the same. Nitrogen uptake is more efficient, but this is less than half the amount applied. The uptake efficiency of other elements such as sulfur, iron and zinc is even more dismal, since by far the greater proportion of most elements either remains in, or is leached from the soil into streams, lakes, and oceans.

Nutrient absorption by the aerial portions of plants was noted as early as 1803, and the ferrous sulfate spraying of pineapple growing on the highly manganiferrous soils of Hawaii have long been a highly successful practice. Spraying to correct boron deficiency of rutabagas growing in Pine County of east central Minnesota was an established practice for many years. Foliar fertilization has been most successful where only minute amounts of an element were needed, such as with some elements of the micronutrient group. However, foliar fertilization of plants, with all of its obvious advantages, has not been an accepted practice for several reasons:

1. Difficulty in retaining the applied nutrient element or elements on the plant leaves for any length of time, since rains, dew, or wind movement usually remove sprays or dusts within a few hours at the most.

2. The inability to develop an effective and rapid absorption reaction for the elements by the aerial protions of most plant species (leaves and stalks).

3. The corrosive effect of soluble compounds containing the needed elements on the sensitive plant tissues. Water solubility and rapid absorption require a highly soluble compound, which in turn is relatively corrosive and may severely damage growing green tissues. Water solutions or dusts of each essential element can be readily prepared, but their very soluble nature renders them more or less corrosive.

At least two mechanisms may be involved in foliar absorption:

1. The cuticle (waxy surface cells) is the first barrier before a foliar applied chemical can contact and possibly react with living protoplasm.

2. Stomatal penetration, if it occurs, is not equivalent to absorption and does not preclude the necessity of cuticular penetration, since substances in the intercellular spaces still must pass through a layer of cutin and the cell wall. Several investigators have shown that foliar absorption is most rapid witn the leaf surface is moist. Wittwer et al (3) have thoroughly reviewed foliar plant feeding and list comparative mobility of elements as follows:

Highly mobile - nitrogen, potassium.
Mobile - phosphorus, chlorine, sulfur.
Partially mobile - zinc, copper, manganese, iron, molybdenum.
Immobile - boron, magnesium, calcium.

However mobility is not always important, since sprays of relatively immobile elements are often effective. Calcium sprays control "blackheart" of celery, and also "Blossom-end rot" of tomatoes. Magnesium (which is also relatively immobile) sprays are effective on celery, tomatoes, citrus and apples for correcting leaf chlorosis. Ferrous sulfate sprays are effective in controlling iron chlorosis of grain sorghum and of pineapples, and boron sprays have controlled root necrosis in rutabagas both in east central Minnesota and other areas.

It may be concluded that many plant species have the power of absorbing limited amounts of at least some nutrient elements through their leaf surfaces. The problem then becomes a question of:

1. Supplying the needed amounts of the element in a form which can be absorbed through leaf tissues.
2. Adherence to the leaf surface for a protracted period.
3. Little or no vegetative damage.

Urea is probably the most widely used nutrient spray material in crop production, since it is a very soluble organic compound and nitrogen is also highly mobile. However, since relatively large amounts of nitrogen are needed by non-legume crops such as corn, serious leaf burning may occur if substantial rates are applied.

In 1949, Shubeck (1) applied foliar sprays at three rates of urea nitrogen in split applications to corn growing on three Minnesota soil types. The urea was dissolved in a minimum amount of water with a spreader-sticker and applied when the corn was some 24 inches tall - resulting in severe burning. The second application was made when plants were 48 inches tall with 2.5 pounds of hydrated lime per 100 gallons of water and using a more concentrated solution but a finer spray. The results were as follows:

See Table 1.

TABLE 1
THE INFLUENCE OF UREA NITROGEN SPRAYS ON 1949 CORN
YIELD ON THREE MINNESOTA SOILS

Fertilizer in lbs/A		LeSueur silty clay loam	Wadena loam	Hubbard sandy loam
Hill	Spray 1/	Ear corn in bu/A @ 15.5% moisture		
10-40-40	0-0-0	90	62	83
10-40-40	7.5-0-0	86	61	78
10-40-40	15-0-0	85	62	78
10-40-40	30-0-0	84	59	77

1/ Spray split into two applications

Dry weather favored urea retention on leaves, but limited fertilizer effect. While the rates used in this experiment of 21 years ago would now be considered totally inadequate, the burning damage to the corn leaves produced by even these low treatment rates was substantial, corn yields were certainly not increased. Although urea is an organic compound, it readily hydrolyzes in water, producting the highly basic ammonia which burns leaf tissues at relatively low concentrations as follows:

UREA FORMS AMMONIA

(urea) (water) (ammonium carbonate) (ammonia)

$$C{=}O\begin{matrix}NH_2\\NH_2\end{matrix} + 2H_2O \xrightarrow{\text{urease}} (NH_4)_2CO_3 \longrightarrow 2HN_3 + H_2O + CO_2$$

Neutral reaction — Strongly alkaline reaction

This is the reaction which resulted in serious leaf burning when Shubeck foliar fed the corn plants, although the inclusion of lime in the second spray treatment reduced this damage. It is obvious that the N leaf feedings did not increase corn yield.

Smith (2) reported a Kansas study comparing winter wheat yields after 45 pounds of ammonium nitrate N was added to the soil compared with urea N sprays supplying 10, 30, or 50 lbs N/A from 50 days before flowering to 30 days beyond the flowering stage as shown in Table 2.

TABLE 2.

THE COMPARATIVE EFFECT OF UREA NITROGEN SPRAY AND SOIL APPLIED AMMONIUM NITRATE AT DIFFERENT STAGES OF WINTER WHEAT DEVELOPMENT IN 1950 - (SMITH - KANSAS)

FERTILIZER	APPLICATION METHOD	Lbs. N/A	GROWTH STAGE		Bu/A
Ammonium nitrate	Soil	45	50 days before flowering		45
urea	Spray	10	50 "	"	35
"	"	30	50 '	"	40
"	"	50	50 "	"	42
"	"	10	at flowering	"	34
"	"	30	" "	"	36
"	"	50	" "	"	38
"	"	10	30 days after flowering		30
"	"	30	" "	"	30
"	"	50	" "	"	30

The highest protein content occured when urea sprays were applied at flowering with the heavier N rates (50 lbs. urea N/A produced wheat of 15% protein) but this decreased rapidly to 11% as the spraying time increased either before or after flowering. He concluded that leaf feeding of wheat was less effective on wheat yield per pound of nitrogen applied, than early soil application, but protein content could be increased by urea sprays at flowering.

Smith also studied NH_4 NO_3 solution leaf feeding and found early soil applications produced 37 bushels of wheat, which was 4 bushels more than that obtained with foliar urea or NH_4 NO_3 sprays applied at the same time. Damage resulting from nitrogen leaf feeding appeared to exceed the benefit resulting from such treatment in comparison to soil applications.

It has been mentioned that potassium, phosphorus, and sulfur are relatively mobile and maybe absorbed to a limited extent when applied to leaf surfaces. Although calcium and magnesium are much less mobile, some experiments have demonstrated moderate absorption into leaf tissue as well. However, there has been very little research on the benefits of spraying these elements on the leaves.

The major research on foliar feeding has been with the micronutrient elements, since very small amounts may correct a nutritional problem, and several of these become rapidly unavailable to plants shortly after being applied to some soils. This is not true in every case, since applied chlorine, boron, zinc and others may remain comparatively available to plants for several years.

Some crop species growing on calcareous soils are subject to a characteristic yellowing of the foliage, usually during the latter half of June and early July. Cold, wet soils, high in lime and/or soluble salts produce a yellowing (chlorosis) of some varieties of soybeans, flax, strawberries, raspberries, and other crop plants as well as many ornamentals. Since sprays of soluble iron compounds have corrected the yellowing of some species, the term of "iron chlorosis" for this condition has often been used. Both iron or manganese are very readily affected by aeration and the relative solubilities and concentrations of the companion element present in the soil. For example, large amounts of soluble manganese in soils (such as some in Hawaii where pineapples are grown) results in low uptake of soluble iron, which is now corrected by ferrous iron sprays. Large amounts of ferrous (soluble) iron reduces manganese uptake. However, the chlorosis problem occuring in the continental United States in most instances is not the result of high concentration of soluble soil manganese, but is more likely a general expression by some species and varieties of plants that have less well adapted root systems attempting to survive under relatively unfavorable soil conditions (wet, cold, high salt content).

Where the electrical conductivity of the soil does not exceed 2 millimhos per centimeter, affected plants of most species will usually become a normal green as soil moisture decreases, temperature increases, and the deficient elements become more available. If conductivity is high(indicating high soluble salt levels) the plant roots may not be able to take up sufficient soil nutrients and water due to the abnormally high osmotic tension produced by the soluble salts present.

There have been many reports from the western United States of successful spray treatments containing iron, manganese, zinc, and boron on such crops as sorghum, onions and many tree species. In Minnesota we have been chiefly concerned with the yellowing of soybeans and of flax, as well as with strawberries, raspberries, and some ornamentals. The development of chelates which would maintain the availability of one or more of these micronutrients in the soil for several months appeared promising, but their high cost and limited effectiveness have precluded their use on the relatively low value field crops.

In 1948, the Iowa Agricultural Experiment Station recommended a spray of ferrous sulfate using 10 pounds to 50 gallons of water per acre. Since no effective soil treatment has been found, it was decided to try the spray treatment on three chlorotic fields in Western Minnesota. Selected 20 foot long soybean plots were sprayed on the 21st of June with ferrous sulfate at the rates of 1 and 10 pounds in 50 gallons of water per acre, and also with Nu-Iron (containing 30% available iron and supplied by the Tennessee Corporation) at both the recommended rate and at one tenth this concentration. These treatments were repeated on half of the plots 10 days later on July 2nd.

The treated soybeans were observed at weekly intervals, and while some beneficial treatment effect was first observed on some replications, similar treatments on other replications showed no consistent effect. The yellowing completely disappeared on the field near Montevideo by the end of July, with some yellowing remaining at harvest in the field near Raymond, but the Lake Lillian field had some gaps where the soybeans did not survive. The harvested yields are shown in Table 3, and it is evident that neither the one nor two spraying times had a significant effect on soybean yield.

TABLE 3
THE EFFECT OF SPRAYING CHLOROTIC SOYBEANS WITH FERROUS SULFATE AND NU-IRON ON 1963 YIELD

LOCATION SOYBEAN VARIETY TREATMENT	LAKE LILLIAN CHIPPEWA	RAYMOND CHIPPEWA	MONTEVIDEO HARMON	AVE.
	YIELD IN BUSHELS PER ACRE			
None	13.5	14.8	27.4	18.6
	YIELD INCREASE FOR IRON SPRAY			
$FeSO_4$ 1#/A June	2.3	0.6	1.8	1.6
$FeSO_4$ 1#/A June + July	2.5	1.7	-0.5	1.2
$FeSO_4$ 10#/A June	4.0	4.3	-3.0	1.6
$FeSO_4$ 10#/A June + July	5.3	4.8	-1.2	3.0
Nu-Iron (1/10 rec. rate) - June	5.1	-1.7	-1.7	0-6
Nu-Iron (1/10 rec. rate) - June + July	2.4	0.1	-1.5	0.3
Nu-Iron (rec. rate) - June	-3.0	1.8	-3.3	-1.5
Nu-Iron (rec. rate) - June + July	-1.0	6.0	-3.8	0.4
Significant (5%)	8.0 bu.	7.4 bu.	5.7 bu	

CONCLUSIONS

Research has shown that:

1. It is possible for small amounts of nutrient elements applied to leaves in soluble form to be absorbed with prolonged contact. Wind movement, rains, and dew make long foliar contact difficult to achieve, even employing spreader-stickers.

2. The greatest promise of foliar feeding occurs in the use of those elements needed only in very small amounts - the elements of the micro-nutrient group

such as iron, and manganese, which rapidly become relatively unavailable shortly after application to soils on which these deficiency problems occur. The other essential elements of the micronutrient group - boron, zinc, copper, molybdenum, and chlorine remain relatively available in soils for comparatively long periods.

3. The secondary elements - calcium, magnesium and sulfur-are relatively low in cost and soil applications are relatively efficient. If deficiencies of calcium or magnesium occur, it is probable that lime is also needed to correct soil acidity, and sulfur is easily and cheaply supplied to soils.

4. Nitrogen is usually needed by non leguminus crops in relatively large amounts, and soil applications are usually more effective and practical, since high solubilities of the nitrogen fertilizer sources produce serious leaf burning. Phosphorus fertilization is usually most needed during the first month of plant growth and there is little leaf area present to foliar feed at this stage. Potassium additions to soil remain comparatively available, and foliar feeding of potassium salts could severely burn leaf tissues.

In general, it may be concluded that small amounts of some essential elements may be fed to plants through the leaves, but it remains a fallacy that major fertilization can be economically accomplished by this method at the present time.

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BENEFITS OF IRRIGATION IN CORN AND SOYBEAN PRODUCTION

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The commercial farmer is interested in maximum profit per acre. In striving for this goal he must look at all factors that limit him from reaching that goal. Lack of moisture either in total or in timing is certainly a yield limiting factor on the sandy soils in Minnesota. Higher crop yields generally offer the greatest opportunity for lowering per bushel or per ton production costs. The question then that it appears I should be addressing is "Can irrigation increase crop yields sufficiently to offset costs so it will lower per unit production costs and thereby increase maximum profit per acre?"

I hope from that opening you are all aware that irrigation is just another production tool for the good manager. It does not stand by itself as a solution to all problems anymore than fertilizer, good weed control or a proper stand will. All management practices must be tied together and the introduction of a new factor such as irrigation may require a change in methods or levels of other crop production practices.

The title implies that this paper will deal with both corn and soybean production. The major portion will deal with corn production because of lack of information on irrigated soybean production in this area. Some farmers have tried irrigating soybeans, but without sufficient success to continue.

Soils may be the key reason for limited soybean success in the area. Lowell Hanson, Extension Specialist in Soils, in writing about differences in Soil Suitability for Soybean Production states "In general it appears that soybeans yield relatively better than corn on soils that are high in organic matter, medium to fine textured and are in the range of slightly acid to alkaline"........." Soil types of Marna, Floyd, Skyberg, Kenyon, Webster, Nicollet, Flom, Aastad, Fargo and Bearden appear to be soils particularly suited to Soybeans. In general these are soils which are moderately well to poorly drained. They are cold in the spring but release large amounts of nutrients in midsummer." These are not characteristics of the central Minnesota sands which are low in organic matter, coarse textured, generally acid, well drained and warm up early in the spring.

In general terms it is difficult to describe irrigation requirements of soybeans. In comparison with crops whose irrigation requirements are better known, Whitt (1) reported that soybeans did not respond to supplemental irrigation in two seasons in which irrigation increased corn yields 20%. Grissom et al (2) concluded that soybeans were less affected by drouth than corn or cotton.

The situation with corn production is quite different. Response to irrigation has been widely studied and described. A Nebraska study (3) shows that a weeks delay in supplying irrigation water to corn can reduce the potential yield up to 34 bushels per acre.

Corn has been irrigated in the Todd, Wadena, and E. Ottertail County area of Minnesota for about 20 years. In terms of acreage it is the leading irrigated crop in the area. Yields reported this fall ranged from 80 to 137 bushel/acre of No. 2 shelled corn.

There are several reasons for this wide range in yield levels including fertilization rates; date, rate and uniformity of planting; weed control; irrigation management; and others. Of these only irrigation management will be discussed here.

Irrigation Management includes the following:

1. When to start irrigating
2. How much water to apply per irrigation
3. How frequently to irrigate
4. How to account for and adjust schedules for rainfall
5. When to stop irrigating

All of these are dependent to some extent on the soil, the rooting depth of the crop and the evapotranspiration rate at the time in question. Soils vary in moisture holding capacity, in depth and in intake characteristics. Rooting depth of a crop such as corn is fairly constant except when restricted by a soil layer. Evapotranspiration rates will vary with time of year, amount of crop cover and time interval being considered. The irrigator who has investigated these factors, understands them and is a good enough manager to adjust them properly is successful in obtaining the higher yields if other management factors are held equal.

I have not really spoken directly to the question of whether irrigation can increase profits. I believe it can. Like any other production practice it must be evaluated by the individual in his situation and managed properly to return the maximum profit on his investment. New developments in irrigation systems have greatly increased the alternatives open to a prospective irrigator and have increased the complexity of decision-making in the irrigation area.

(1) Whitt, D.M. 1954 Effects of Supplemental Water on Field Crops. Missouri Agr. Exp. Sta. Bull. 616
(2) Grissom, P., W.A. Raney and P. Hogg 1955 Crop Response to Irrigation in the Yazoo - Mississippi Delta. Mississippi Agr. Exp. Sta. Bull. 531
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TILLAGE FOR 1971

W. E. Larson

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Tillage practices for row crops will continue to change in the 1970's just as they have changed during the past 20 years. Tillage practices today are characterized by many alternatives available to fit soil and crop conditions. Farmers will continue to seek (1) cheaper tillage practices, (2) tillage practices that provide better wind and water erosion control, and (3) tillage practices that cause less soil compaction.

The many tillage practices advocated by researchers, farm advisors, machinery dealers, and farmers can be grouped into five categories. In category 1 are those which include plowing (either fall or spring) followed by several secondary tillage operations. This has been the conventional practice. Category 2 includes plowing plus reduced secondary tillage over the entire surface area. This may involve pulling an implement behind the plow, tilling the soil in the same operation as planting, or a single tillage operation following plowing and then planting. Chisel-plowing and rotary tillage can be included here. Category 3 includes plowing plus secondary tillage in a strip over the row. Category 4 comprises tillage in a strip in the seed row with no tillage in the interrow zone. And category 5 is no tillage other than placement of seed in the soil.

CORN YIELDS

Differences in corn yields with tillage practices, assuming fertility is adequate, are usually because of differences in stand, water conservation, soil temperature, or soil crusting. While all of these factors are important in Minnesota, their relative importance varies in the different soil associations. Crusting and water conservation are important factors influencing yields on the silty forest and prairie soils of southeast Minnesota. Practices to enhance soil temperatures and stands of row crops are desirable on the medium- to fine-textured prairie soils of south central Minnesota. Water conservation is the strong consideration on the silty prairie soils of southwestern Minnesota. Practices to enhance water conservation and spring soil temperatures are desirable on the medium- to fine-textured prairie and prairie-border soils of western Minnesota. Water conservation is the big consideration on the sandy soils.

Much has been written recently about no-tillage practices for corn and soybeans. Generally in southern United States the practice has produced yields about equal to plowing treatments if the soil was in good tilth. In the north yields have not always been as high as from conventional, particularly if crop residues are heavy or if the soils tend to be wet (Crops and Soils, 1969). It is another tillage alternative for problem soils.

In recent years the trend toward less post-planting cultivation has increased. We are often asked if omission of cultivation will reduce yields. Van Doren and Triplett (1965) have summarized the Ohio data in Table 1. The data indicates that cultivation is usually desirable on crusting soils but may not be necessary on non-crusting soils. Our Minnesota experience agrees with the Ohio data.

FERTILIZER USE AND PLACEMENT

Row fertilizers will usually be more beneficial in increasing yields in reduced tillage practices than in conventional tillage practices. We think the reasons are that many reduced tillage practices place the seed in cooler and often wetter soil, and the soil environment may not enhance early root growth as compared with conventional. Cool and wet soils often depress plant uptake of the major nutrient elements and some of the microelements.

In most of the no-plow tillage treatments it is more difficult to place the fertilizer deep in the soil, and hence, it is often placed near the soil surface. We are often asked, "Will placement of the fertilizer near the surface, where the soil is sometimes dry, reduce yields?" Our background information suggests it is not desirable to place all fertilizer near the surface in all years because of its low availability during dry periods. Duncan (1969) recommends in Iowa that fertilizers be knifed deep in the soil occassionally if the soil is not plowed. However, in other short-term experiments with reduced tillage deep placement has not been shown necessary.

At present there is much concern about nutrient enrichment of waters from agricultural land runoff. Surface placed fertilizer can result in greater concentrations of nutrients in runoff waters.

SOIL AND WATER LOSS

Tillage practice can have a marked influence on water runoff and on wind and water erosion. Data from a Russell silt loam in Indiana on a 5% slope are summarized in Table 2. Minimum tillage markedly reduced erosion from water over a five-year period. Greater erosion control was found from minimum tillage following meadow than from the same practice following several years of corn. Five inches of artificial rain were applied. Similar data from La Crosse, Wisconsin, also show the effectiveness of mulch and wheel-track planting methods in reducing soil loss and runoff.

Tillage practices that leave mulch on the surface create rough soil surfaces and high porosity, which decreases runoff and water and wind erosion. Tillage practices that leave rough, loose soil surfaces may enhance evaporation but we believe that in humid regions the increased infiltration will more than compensate for the greater evaporation.

Table 1. Yield increase from cultivation on Ohio soils from Van Doren and Triplett (1965).

		Yield Increase or Decrease Due to Cultivation*	
Previous Crop	Seedbed Preparation	Crusting Soil	Non-Crusting Soil
Row Crop	Plow + Equivalent of 2 Diskings	+ 10 BU/A	+ 1.7 BU/A
Sod	Plow + Equivalent of 2 Diskings	+ 7.3	+ 1.1
Row Crop	Plow	+ 6.9	- 2.6
Sod	Plow	+ 5.7	- 4.0
	Average	+ 7.5	- 1.5

* Cultivated twice

Differences due to soil significant at 5-percent level.

Stands were the same.

Weeds chemically controlled.

Table 2. Effect of minimum tillage on soil losses from Russell silt loam in corn: Indiana artificial rain tests (from Mannering and Burwell, 1968).

After corn planting (seedbed period)

Tillage Practice	Soil Loss		
	First-year corn (1959)	Third-year corn (1961)	Fifth-year corn (1963)
	Tons/acre	Tons/acre	Tons/acre
Conventional tillage (plow, disk, and harrow)	16.7	26.9	21.1
Minimum tillage (plow, wheel-track plant, and plow-plant)	8.6	19.6	14.1

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ANOTHER LOOK AT AN OLD PROBLEM

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Scientists have been searching for many years for a method or means of determining the nitrogen supplying power of our soils. An estimate of the nitrogen supplying power of the soil is important, since it is this soil nitrogen, plus the nitrogen supplied by fertilizer, giving consideration to the efficiency in which fertilizer nitrogen is taken up by the plant, that determines the total amount of nitrogen available to the crop.

NITROGEN SUPPLYING POWER OF SOILS

The ability of a soil to supply nitrogen is influenced by: (a) total organic matter, (b) soil moisture, (c) soil temperature, (d) cropping history and, (e) residual fertilizer nitrogen. Most mineral soils of the world do not have sufficient nitrogen supplying powers for satisfactory yields of our cultivated non-legume crops. Few can supply sufficient nitrogen for even one crop at the production potentials that are now acceptable in favorable seasons with good management.

In cropping systems where legumes are grown at regular intervals, nitrogen fixation supplements the soil supply and may meet the needs for high crop yields provided the legume crops are good. In livestock farming systems, manure supplements the soil supply of nitrogen. On most farms when non-legume crops are grown, supplementary nitrogen fertilizer is necessary for high yields.

LABORATORY TESTS FOR SOIL NITROGEN

Soils tests for nitrogen include: plant tests, microbiological tests and chemical tests. In plant tests, the soils to be tested are cropped with a non-legume crop on a small scale in a growth chamber or greenhouse. The plant is harvested and the amount of nitrogen in the plant determined. This nitrogen gives an indication of the nitrogen supplying power of the soil.

The soil sample is incubated in microbiological tests under specific conditions of temperature and moisture and the amount of nitrate formed in a certain period of time is determined. The rate of nitrate formed is then related to crop response in greenhouse and field trials.

A nitrification procedure was developed and used by Iowa State University for several years.

Today, biological and plant tests are not used in soil testing laboratories. They are time consuming, not easily adaptive to routine soil testing laboratories and often do not offer great advantages over chemical measurements. Many of these tests, however, are still used in research studies.

The determination of the organic matter content of the soil has been the most widely used chemical test for determining the nitrogen supplying power of the soil. The procedure most extensively used is based on a wet-combustion reaction adapted to rapid routine testing. Chemical determinations of the amounts of ammonium and nitrate forms of nitrogen in the soil have also been widely used. In the past, research workers have not found a close relation between nitrate content of soil samples and nitrogen response. Determinations of nitrate nitrogen and ammonium nitrogen have been useful in measuring residual amounts of nitrogen in the soil.

SUCCESS IN USE OF NITRATE TEST

During the past 10 years, North Dakota and Canadian researchers have found a close correlation between nitrate nitrogen tests of the soil and the response to nitrogen fertilizer use.

Nitrogen fertilizer recommendations from North Dakota State University are based on nitrate nitrogen tests, stored moisture at seeding and probable growing season precipitation.

Nitrate-Nitrogen (NO_3-N) tests are made on the top 2 feet of soil at or near seeding time. Nitrogen fertilizer rates are based on specific yield potentials.

To determine the actual nitrogen to apply, the (NO_3-N) in the soil is subtracted from the total nitrogen required.

Under good moisture conditions in the Red River Valley, it is estimated that a yield of 35 to 40 bushels of wheat per acre can be obtained. This yield will require approximately 110 pounds of nitrogen. If the nitrate nitrogen test shows 50 pounds of (NO_3-N) present, it will be recommended that 110 pounds minus 50 pounds or 60 pounds of nitrogen per acre be applied. The State of North Dakota has been zoned according to production potentials and nitrogen required to reach these yield levels. It is recommended that the farmer test his soil each cropping year.

South Dakota has also adopted the nitrate test as a means of adjusting nitrogen recommendations. Nitrogen fertilizer recommendations are made on the basis of organic matter content of the soil. These recommendations are then adjusted based on the amount of (NO_3-N) in the top 2 feet of soil. Recent communication with South Dakota researchers indicate that they have obtained good correlation between nitrate nitrogen content of soil samples taken to a depth of 2 feet and response of small grains to nitrogen fertilizer.

The use of the nitrate specific ion activity electrode for measuring NO_3-N in the soil has proven to be rapid, simple, precise and adaptable to routine laboratory testing. Additionally, with new soil sampling equipment, the ease and practicability of obtaining 2 foot samples has encouraged the adoption of this method for determining the nitrogen supplying power of the soil.

RESEARCH RESULTS - UNIVERSITY OF MINNESOTA

Research data obtained by the Soils Department of the University of Minnesota shows that the nitrate soil test can be a valuable tool to measure the residual nitrogen in the soils of Minnesota. Findings have not indicated that this method can be a reliable method of estimating the nitrogen supplying power of all soils of Minnesota.

Investigations indicate that most soils of southern Minnesota have much greater nitrogen supplying power than a nitrate nitrogen test at 2 feet, or even 4 feet depth, would indicate.

Let us look at the NO_3-N content of some continuously cropped soils of southern Minnesota. Table 1 shows the NO_3-N content of soils cropped to corn for 11 years. The pounds of NO_3-N to depth of 4 feet is less than 45 pounds per acre. Yet the soil at Morris produced corn yields of 50 bushels per acre without benefit of nitrogen fertilizer application. Similarly, the soils at Lamberton and Waseca have consistently produced more than 70 bushels of corn per acre without benefit of additional nitrogen fertilizer.

Table 1. Pounds of NO_3-N per acre in soils cropped to corn for 11 years.

Soil Location Depth	Barnes Loam Morris	Webster S. Clay Lamberton pounds NO-N per acre	LeSueur S. Clay Waseca
0-1'	16.1	5.3	29.1
1-2'	10.8	3.7	7.6
2-3'	8.0	2.6	4.4
3-4'	9.8	4.3	3.0
Total	44.7	15.9	44.1

Studies conducted by Caldwell and Ogata from 1949 to 1952 indicate similar NO_3-N accumulations in a continuously cropped soil, but significantly different levels in a fallowed soil (Table 2).

Table 2. Pounds NO_3-N per acre in Skyberg silt loam soil under various cropping.

Depth	Continuous Crop	Cropping Pattern Fallow 1 Year pounds NO_3-N per acre	Fallow 2 Years
0-6"	18	290	576
6-12"	8	144	354
12-24"	6	116	288
Total	32	550	1218

Farmer samples from the Red River Valley of North Dakota analyzed during the period from July 1969 to June 1970 indicate a somewhat higher level of NO_3-N for non-fallowed soils (Table 3).

Table 3. Nitrogen soil test results - Red River Valley, North Dakota - July 1, 1969 - June 30, 1970.

	Non-Fallow lbs. N/A 2 feet			
Level	0-30	31-60	61-100	over 100
140 fields	63	110	116	107
% of fields	16	28	29	27

Table 4 illustrates the high level of NO_3-N often found in non-fallow soils of the Red River Valley of Minnesota.

Table 4. Nitrogen soil test results - Red River Valley, Minnesota - 1962.

		Non-Fallow	
Soil	Fargo Clay Crookston	Fine Sandy Loam Ada	Bearden S.C.L. W. Polk
0-1'	95.6	96.4	111.2
1-2'	59.6	37.2	81.6
2-3'	48.8	24.8	60.0
3-4'	39.6	28.4	40.0
Total	243.6	186.8	292.8

A summary of nitrogen soil test results representing 133 fields in the Red River Valley of North Dakota show that 83 percent of the fallow fields contained more than 100 pounds per acre of nitrate nitrogen.

MEASURING RESIDUAL NITROGEN

Of particular interest to the scientist, as well as the farmer, is the possible accumulation of nitrogen in the soil as a result of nitrogen fertilizer applications.

Investigations conducted by several members of the Soil Science staff of the University of Minnesota show that the NO_3-N test can serve as a good means of measuring residual nitrogen accumulations. One example of this work is shown in Table 5.

Table 5. Influence of nitrogen fertilizer applications on NO_3-N accumulation after 11 years continuous corn - Barnes S. Loam, Morris, Minnesota.

Annual	0	40	240
11 Years	0	440	2640
Depth	pounds NO_3-N per acre		
0-1'	31.5	43.0	205.4
1-2'	8.8	10.4	123.8
2-3'	9.4	9.6	110.8
3-4'	6.6	12.2	72.3
7-8'	6.6	18.3	145.8
11-12'	17.3	22.8	47.9

During 11 years of continuous corn at the Morris location, an application of 40 pounds of nitrogen per acre resulted in significant increases in corn yields. Applications exceeding 40 pounds of nitrogen per acre resulted in little or no significant increases in corn yields. Since this excess nitrogen was not consumed by the corn plants, it accumulated in considerable quantity, as indicated in the 240 pound annual application.

SUMMARY

Research findings in North Dakota, Canada, and South Dakota have shown that the NO_3-N content of the top 2 feet of soil is well correlated with the nitrogen supplying power of the soil and the response to nitrogen fertilizer applications. The use of the nitrate specific ion activity electrode for measuring NO_3-N in the soil has proven to be accurate and adaptable to routine testing. The ease and practicability of obtaining soil samples from a depth of 0-24 inches, with new equipment, has encouraged the adoption of this method as a means of determining the nitrogen fertilizer needs for a crop to be grown on a specific soil.

Research in Minnesota has shown that the use of the NO_3-N test would be a poor indicator of the nitrogen supplying power of a large number of cultivated soils of southern and central Minnesota.

Determinations, however, can serve as a means of measuring residual nitrogen accumulations.

Investigations show that the nitrate nitrogen soil test can be very helpful in estimating fertilizer nitrogen needs of soils of the Red River Valley.

FUTURE NITRATE NITROGEN TESTING - UNIVERSITY OF MINNESOTA

RED RIVER VALLEY, MINNESOTA

Farmers in the Red River Valley of Minnesota will be encouraged to make use of the NO_3-N test for determining their nitrogen fertilizer needs.

The University of Minnesota Soil Testing Laboratory will accept samples for testing which have been taken from the depth of 0-24 inches. If a farmer wishes to obtain a complete fertility recommendation, he should submit from each field a sample taken from 0 to 6 inches, as well as a sample taken from 0 to 24 inches. Lime, phosphorus, and potassium recommendations will be made on the 0 to 6 inch sample, while nitrogen recommendations will be made on the 0 to 24 inch sample.

Those farmers from the Red River Valley who submit samples taken from the 0-6 inch depth only will receive nitrogen fertilizer recommendations based on organic matter content and past cropping history.

OUTSIDE RED RIVER VALLEY MINNESOTA

Farmers and land owners in central and southern Minnesota who wish to obtain information on the nitrate nitrogen buildup in their soils can take advantage of the nitrate test offered at the University of Minnesota Soil Testing Laboratory. The sample submitted for this test should be a composite sample taken from 10 to 20 locations at a depth of 0-24 inches. This test will not serve as a basis for making nitrogen fertilizer recommendations.

THE FUTURE

Rollin M. Dennistoun, PhD, Administrator
Plant and Environmental Concerns
Minnesota Department of Agriculture

I. Fertilizer - Soil Conditioners

A. Public Sentiment

1. Home Owner

a. Lawn Use

(1) Nitrates

(2) Phosphates

2. Agriculture

a. Concern of User

b. What has Priority?

c. Losses?

B. Products

1. Soil Conditioners

2. Specialty Materials - lawns, gardens, etc.

3. Agricultural Materials

a. Regular

b. Pesticide Mixtures

C. Proposed Legislation

1. A new fertilizer law which:

a. Revises and updates the present law so that it is essentially the same as the model bill.

b. Provides for the registration of all soil conditioner materials.

c. Lowers the plant food content for agricultural materials from 27 to 24 units.

d. Increases the fees on specialty fertilizer materials and places a fee on soil conditioner materials.

e. Changes the licensing and regiatration date from July 1 of each year to January 1.

II. Pesticides

A. Public Sentiment

1. Home Owner

a. Aesthetic Value & Alternatives

b. Other Considerations

2. Industry

a. Fewer New Materials

3. Governmental Agencies

a. Greater Activity by Federal Agencies - Cancellation, Suspension

b. States will be required to review and up-date their requirements

4. Agriculture

a. Concern for

b. Fewer Materials Available

c. Economics of Use - "Benefit - Risk Ratio"

B. Future Regulatory Possibilities

1. Restricted Use List

a. Prescription Use

2. Licensing of Pesticide Dealers

3. Memorandum of Understanding

4. Classification of Products on basis of ? ? ?

5. Other

AGRICULTURAL CHEMICALS AND PESTICIDE MANAGEMENT - THE PRESENT

Leo Lehn
Agronomy Services Division
Minnesota Department of Agriculture
St. Paul, Minnesota

The Minnesota Department of Agriculture administers laws and regulations covering Fertilizer, Soil Conditioners, Fertilizer-Pesticide combinations, Pesticides and Pesticide usage.

FERTILIZERS AND SOIL CONDITIONERS

Currently a license and registration is required to manufacture, blend or distribute all fertilizers. License fees are $50.00 for manufacturing or blending plants, $50.00 for a single portable blender, $25.00 for each additional portable unit. No registration fees are required for grades or materials sold in packages some of which are over 25 pounds or those sold in bulk.

A registration fee of $25.00 per item is required for products sold exclusively in package units of 25 pounds or less. These small package items are primarily specialty, or more commonly known as lawn and garden products.

Tonnage tax fees are assessed at the rate of 10¢ per ton for all materials and grades except for the products in the small package class. Reports of sales along with fees due are required semiannually. Tonnage figures are tabulated and published from these reports.

The Agronomy Service staff of 16 field inspectors sample products sold or offered for sale and submit the samples to the Division of Laboratory Services for analysis. A report of the finding is furnished to all parties concerned.

Currently there are 623 companies licensed to manufacture, blend or distribute products in Minnesota: 497 companies in state, 62 out of state, 57 small package only, 7 mobile fertilizer units.

No fees are involved for registration or distribution of Soil Conditioner products. Regulations require submission of a label of each such product offered for sale. Products labeled according to the regulations are approved and distribution is permitted. Control of such materials has presented numerous problems to the department.

PESTICIDES

Registration is required of all items or products which fit the definition as stated in 24.069, Subdivision 2 of the Economic Poisons and Devices Law:

"The term Economic Poison shall include any substance or mixture of substances intending for use in preventing, destroying, repelling, or mitigating any and all insects, rodents, fungi (including bacteria), weeds, and other forms of plant or animal life which the commissioner shall declare to be a pest."

"Devices are those instruments or contrivance intended to trap, destroy, or repell except for rodent traps."

Examples of a device is a light trap or an electrocution device.

Registration involves submitting an application along with a complete label of each product to be registered. Registration fees are $9.50 for each of the first five products and $2.50 each for all additional. A 50% penalty applies if renewal is made after July 1. The penalty also applies if products are being distributed over 30 days prior to application for registration.

The regulations adopted during the past year require closer scrutiny to determine whether or not the products containing restricted pesticides are packaged and labeled for uses which are permitted. Such products labeled only for home use are rejected.

Over 600 companies have products registered. There are over 4,000 different pesticide products involved.

CUSTOM APPLICATION OF PESTICIDES

The spraying and dusting law along with the regulations which include the restricted use of seven pesticides involves a considerable amount of detail and affects a large number of companies and individuals.

All persons applying pesticides for hire are required to obtain a license to do so and also to register each piece of equipment they use in making the applications. To obtain a license the person must submit an application stating the nature of the work he intends to engage in. An open book test is then furnished the applicant. Upon satisfactory completion of the test and receipt of the $5.00 license fee plus $2.00 registration fee for each piece of equipment the license is issued. These licenses expire on December 31 of each year. Renewal application must be made before April 1 to avoid the 50% penalty for late renewal applications. This late renewal deadline has caused some problems as the spraying season is getting in high gear about that time and any delay in the mails or in processing of an application does not set too well with the applicant or his customers.

A recent change in the regulations now permits applicants who have been licensed for 1969 and 1970 to qualify for renewal for 1971 and future years by attending an approved short course in lieu of writing the exam. The applicant can choose which he would prefer. Thus far this short course is the only one which has been approved. There is a strong possibility that there will be several others also approved.

Close to 1000 persons have qualified as Custom Pesticide Applicators and have registered nearly 1700 spraying or dusting rigs. Over 100 of the licensed Custom Pesticide Applicators are aerial firms.

In conjunction with the Spraying and Dusting Law are regulations restricting the sale and use of 7 pesticides. This regulation requires that the dealers who offer such products obtain a dealer permit. It also requires that each user obtain a permit. Only certain specific uses are acceptable. Display of restricted pesticides is not permitted.

The Agronomy Services staff of the Minnesota Department of Agriculture with assistance of the County Agricultural Inspectors are carrying out the inspection work related to application and use of pesticides.

STRUCTURAL PEST CONTROL

Structural pest control companies and operators are licensed under a different statute. These people are required to have adequate training, experience, and technical knowledge to properly determine, supervise and apply pesticides used in structural pest control. A yearly refresher course is a requirement. Proof of financial responsibility must be established and maintained.

We are sure at least some of you have ideas and opinions regarding the laws and regulations as they now stand. We can see several areas where changes would be desirable and with the cooperation of industry, the general public and all others concerned at least eome of these changes can become a reality.

THE DECADE AHEAD

Edgar M. Urevig, General Manager
The Tilney Farms
Lewisville, Minnesota

From the time of primitive man making sacrificial offerings to the wind and rain Gods, to the prophesy of Priests of Babylon and Greece, the human race has tried to lift the curtain hiding the future--usually without much success. History is full of embarrassing predictions by experts.

In 1956 Dr. Richard Van Der Riet Wolley, England's Astronomer Royal, said, quote, "Space travel is impossible." Unquote.

The National Academy of Sciences approached a group of leading engineers to study the jet engine. The experts studied all the data and reported it impossible.

In 1878 the British Parliament was asked to determine if Thomas Edison's electric light held any promise. They concluded it unworthy of the attention of practical and scientific man.

Originally we were a hunting, nomadic society. Gradually we changed to our agricultural, civilized--or what is now commonly called a production--society. As a result of the production-oriented programs our capacity to produce has never been equalled. Unfortunately what was good for the farm unit was not always good for the farming industry. To illustrate a point--at a football game you rise to see a certain play. You have the advantage until everyone stands. Your advantage is then lost. The same applies to farming. Adopting new technology first may have a temporary advantage but as soon as the entire industry adopts, the advantage is lost.

I shall first briefly discuss our present agricultural production oriented system, which has developed so dramatically over the past years. Then I shall attempt to analyze some of the problems created by this system, which will mean the addition of several new dimensions to our already complex agricultural situation.

Some of us, nostalgic for an agrarian past, may deplore the trend, but the fact is that farming is increasingly becoming a big business. As the poorer farmers fail to compete their land is absorbed by a smaller but more able group of operators who have the capital and the management. The small farm that counts its family labor as its chief asset is passing on like the small grocer or shopkeeper. In 1935 there were 6.8 million farmers; in 1960--3.9 million. Today there are 2.9 million; by 1980 perhaps less than a million. Over six hundred thousand farm people leave the farm yearly.

New systems of mass production are in the making to satisfy the vast needs of a vastly multiplied and urbanized humanity. It is hard to face up to the fact that throughout the economy it is more profitable to employ capital than people. New technology and modern tax policy have made it wise to use machines rather than men wherever possible. Machines can be depreciated through a fast write-off, which is a gain. Men have to be pensioned, which is a cost. Machines keep improving; men haven't changed much.

A farmer will employ capital because he can predict more accurately what it will do and what it will cost. Thus the farmer who is short on capital but long on labor is becoming obsolete as a production unit.

AN EXAMPLE OF THE ECONOMICS INVOLVED:

		CAPITAL	PER HOUR RATE OF PAY	ACRES PLOWED PER HOUR	COST PER ACRE
1.	One Man	Assuming no capital. Free team of horses, plow, & feed.	$1.25	1/4 acre	$5.00
2.	One man	Tractor, plow $10,000	$2.50	3 acres	$4.00
3.	One man	Tractor & plow $25,000	$5.00	8 acres	$3.00

The operator's wages have increased 4 times. By capital input man's performance is increased 32 fold and the cost is reduced by 60 per cent.

HOW RAPIDLY IS THIS CHANGE TAKING PLACE?

YEAR	TRACTOR HP
1920	20 hp tractor
1930	30 hp tractor
1940	40 hp tractor
1950	50 hp tractor
1960	Based on history we could expect a 60 hp tractor. Instead we went to well over 100 hp and up to 200.

Labor on U. S. farms is at an all time low of less than 7 billion man hours of which 3.4 billion are devoted to crops and 2.6 billion to livestock. Overhead jobs account for most of the balance. Relating man hours of labor input to the value of machinery shows an investment rate of $3.62 per man hour versus 19 cents in 1940.

The changes and problems will continue at an ever increasing tempo under further economic growth of the nation and change in the relative price and productivity of capital and labor. There are many reasons why we can expect more rapid changes, such as

1. Improvement in educational opportunities.
2. National programs aimed at reducing economic disadvantages
3. More effective and rapid communication and transportation
4. A better understanding of the process of economic growth
5. A greater competition within the farm industry as capital, land and agricultural resources are controlled by more able managers.

The effect of economic growth and full employment on relative inputs can be noted by comparing trends in prices over the past years. Resources with a declining relative price will increase in use; those with increased relative price will decrease. Since 1950, comparing the price of labor with the cost of fertilizer, fertilizer has dropped over 70 per cent. Obviously these price differentials encourage the use of more capital and less labor. Even with low prevailing prices for grains the cost of fertilizer has declined over 40 per cent in the past 15 years. Thus 60 bushels of corn will buy the same amount of fertilizer that over 100 bushels of corn would buy in 1940.

Opportunities for increased production in the United States are tremendous. Agriculture is a process of converting solar energy into a form usable by humans, either through plants or a second phase--livestock. Scientists tell us that in the temperate zone on a warm day the solar energy on one acre of land is roughly equal to the energy of five tons of coal. If this is averaged through the calendar year to include winter the daily solar energy input per acre is equivelant to three to four tons of coal. If we produce 100 bushels of corn per year this is the energy equal to about three tons of coal. This means, in what we think is an advanced agriculture, we now capture as much energy in one year as God pours on each acre every day. In effect, we capture 1/365 of the energy available. Sometimes we are naive enough to think that we are really efficient.

Agriculture is not a dying business as we are sometimes lead to believe. It is an industry that is expanding rapidly in every respect except that it is taking fewer people to run it. Total agricultural output has increased 40 per cent the last two decades while the number of workers had decreased over 5 million.

Food production is America's biggest business. It is three times larger than the automobile business, bigger than steel, bigger than aerospace. A high level of farm efficiency is necessary to make a country prosperous. In the poorer, underdeveloped countries of the world almost all the people are engaged in a race to keep a single step ahead of starvation. There are few people left to develop the industrial base. The personal income of our farm population the past years is about $15 billion--about three times that of 25 years ago--and the farm population is down to less than one-half of what it was at that time. Investment in agriculture is more than 6 times that of 1940. Production and efficiency is the name of the game.

We have demonstrated this past decade that our ability to produce is tremendous. We know how to adopt new technology and put it to use, but in the next ten years we must learn how to deal with the problems imposed upon us by our production system. Man cannot live by bread alone. Being the richest man in the graveyard is not total fulfillment. In the next decade we must not only deal with more and more complex technology, but also man must become more important than machines. Environment and social structures all must be given important consideration in the future.

We have inherited from our forefathers the basic belief that if we are to survive we must produce more children--more crops--more everything. Scarcity was our most constant worry. Not to produce meant we could not survive. Man originally was a hunting nomadic society. He then changed to an agricultural civilized society, but his chief challenge was scarcity--scarcity of population and of goods. Its chief assets were seemingly endless resources of land, space, clean air, water, food, fiber and mineral resources, which God in his infinite wisdom had concealed for man to find--the precious metals in the heart of the mountains; the oils in the depth of the earth. Each of these resources had to be captured in its raw state and harnassed for the usage of man. Man was told he had dominion over the earth and his chief accomplishment was to gain control over natural resources that he might survive.

Man has indeed been productive, although he may not have been a good stewart. We have lived and prospered in the production phase of our existence for some time but in the words of the philosopher, "Coming events cast their shadows before." Many ecologists are of the opinion that the production phase could cause earth's life support environment to deteriorate. The dynamic Paul Revere of ecology, Paul Ehrlich, warns us that unless we change our ways, reduce our population, cut pollution, we will destroy the life of the oceans within a decade--10 years. Or the more conservative Thomas Malone of the Traveler's Life Insurance Company says we at the moment have 50 years in which to save our environment.

Suddenly we are entering a new era in the history of mankind. It is said by others that mankind, to survive in this planet "earth" beyond the next generation will have to bring technology into better balance with nature. Ecologists tell us that the survival of all living things is dependent on the proper function of the cycle of biological processes in the earth's ecos--a Greek word meaning "habitation" or "whole habitat."

Modern man has linked his productive economy to precisely those features of technology which will destroy the environment by disrupting this vital cycle of processes. Frederick Smith, a prominant ecologist, recently estimated that this country is deteriorating the environment at the rate of 30 billion a year. It would cost this much to keep it from getting worse. It would cost more to improve it. Many others have joined this chorus, stumping the country like a modern day Malthus telling all who will listen we are all doomed if we don't control population growth. All this goes on with scarcely a voice raised to challenge such arguments. In Genesis God admonishes man to be fruitful and multiply. I know of no biblical quotation that tells man to limit the population.

It is easy for the demographers of doom to conclude it is only a matter of time until the government will find it necessary to regulate population expansion, perhaps to adding chemicals to the water supply, a step Medical World News says will be technically possible one day. The alarmists have won a considerable following on campus and off, largely because of a widespread and ligitimate concern about the quality of life, especially in the cities. But would the quality of life become materially better just through the halt in population growth? Is it necessarily true that more people create more crime and pollution? And is it a fact that we are multiplying so fast that the world cannot sustain us for long?

Census figures for 1970 reflect a continued but subsiding flight to metropolitan areas on the two coasts. While people have been migrating into cities and suburbs, states like the Dakotas, Wyoming, Mississippi, and West Virginia have been losing population, leaving vast open spaces that were once inhabited, so over-population density isn't a problem. The United States has only 56 persons per square mile versus 588 for England and 975 for Holland, but unplanned urban sprawl certainly is, with almost two-thirds of our population now living in metropolitan areas.

Such concentration of population in crowded cities is a problem that can be attacked by any number of means short of chemicals in the water supply. Formation of new cities with proper planning and tax incentives for industry to relocate might be one consideration.

As for the availability of resources to sustain growing population, the explosionists see these being depleted in another 80 years or so. We may indeed run out of such resources as oil some time in the next century but in all likelihood not before adequate substitutes are found, be they nuclear or something yet unheard of. The only certainty is that Mr. Erhlich is as wrong as the ancient Greeks when he says as they did, "We know almost exactly what technological advances are possible."

Oil and non-renewable resources will be exhausted eventually whatever the earth's population. Likewise the problems of crime and pollution can't be reduced to mere numbers. Great Britain, with a population density of ten times that of the United States, has fewer murders in a year amongst its 50 million population than Chicago or Cleveland. A slum or moral decay may breed crime. Most population density can't be planned. Pollution isn't just a numerical ratio either, as evidenced by the fact that Stubbenville, Ohio recently won top Federal rating as the sootiest city, yet the population explosionists contend factories like the Stubbenville steel mills are needed to support our growing population and fewer people would mean less demand and therefore less output and less pollution.

This is right to a point. Idle factories certainly won't pollute air and water the way some producing ones do, but plenty of problems would persist. Los Angeles would still have plenty of smog without the addition of a single resident or a single automobile, and Lake Erie would remain ecologically moribund without the addition of another drop of mercury. The major point the doomsayers skirt is the added people they blame for creating the problem might also be the help in finding solutions to the problem. More people paying more taxes would help provide the sums necessary for programs to control pollution.

I might mention pesticides. Certainly this is an area that has received considerable attention of late. Perhaps you have been asked why we need pesticides. Man is dominant on this planet. To achieve and maintain this position he has brought about ecological changes to work in his favor. Man has added this for the balance of nature so that he could eat and remain healthy. Left alone insects would abound in teeming trillions. If undisturbed weeds would take over the land. If uncontrolled, rodents would create catastrophies comparable to those from the dark ages in the eighteenth century.

One way to change the balance of nature is to grow crops instead of weeds. Man has fostered the growth of hugh herds of cattle and poultry instead of allowing these animals to grow wild according to natural selection. He strives to manage food growth instead of remaining a hunter. All these acts are contrary to nature.

Most of the things we do are contrary to nature. When we build a home we take from nature's resources for the structural material and needs to construct a home. We do this to protect ourselves from the heat and cold. Land in its original state needed plowing, rocks had to be removed, it might have to be fenced, drained, and tiled. If it is acid the addition of lime is necessary to make it productive. But as soon as man abandons the land it reverts back to its original state. It grows weeds instead of crops; the tile deteriorates; the potholes fill with water; and it is no longer productive. Nature--the kind that the romantacists want to keep in balance--is an unrelenting enemy of man. This is the part of the balance of nature's perspective all of us must see and understand.

Man is dominant on this planet. To achieve and maintain this position he has by necessity and plan been forced to change ecological checks and balances so they work in his favor. Some gifted writers have effectively managed to persuade many people--including some politicians--that the balance of nature should not be disturbed and even some scientists back this romantic concept of the balance of nature.

We are fortunately discovering the evils of pollution but many of the good things we do to control the balance of nature in our favor are now being illogically questioned. If we lose our perspective we can go backward and lose the balance of man. The news media recently had a news release explaining a large area of a southwestern state being sprayed with 2-4-5-T and followed with a scene of a crippled duck, a crippled lamb, and a baby with a stomachache, with the unuendo that it was caused by the chemical. I'm not defending 2-4-5-T but they did not have proof any of the injuries were from this chemical.

Numerous instant expèrts, articles, and exposures of this kind often create emotionalism that sometimes lead to a verge of hysteria and often hasty legislation follows. The American Medical Association has stated there is no evidence to date that humans are appreciably affected by the long-term ingestion of the minute traces of pesticide present in raw and processed food.

It is possible to find minute traces of pesticides in our waterways because of our extremely sophisticated instruments which can detect presence of chemicals in parts per million--billion--trillion. If I were to venture a guess I would say that with today's instruments nitrates could have been detected in the Missouri River 100 years ago. As R. G. Van Buskirk states in his May 16th article in The Grower, Quote,"What could it be like without pesticides as man becomes less of a hunter and more a farmer. He could not cope with insects but by now he could recognize them as an enemy." Unquote. He felt insect infestations as being supernatural, from which there was no escape.

In the Middle Ages, between 540 and 590 A.D. all the known world was ravaged. The Plague killed as many as 10,000 a day in Constantinople alone. In 1348 and 1349 one-fourth of the European population was destroyed. People didn't realize fleas carried Plague from rats to humans, so sick people were burned. Plague still lurks in parts of the world, ready to kill. Gradually man has learned about sanitation, microbes, viruses, and disease carrying insects, but it took centuries before he found out how to protect his crops.

I'm not trying to say, "Keep all the chlorinated hydrocarbons." Far from it. But pesticides have been caught in the mainstream of ecological concern and the record shows that pesticides help man to have the basic essentials of life.

Viewing the present state of affairs, man needs to seriously study the problems of what will make it possible for man to live with himself and with other people. Somehow we will have to domesticate mankind so that he will not destroy himself by one means or another. It may be that the very magnitude of our difficulties will provide the impetus for more people to pay attention to the general predicament.

Buckminister Fuller, in his article, "Vertical is to Live--Horizontal is to Die" observes how the consciousness of the consequence of carelessness forces a person to be careful. The airplane mechanic, as an example, recognizing that lives can be endangered if he does his work poorly exercises the greatest care when performing his professional duties, but like all mechanics at the end of the day he gets into his car and is just as foolish as everyone else.

Perhaps the time has come to recognize that we are really dealing with survival of man, as much on the farms as in preparing a plane. People may have to become so inter-dependent and human problems may have to become so threatening that our society will not survive the free wheeling behavior on the part of industry and the farmer any more than the plane would remain in flight if the mechanic took the same attitude. As J. H. Field once said, "All worthwhile men have good thoughts, good ideas, and good intentions, but precious few of them ever translate those into action." Unquote.

The logical question arises then, "Can man have a high standard of living with all sorts of comforts and at the same time have a clean environment?" Russel Train, the government's top advisor on environmental problems says that he believes, quote, "A high standard of living is compatible with a good environment. With present fuels, technology, and methods of generating power it seems hard to believe that we can keep on consuming as much energy as we do in the United States and maintain a complete environment. Looking ahead we can expect alternative sources of energy which are substantially non-polluting. We may have power generated by fusion, as an example, and we may learn how to utilize solar energy. Scientists say that controlled fusion reaction will be virtually 100 per cent efficient. That means there will be no waste problems to pollute the air or waste heat to create thermal pollution of water." Unquote.

The point I am trying to make is, given time industry can satisfy the seemingly insatiable appetite for food and energy if sound, long range planning can be made. We cannot discuss pollution and social problems in today's rapid transportation and communication without involving everyone. If technology can solve our pollution problems and still maintain a high standard of living, then how about rural America and its social structure?

As the clock of history ticks on rural America continues to adopt new technology, but along with this in our production phase of existence we have created many problems. The exodus of rural peoples to urban areas continues but at a much slower pace. The out-migration of rural people is out of context with the old settlement pattern which was based on the speed of travel. At the time towns were established the mode of travel was the horse. For some reason we seem to live in 60 minute communities, so it was natural that towns be spaced about 8 miles apart, as a horse travels about 4 miles an hour.

We still live in the 60 minute community, but with today's mode of travel we travel about 50 miles an hour, or about 12 times the speed of a horse. The time is the same but we travel 12 times as far. Our schools, churches, and groceries have become centralized and are much larger. This pattern does not make for more and smaller towns; rather, just the opposite--large towns farther apart.

As I think back 40 years threshing was a community project. Seven or eight neighbors and ourselves spent 10 days to two weeks getting the job completed. Today one man and a large combine can perform the same function in less time than our entire crew. This improvement in performance is not singular to any given segment. To make it possible to increase man's performance manyfold it has been necessary to change the structure. As an example--a 7-bottom plow performs the same function as a 1-bottom plow except that it is seven times as fast. This is made possible by the structure that holds the units together. It seems to me we should apply the same principle to our rural community. They must work together to develop a workable structure so each can perform its own function in harmony with the community. For each small town to expect to attract large industry is unrealistic. I live in a small town (Lewisville) of 300 people. If Truman, a town of 1250 seven miles to the south, gets a new industry it is a great asset to Lewisville as well. Or if Fairmont, a town of 10,000 seventeen miles south, grows and gets more industry it helps us. It takes a community structure to bring towns and villages in harmony to cope with the changes imposed on us by technology.

We have a striking example of what happens when there is individual innovation and the absence of group innovation. Farmers, as individuals, are innovators in the area of production but farmers as a group have resisted to be innovators in the area of group programs. In the words of Dr. E. W. Mueller, "I am of the opinion that this countryside will not develop until people in the countryside have viable planning levels, community educational courses, face the problems of human relations and make a committtment to their group. People must constantly appraise their changing social situation, develop more adequate social structures, so the basic qualities of human relationship established by God, such as justice, orderliness, wholeness, freedom, initiative, human fulfillment, compassion, love, and others are more fully expressed." Unquote.

Throughout our history our greatest resource has been our land. We have treated our land as if it were a limitless resource. Traditionally Americans have felt that what we do with our own land is our own business. This attitude has been a natural outgrowth of the pioneer spirit. The time has come when we must accept the idea that none of us has the right to abuse the land and that on the contrary, society as a whole has legitimate interest in proper land use.

The Bible tells us that God gave man dominion over all the earth and over every living creature on it and man has misinterpreted this injunction as a license to exploit rather than a conferral of responsibility. Man indeed has dominion over all the earth but this puts him under grave obligation. Morally no society has the right to over-utilize the world's resources for its own contemporary and selfish interest.

Man must understand biological society and conduct his affairs in such a way as to improve the quality of life rather than degrade it through wanton exploitation. We deal in a finite world where many changes and processes are irreversible. When those that are non-renewable are consumed or transferred they cannot be replenished. Complex genetic material, once destroyed, cannot be recreated in a laboratory.

We, as a nation, have become so engrossed in technology in almost every area of potential--and it seems right that we should do this--but along the way man has become less important. Machines tend to run man rather than man run the machines. Material wealth has become more important than conscience. We know more about war than we know about peace. We need to take a new look at our value system. Somehow we seem to have missed total fulfillment. Being the richest man in the graveyard does not seem like the ultimate. The free enterprise system works--it will create production--but this does not give the strong the right to exploit the weak. We cannot be truly a great people or nation if we don't stop long enough to help the less fortunate in our short appearance on the stage of life.

FARM CHEMICALS AND WATER POLLUTION

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INTRODUCTION

The terms "Pollution" and "Contamination" have in recent years become household words among the American public, and around the world. From newspapers and magazines, radio and TV, generally more concerned with circulation and Nielsen ratings than with objectivity and veracity, has issued an incessant stream of propaganda to incite and alert the public to the possible dangers and hazards of environmental pollution.

It has been deliberately made to appear that this is an entirely new peril to mankind, induced solely by the invidious ravage of modern man, his technology or science, and has been aided and abetted by the chemical industry in general and the agricultural chemical industry in particular. A new vocabulary has been introduced to denote new concepts, including such terms as "ecosystems", "bionomics", "territorial integrity", "behaviorism" and "biotope", which often actually defy concrete definition and convey nothing but a sense of overwhelming confusion to the general reading public.

The fact remains, although not widely recognized, that life everywhere has always been threatened by pollution and the hazard of contamination, that reduction of one form of pollution, be it animate or inanimate, in one place generally creates another, hopefully less injurious or annoying contamination elsewhere; that pollution is a relative matter, the hazard of which depends entirely upon the biochemical activity of the substance involved, its rate of decay or conversion, the nature of the degradation products, the route, degree and frequency of exposure to humans, domestic livestock, wildlife and crop plants and their relative capacity to metabolize such compounds.

Solution to Pollution - Dilution

Classically "the solution to pollution is dilution", and this is still the general approach in most areas of the world including the United States. This concept is, however, manifestly obsolete today particularly in the concentrated populous regions, for the abundance and diversity of pollutants is rapidly running out of diluent in many areas.

Major water courses often have to accept effluent outfalls while still heavily polluted with preceding effluent outfalls upstream. The Delaware River is a precise example of this piling of Pelion on Ossa.

On the other hand, today, the public is often erroneously informed that pollution occurs when any undesirable substance, regardless of amount, is present. This completely ignores the age old axiom, attributed to Paracelsus that "the dose makes the poison". For as toxicity is a function of the combined impact of concentration, exposure and metabolism, pollution by any substance or group of substances must be related to both the quality and quantity of the contaminants.

Were a single gallon of water with all its molecules dyed red completely dispersed through all the waters of the earth, a gallon of the diluted product would still carry

60,000 red molecules from the original gallon - contamination perhaps but not pollution. Similarly a pound of DDT spread evenly over the 48 contiguous states would deposit about two billion molecules of DDT per square foot - again contamination but one of pharmacologic insignificance.

Actually much of the clamor concerning pollution today in the lay press constitutes more an accolade to the fantastic precision of analytical techniques and modern instrumentation rather than to indicating hazardous contamination. In the case of the pound of DDT, spread over the United States, for example, modern technique could detect the presence of DDT collected from 1000 square feet of such treated land. Lamar et al (1965) reported the qualitative - quantitative identification and assay of 10 ppt of lindane, aldrin, and heptachlor epoxide in river waters. As the samples collected were 4 liters, 10 ppt indicates a total weight of pesticide of 4×10^{-8} gms= 40 nanograms/sample. This is equivalent to 86, 66 and 64 trillion molecules of lindane, aldrin and heptachlor respectively. A compliment to modern analytical technique perhaps, but certainly not a hazard to man or his environment.

Pollution Is Ubiquitous

Despite the recent horrendous and alarming clamor concerning the present contamination of food, water and air, the fact indisputably remains that all food and all water and all air is contaminated and to varying degree is therefore polluted all the time and always has been. Indeed, there is ample evidence from germ free or gnotobiotic studies, that some modest exposure, particularly in early life, to a variety of bacterial viral, fungal and worm infections and substance exposures, is actually prophylactically beneficial, and that such subclinical contamination elicits tolerance and resistance to subsequent serious insult, which in later years might otherwise prove to be fatal. Certainly those who have encountered "Montezum's revenge" (bacillary dysentery) and other acute reactions while on foreign excursions following exposure to "contaminated" exotic foods and waters, are familiar with the distinct limitations of a "glasshouse" rearing in an environment of limited exposure.

This is, of course, no plea for abandonment of sanitation, caution or control of the insertion into the environment of substances of high or unknown acute or chronic toxicity, but merely to regard the problem in focus and reality. For despite the current furious accusations and raging denunciations of modern Western agriculture and food processing, we actually live in a healthier environment, eat cleaner, nutritious and more abundant foods, drink safer water, breathe cleaner air, dwell in more sanitary houses, located in better appointed towns and cities and reveal the effect in longer, more secure and productive lives than does any other contemporary nation on earth or even since history began.

There is, of course, much yet to be done to reduce pollution in our environment, to rid our bodies of undesirable contaminants both viable and inanimate; and with calm, objective, scientific collaboration, of all concerned in industry, in education and in government we can achieve these improvements.

As our population doubles to 400 million over the next 30 to 40 years, these needs will become increasingly as acute all over the nation as they are in some areas at present. The solutions to "Peopollution" are not insuperable, although they will unquestionably be expensive. Fortunately the technology, implements and finance are actually currently available.

One favorable facet of an aroused public is that Congressional and State Assembly members are exceedingly sensitive to the public concern over environmental pollution and consequently are amenable to the appropriation of funds for meaningful and effective research into the problem.

DEFINITION AND CLASSIFICATION OF POLLUTION

"To pollute" can mean several things--e.g. to defile, to desecrate, to profane--but in the sense related to the environment, it means essentially - "to render unclean" and suggests a loss of purity or cleaness through contamination, which in turn raises the qualitative--quantitative questions of what is "pure," "clean," "contamination." As Hammond (1960) puts it:

> "To the popular mind...the term pollution appears to connote something sinful; the sullying of something previously without spot or stain, the destruction of purity."

Little do they realize this embraces virtually everything on the planet. To avoid a hopeless entanglement in semantics we refer to: -

Pollution--as the introduction (or contamination) into man's environment--air, food, water, soil, etc.--of a deleterious substance(s) living or inanimate, in sufficient quantity and/or frequency to constitute a danger, hazard or inconvenience to the health and well being of man and his favored plants and animals be they domestic or wild. Admittedly these constraints are open to debate, for what are favored plants and animals may vary widely among different individuals, groups, nations and even races of man. There are, however, some creatures on the planet for which surely no man would pine, e.g. malaria, the anophelene mosquito, trichina, syphilis, poison ivy or dodder. Certainly we must all agree that the purpose of conservation is to conserve man and all those animate creatures and inanimate creatures which contribute to his conservation of mind, body and soul (Kesteven 1968). Anything else is not conservation but merely conversation. Within this definition dilution does indeed reduce the hazards of pollution; although as the source of all needed elements and the storage for all pollutants is clearly limited on this spaceship Earth, our approach to depollution must become one of restoration, a cyclical resource renewal into which our sole investment is energy, time and intelligence.

MAJOR AREAS OF POLLUTION

There are three distinct areas of our living environment, or biosphere, which are constantly prone to pollution: -

1. Air 2. Land and 3. Water

1. Air pollution - is primarily an urban and industrial problem of effluvia (smoke, soot, gases) from factory stacks, building chimneys and auto and other engine exhausts. It is essentially a localized economic and distinctly political problem, and as there is already the equipment and methodology to reduce these sources of air pollution substantially, their continuance can only be regarded as political problems. Agricultural contributions to air pollution are negligible except for wind erosion of soils, which at one time was exceedingly serious, but which is now generally well controlled. Air pollution from fertilizers and pesticides is quite localized, fleeting, limited in effect and essentially insignificant.

There is often complaint, particularly from suburbanites and exurbanites, concerning manure odors from nearby farms, chiefly poultry farms, and many legal actions have been instituted against farmers to force their removal from the locality involved. Again this is entirely a political and aesthetic controversy, for the pungent and arresting odors emanating from decaying chicken manure are quite harmless. Fortunately, management procedures can usually adequately control this relatively minor problem.

There are also natural sources of air pollution including volcanic gases, swamp fermentations and even certain emanations from forest verdure. Probably the most serious form of air pollution in the long term comprises carbon dioxide which if continued at its present rate, as pointed out by Lamont Cole, will within a thousand years, induce a significant greenhouse effect which would elicit substantial changes in terrestrial climates and produce marked effects in the biosphere. This situation can, however, be completely obviated by an increase in the photosynthetic surface, particularly of water surfaces by the massive controlled cultivation of green algae and other plants for multiple purposes of depolluting fresh waters producing new sources of livestock feed and industrial raw products, and releasing vast amounts of oxygen into the atmosphere.

2. Land pollution, or specifically soil pollution occurs when it becomes overloaded with industrial and municipal wastes and effluents, and in some cases by the excessive and repeated application of certain agricultural chemicals which tend to persist.

   Soil pollution itself is essentially a local condition and is of minor significance to the public at large. It is when these contaminants enter the surface waters in run off or reach the aquifers beneath by percolation and thence travel long distances to enter streams, rivers and estuaries and pass into domestic water supplies en route that serious concern arises.

3. Water pollution - of the three types, water pollution is by far the most serious and currently the most pressing. Water pollution has four major sources: -

   i) Municipal sewage and septic tank effluents
   ii) Industrial effluents and operations
   iii) Agricultural operations
   iv) Natural sources

   i) Municipal sewage and septic tank effluents are unquestionably the major source of water pollution in populated areas. In many municipal sewage plants present treatment is quite rudimentary and generates outfalls into open streams and rivers at excessively high carbonaceous levels of Biological-Oxygen-Demand (BOD).

   Virtually all municipal sewage plants, even the most advanced, however, make no provision for reduction of soluable nitrogen and phosphorus levels, which when released into open waterways stimulate excessive algal blooms, that in turn amplify the BOD. The soluble phosphate now enhanced by the general use of household detergents, is usually quickly absorbed on to organic and soil particles and tend to accumulate on benthic deposits, but the nitrogen is oxidized to nitrate and continues into downstream water supplies, whence the cycle is repeated and frequently amplified.

From septic tanks in concentrated built-up areas essentially the only significant contribution into aquifers is nitrate nitrogen. Occasionally organic matter--e.g. bacteria--may slip down subterranean rock fissures into surface ground waters that feed shallow wells and may provoke a pollution problem, but these instances are essentially local and of minor import.

ii) Industrial wastes constitute a major source of water pollution and comprise both organic effluents of high BOD such as the cellulosic wastes from pulp and paper mills and inorganic effluents heavily loaded with various minerals including phosphates, calciumsalts, sediments and various organic chemical by-products. These may in themselves be toxic or generally deleterious, or they may degrade or react into undesirable contaminants. Most states and municipalities exert quite rigorous control over specific highly toxic industrial effluents but the general run of industrial waste out falls is astonishingly poorly controlled in many areas (Carter 1968) and results in enormous areas of pollution, such as the 25 mile stretch of the Houston ship canal draining the effluent of a hundred factories into Galveston Bay (Eckenfelder et. al. 1969) or the Cuyahoga River which serves as a cloaca maxima to drain sewage from Cleveland into Lake Erie and was so contaminated with oil recently that it actually burst into flames.

Unquestionably among the populated industrial states contributions of pollutants to the total environment from agriculture and ancillary sources is relatively insignificant. Frink (1969) recently estimated that the contribution of nitrogen pollution to the Connecticut environment from various sources is: -

Source	M Tons N	%
Industrial Smoke	44	33.0
Auto Exhausts	38	29.0
Domestic Wastes	16.5	12.5
Animal Wastes	13.5	10.0
Animal Feeds	13.0	9.8
Agricultural Fertilizer	4.6	3.5
Non-agricultural Fertilizer	2.8	2.2
Total	132.4	100.0

Though the major contribution of nitrogen occurs as air pollutants (8 2 M tons or 62%), much of this gaseous nitrogen perhaps 40% is returned to the earth (or sea) by precipitation and direct absorption (Malo and Purvis 1964). Thus considerable quantities of industrial sources of waste nitrogen can find their way directly or indirectly into streams and lakes and generate the eutrophication against which conservationists complain and for which Commoner (1966) accuses agriculture.

Add to this the excessive contribution of nitrogen to aquifers from even the most advanced of municipal sewage treatment plants and one obtains a figure of at least sevenfold the total quantity of nitrogen applied as fertilizer in the case of Connecticut. In the case of New Jersey the difference would be even greater. Furthermore, as discussed later, the proportion of nitrogen applied as fertilizer that actually percolates to the aquifers or surface washes off into streams and rivers, probably does not exceed 10% on average, the differential actually approaches 70 fold.

Without penetrating the details and data any further one wonders from where Commoner could have gathered his preposterous ideas, except that it currently seems both fashionable and perhaps profitable to carp and criticize the agricultural chemical industry, blaming it for all the irritations and frustations of modern America.

Pennsylvania-Jersey-Deleware

The immensity of the water pollution problem is typified by a major mid-Atlantic region comprising parts of three states.

The Pennsylvania-Jersey-Delaware area located at the southern end of the Delaware River basin provides a model for the intensifying water supply and pollution problems, which are necessarily interrelated, that are developing in numerous other similarly congested areas all over the U.S.

This area comprises some 377 municipalities distributed within 11 counties of 3 states. In 1960 the combined population exceeded 5 million, and is expected to go above 8 million by 1980. There are over 100 major industrial plants in the region. There are estimated from meteorological records to be available in the area 3.5 billion gallons of water/day; in 1964 use of water was already 2.9 bg/d. It is estimated demand by 1990 will exceed 7.5 bg/d. This clearly bodes a collision course with disaster. Water pollution in 1965 was estimated at 225 million lbs. BOD/yr., with an anticipated increase to over 335 million lbs. BOD/yr. by 1975. To add to this incredible pollution burden, in 1959 Philadelphia released daily into the atmosphere 830 tons of SO_2, 300 tons of NO_2, 1350 tons of hydrocarbons and 470 tons of miscellaneous particulates. This air pollution enhances the already overwhelming water pollution, for within 15 miles of the city perimeter some 7000 tons of fall-out per month is observed, some of which obviously falls directly onto water courses, while additional amounts reach the water ways from the land. Finally the city in 1964 was disposing of 2,000,000 tons of solid wastes per annum by land fill, which also contributes to water pollution from surface run off and drainage. This item is expected to reach over 8,000,000 tons per annum within 30 years.

When this is amplified by comparable pollutive contributions from the other 376 municipalities the Pennsylvania-Jersey-Delaware area could understandably sink beneath the towering burden of its own detritus within a quarter century. (Presidents Sci. Advisory Comm. 1965.) Three points are, however, obvious from the Panel's Survey; first the miniscule contribution of agricultural chemicals to this massive pollution is insignificant, second, the Pennsylvania-Jersey - Delaware area and its people will run out of potable water before they exhaust either air or space and third, it is an area where immediate measures of research and development leading without impedence to application are essential if this major mid-Atlantic area is to survive as a viable socio-political economic area.

ECONOMIC-SOCIAL EFFECT OF NITROGEN FERTILIZER

Apart from the myriad technical papers, and experimental station reports which attest to the absolute necessity for regularly applied nitrogen fertilizer to maintain crop yields, Tanner (1968) has made an extraordinarily interesting study of the relation between nitrogen fertilizer use and economic development among various nations, and finds a direct correlation between the Fertilizer Nitrogen Equivalent Diet (FNED) and income for 19 countries. As income rises the relation to FNED becomes flattened to a steady state around 80 lbs./cap/annum.

Based on the FAO and WHO standards for human protein requirement of 70g protein/cap/diem equivalent to 55 lbs./protein/cap/annum or 8.8 lbs. N and assuming half of this needs to be animal protein with a conversion efficiency of 15% and the other half plant protein with a conversion efficiency of 50% this computes (4.4/.15 + 4.4/.5) to 38 lbs. fertilizer N/cap/annum. This extended over 3 x 10^9 humans aggregates 57 million tons of nitrogen as the minimum plant nutrient requirement to maintain the present human population--about three times the present world production of nitrogen. From this can be deducted the nitrogen precipitated from rain, dust and other fall-out, physical and biological nitrogen fixation, and additions released to the land as animal and plant wastes.

On favorable arable soils in humid temperate latitudes it requires from 2 to 2.5 acres of land to provide about 38 lbs. of nitrogen from these natural sources. Thus under ideal conditions for crop and livestock production it would require (2.5 x 2 x 10^8) 500 million acres of optimum arable land to sustain the population of the U.S. at a bare subsistence level of protein intake, allowing nothing to be lost to flood, drought, frost, insects, disease or weeds, providing no carry over for future crop or livestock failures and certainly leaving nothing for export to other hungrier nations.

The American diet is actually considerably above bare subsistence in terms of daily protein intake for it is about 100/gms in quantity and very much higher in quality being 70% animal and 30% plant protein; furthermore losses to pests are at least 10% even with the use of the much maligned pesticides, while flood, drought and windstorm losses are on average at least 5% nationwide and another 5% is required for carry over. This aggregates to a total Fertilizer Nitrogen Equivalent (FNE) of 81.2 lbs./N/cap/annum or a total of 8.12 million tons of nitrogen per annum to maintain the food supply of the present U.S. population at their current average diet level. To this must also be added the 850,000 tons of nitrogen required to produce some 15 to 17 million acres of cotton, and another 500,000 tons of nitrogen at least to maintain home gardens, lawns, parks, golf courses, highways, turf farms, etc. Total U.S. nitrogen production for all industrial and agricultural purposes in 1967 was 5.5 million tons or about 60% of that required to meet the dietary needs of the people. The balance is derived from fixation and absorption of atmospheric nitrogen from animal wastes and from reserves of nitrogen still available in our more fertile soils.

The virgin corn belt soils in Iowa for example once carried 0.6% N or (2 x 10^6 x .006) 12,000 lbs. of nitrogen per acre. Today following a century of crop depletion, elution, erosion and denitrification they respond favorably to applied nitrogen fertilizer.

During the period 1948 to 1957, examined by Tanner the FNE Diet in the U.S. was 65 lbs./cap/annum, which for the population at that time totaled 6 million lbs. of nitrogen, or about double the amount produced as mineral fertilizer nitrogen. Therefore more nitrogen was withdrawn from U.S. soils as crops and livestock during those years than was replenished as mineral fertilizer. Today, twelve years later we are consuming over 8 million tons of nitrogen in our diet and are returning annually about 60%.

Interestingly, Tanner computes that as the FNED approaches 80 lbs. N/cap/annum the curve flattens and no further increase in nitrogen requirement per capita will occur regardless of any further rise in income. When the maximum food needs, as protein, are met per person further increase in fertilizer nitrogen applied to the soil can come only in response to an increasing population. The U.S. has virtually reached this stage now.

There may still be a further shift from vegetable proteins to the more costly and less efficient animal proteins, though this seems rather unlikely, as U.S. consumption of animal protein has already reached over 7 times the absolute minimum daily requirement.

Supplements of fertilizer nitrogen instantly available to rapid crop plant growth are therefore clearly on the critical side and must be increased as the population enlarges and available arable lands decline or both the dietary standards and the income standards of all our people will inexorably decline.

Furthermore the cultivation of crop soils encourages losses from denitrification, which can reach 10 to 20% of that applied under favorable conditions. (Verhoven 1952; Schwartzbeck et. al. 1961.) Bremner and Shaw (1958) even noted losses of gaseous nitrogen in excess of that applied, indicating conversion of organic nitrogen reserves. In addition there are substantial losses of soil nitrogen and phosphates from wind and water surface erosion. It has been estimated that 1.75 billion tons of organic nitrogen has been lost from the cultivated soils of America within the past century. This averages out to over 50 lbs. N/A/annum, and constitutes the main factor in the fertility depletion in our cultivated soils. It is clear that unless this essential fertility is continually and adequately replenished, not only the food and fiber productivity of the nation will disastrously decline but with it will shrink the total national economic and social standing also.

For despite the enormous growth of American industry, we remain basically an agrarian nation with all of our urban, suburban and industrial complex resting solidly upon our food supply, which in turn depends entirely upon our soil fertility and the science and skill of our farmers to convert it into food and fiber. Should this base be disrupted or destroyed there is no other nation to which we could turn for food and our position of pre-eminence in the world would precipitously decline.

The specious argument of Commoner (1966) that "it will become necessary...to impose severe restrictions on the present unlimited use of mineral fertilizers in agriculture" is therefore totally untenable and unacceptable on socio-political and economic grounds if the nation is to be fed adequately regardless of whether we continue to aid less advanced peoples with food support until they can themselves become self-sufficient.

SOURCES OF NITROGEN POLLUTION OF AQUIFERS, AND WATERWAYS

As a result of the formidable concern over water pollution in general and that allegedly attributable to nitrates in particular a number of experimental stations, geological survey units and some public health offices are currently assiduously investigating the possible sources of nitrate and phosphate contamination of the nation's waterways. There are at least 50 major Federal research projects currently active in various states that are directed specifically at the problem (U.S.D.I.-1968), and from these studies there will undoubtedly issue valuable data and methods for dealing with the problem.

Municipal Sewage and Septic Tank Sources

For the more populous and industrial areas of the country the major sources of nitrogen and phosphate contamination of waterways and aquifers are municipal and industrial effluents, as discussed earlier for the Penn-Jer-Del region, and sediment wash-off from building sites streets and big highways, parking lots, airports etc.

The Environmental Pollution Panel

The President's Science Advisory Committee (1965) reported that 125 million people in the U.S. were served by domestic sewers, the sewage from 13 million of these people was actually discharged raw into the nation's waterways, that effluent from an additional 30 million people was also discharged after only primary treatment, and as most of the older cities had no provision for a separate system of storm sewers, overloading was frequent during periods of heavy rainfall and spring thaws and at such times the systems had to be discharged raw into the watercourses. The total effect of this insult to the environment is equivalent to the raw sewage discharge of over 50 million people.

Furthermore sewage effluents, whether or not treated by the archaic methods still practiced, carry considerable quantities of nitrogen, phosphorus and other plant nutrients and comprise the principal source of injurious over fertilization and eutrophication of rivers, lakes and estuaries. The nitrogen in such effluents inevitably enters water treatment plants and continues into the potable water supplies of many communities.

Add to this the effluent from septic tanks employed by some 80 million people, 20% of the nitrogen fraction of which, probably reaches the aquifers, on average, and the total insertion of urban and suburban nitrate into the nation's waterways far exceeds that contributed by agricultural fertilizers.

The U.S.P.H.S. has set a standard allowable tolerance level of 10 ppm of nitrate-N, but there are many occasions when this tolerance is exceeded several fold. Under such conditions it can contribute substantially to the incidence of methemoglobinemia among infants. Phosphates largely derived from detergents have also markedly increased in recent years in the nation's waterways, and induce algal and aquatic plant growth as much as does nitrate nitrogen.

Agricultural Sources

The total contribution to this pollution made from agriculture is relatively minor, although animal wastes from stock yards and intensive livestock units is a major water pollution problem in certain rural localities.

Fertilizer Nitrogen Losses in Cropped Soils

Obviously the potential loss rate of applied nitrogen is a matter of considerable concern to the farmer. Nitrogen is the most expensive nutrient he buys, and he is therefore continually on the alert to conserve it for conversion into saleable crops or livestock. He tries to add as much nitrogen as is needed for his particular climatic and edaphic conditions to yield optimum returns, and he is certainly no more interested in having his soil nitrogen leached into the aquifers than are the conservationists or the health officers.

There have, therefore, been numerous studies to assess the relative nitrogen balances sustained on various soils, in different climates and under divers cropping systems (Allison 1966). In general crops remove more nitrogen than is applied in the fertilizer.

In a study on the effect of contour corn cultivation on soil loss, run off and leaching of soluble nutrients, Van Doren et al (1950) recorded total nitrogen leached through tile drains to be about 3 lbs N/A/yr. an insignificant amount.

This compares to a tile drain nitrogen effluent in an Illinois study which recorded from 5.4 to 7.7 ppm of NO_3-N in one drain and from 11.1 to 17.4 ppm of NO_3-N in a second drain in weekly assays over a two month period following a fertilizer application of 120 lbs N/A as ammonium sulfate (Welch et al 1969). The higher levels occurred early in the season when the crop was small and were directly related to rainfall and flow in the drains.

Robertson (1969) concludes that as the aerial portion of field corn yielding 130 bu/A in Michigan consumes 210 lbs N/A and the average farmer applies less than 150 lbs N/A as fertilizer, there is generally a negative nitrogen balance, which is made up from soil absorption of atmospheric nitrogen plus depletion of native organic nitrogen reserves in the soil. He regards leachate into the aquifers as virtually insignificant and considers the only important loss of fertilizer nitrogen is from erosion that might fortuitously occur from heavy rain wash-off shortly following fertilizer application.

Timmons et al (1968) reported on the ammonium and nitrate nitrogen losses over a two year period from surface erosion on fallow ground compared to that under four cropping systems. With a 6% slope to the land the surface soil losses per acre of fallowed land were 3.8 and 10.3 tons per acre for 1966 and 1967 respectively which were 3 and 10 fold that lost from continuous corn 16 and 20 fold that lost from corn in rotation, and 10 and 380 fold that lost from oats respectively in each year. On hay land no surface soil was lost in either year. The coincident ammonium and nitrate nitrogen fertilizer losses were in all cases but one below 1 lb/A and the one case was 2.6 lbs of NO_3-N/A on the fallow plots in 1967 following a 4.63 inch run-off. The significant nitrogen losses from erosion occurred in the organic nitrogen which reached 90 lbs N/A on the fallow soil under the 4.63 inch wash-off in 1967. Nitrogen being readily available to plant growth is rapidly absorbed and removed from both leaching and erosion forces. Smith (1967a) reports a similar finding in Missouri.

Carry over data following a drouth season, from the Nebraska station on increments of applied fertilizer nitrogen up to 240 lbs N/A on corn and sorghum indicated that from 50 to 70% of the residual nitrogen remained in the top 24 inches. (Adams 1968). Incidently, there was more NO_3-Nitrogen at the 4 to 5 foot depth beneath the unfertilized plots than beneath those which had received fertilizer nitrogen. This was also noted in the Missouri studies of Smith (1967b), and suggests that as adequately fertilized crops grow better, a fertilized crop will leach less NO_3-N than one unfertilized.

A five year irrigated lysimeter (6 ft) study in California on four soil types (two sandy loams and two clay loams) on which were grown sweet corn and swiss chard successively each year, compared three sources of fertilizer nitrogen as ammonium sulfate, calcium nitrate and as ammonium hydroxide (aqua ammonia), with respect to the distribution of the applied nitrogen. Applications were increased from 200 lbs N/acre the first year to 600 lbs during the last year, with an annual average of 420 lbs N/A.

The distribution of nitrogen from the three fertilizer sources was the same both for that utilized by the crop and that which was leached. On average the sandy loams leached about 10% of the applied N, while the clay loams leached around 17%. The clay loams, however, had a higher initial organic and bound nitrogen content as judged from the fact that crops removed over the five years 131% of the applied N and there was, therefore, a surplus of nitrogen present which resulted in slightly more nitrogen leachate.

This rather extensive study even under conditions which favored leaching, indicates that only from 10-20% of the applied fertilizer nitrogen can be expected to leach from soils cultivated to short season row crops, even when nitrogen fertilizer applications substantially exceeded general farm practice (Pratt et al 1967).

It appears then that although nitrogen leaching from fertilized open cultivated soils will occur it is relatively minor compared to the erosion losses of organic nitrogen that can accompany sweeping rains, particularly on sloping soils that are not worked on the contour.

In general farmers still tend to hold their fertilizer nitrogen applications to below the optimum for economic reasons and continue to rely as much as possible upon residual native soil nitrogen and that derived from the atmosphere. Certainly as the native source declines with continued intensified cropping, additional fertilizer nitrogen will become essential to maintain or increase yields, and it will be economically essential to monitor carryover nutrients each season to meter the fertilizer to the precise needs of the crop and to avoid excessive leaching of nitrate into aquifers.

To avoid excessive losses of fertilizer nitrogen through leaching and run-off the following recommendations are made by Sommers (1969).

1. Apply fall nitrogen only as ammonia when soil temperature is less than 50°F.
2. Apply fall nitrogen only on medium heavy soils - never to sandy soils.
3. Apply off-season nitrogen only to soils not susceptible to erosion.
4. Incorporate broadcasted applications immediately by discing.
5. On well drained leachable soils apply nitrogen in repeated small increments.
6. Avoid fall applications on poorly drained soils that tend to pond or wash off.
7. Avoid high level nitrogen applications on soils that are subject to drouth.
8. Meter fertilizer applications to crop needs - avoid excess nitrogen.

Animal Wastes

U.S. livestock produces over 1 billion tons of fecal wastes per annum, plus 400 million tons of liquid wastes, which combined with litter, abattoir paunch refuse and dead carcasses aggregates over 2 billion tons per annum. On a dry weight basis this is about 600 million tons. The nitrogen content depending on species ranges from 0.5% to 5% N; a fair approximation would be 2% N. This amounts to 120,000 tons of nitrogen, most of it initially in the organic stage (protein, amines, urea, etc.). (Wadleigh 1968).

The economics and distribution of modern farming preclude spreading it on the land as fertilizer as in former years.

Incidently, for the benefit of the organic farmers, who insist that the only acceptable form of nitrogenous fertilizer is farm manure, a simple calculation reveals that if all the animal wastes could be spread over the 500 million acres of arable soils of the U.S. they would provide an average of 1/2 lb of N/A or the total manure production of the nation aggregates about 2% of the current fertilizer nitrogen use. Even if it were feasible to apply all the nitrogen from domestic sewage, this would still amount to less than 4% of the present usage. Were U.S. agriculture confined to natural sources of plant nutrients as recommended by Rodale (1960), the nation would rapidly starve to death.

Disposal of these animal wastes has become a serious problem in many localities where intensive cattle, sheep and swine feed lots, confined dairy herds and large broiler and layer poultry operations have developed, waste disposal constitutes a major management, health, economic and political matter. A variety of methods are under investigation, including heavy spreading or plow down, lagooning, feeding fish and livestock, burning, fermenting and drying and selling as slow release fertilizer for suburban lawns.

All methods employed to date either postpone the inevitable or allow it to occur immediately, sooner or later the material becomes leached the soluble nitrogen component either escapes into the atmosphere, leaches into the soil or washes off in heavy rains and in all cases ultimately reaches the aquifers.

Surprisingly, however, a relatively small amount reaches the aquifer through leaching for if the C:N ratio in the soil is held at 10:1 or greater, the preponderance of the soluble N returns to the organic form and either stays in the soil or moves very slowly.

Smith and co-workers (1967; 1968a; 1968b; 1969) (Keller & Smith 1967) have thoroughly investigated the possible pollution of aquifers from agricultural sources and conclude that whereas normal applications of recommended levels of fertilizer nitrogen contribute relatively minor amounts of soluble nitrogen to waterways and wells in Missouri, animal wastes do make substantial contributions from the combined effects of run-off surface drainage and leaching.

They emphasize, however, as both livestock production and crop cultivation become increasingly intensive, deeper soil profiles become contaminated where micro floral activity is minimal and elimination to aquifers can be expected to rise.

Nitrates in rural well waters at the present time, they conclude, come primarily from animal wastes, septic tanks and municipal effluents although part, at least, also comes from mineralizing of native organic nitrogenous humus, including legumes, and from mineral fertilizers. Their data, however, show that a greater proportion of the fertilizer nitrogen that leaves the land to which it was applied does so from surface erosion than by leaching.

They conclude, however, that although there is little evidence that nitrate in waters originates from fertilizer nitrogen at present, should growers go to substantially higher levels an increasingly greater proportion of applied nitrogen will enter the aquifers.

In spite of the loud clamor concerning nitrate pollution of waterways, Enfield (1969) recently compared the present NO_3-N readings on the Wabash River near Lafayette and noted no difference in the levels yearly from 1957 to 1963, which ranged from 4.9 to 6.9 ppm, and that recorded in 1906 at 6.4 ppm. Evidently in this major waterway the fertilizer advances in the surrounding agriculture have not been reflected in nitrate pollution as yet.

NITRATE ACCUMULATION IN CROP PLANTS

Nitrate poisoning of livestock, though a relatively minor cause of death among farm animals, can be a serious economic loss to a particular farmer, and to avoid it every livestock grower must be continually alert.

Under a specific combination of environmental conditions will promote excessive absorption of soil nitrates by plants that are not then rapidly converted into organic nitrogen - protein, and distributed into growth. Cloudy wet weather, which promotes nitrate solution and absorption often more rapidly than that required to meet the carbohydrate production of the reduced photosynthesis, will cause a temporary accumulation of NO_3-N. A foliar disease or insect pest that reduces the photo-synthetic surface may allow momentary NO_3-N accumulation (Brown & Smith 1967). Generally the C:N balance of about 10:1 is rapidly restored when conditions favorable to photosynthesis return and the NO_3-N converts to organic forms and is dissipated in growth. Even though such accumulations may be quite ephemeral, if the crop is harvested or grazed by livestock at the critical period the imbalanced C:N ratio which promotes high levels of NO_3-N in the plant sap may enter animals' or even humans' diet.

If the amount so ingested is excessive, the free nitrate nitrogen can readily become reduced in the gastrointestinal tract into nitrite nitrogen (NO_2-N) which upon absorption into the bloodstream converts hemoglobin, the oxygen transporting pigment of the blood cells, into methemoglobin, which does not transport oxygen. Cyanosis - "blueing" - occurs due to the oxygen deficiency and can become fatal.

Among livestock, ruminants, particularly bovines, are especially sensitive. Most short gut, monogastric animals including swine, poultry, dogs and man are generally resistant to this syndrome first because they do not ingest massive volumes of raw vegetation and second their g.i. tract is not populated with a suitable conversion flora. Even horses are not particularly prone.

Infant humans however, are quite susceptible to methemoglobinemia presumably because their g.i. flora have not as yet, settled into the normal spectrum, and also they are acutely sensitive to lowered oxygen tension in their blood.

Tucker et al (1961) conclude the factors which affect nitrate accumulation in plants as:-

1. The stage of plant growth - the vegetative or preblooming stage is the most amenable.
2. Excess available NO_3-N in the soil.
3. Abundant moisture supply.
4. Acid rather than alkaline soil reaction.
5. Relatively low temperatures i.e. $\overline{<}$ 55°F.
6. Reduced light intensity.
7. Impaired photosynthesis.
8. Low soil phosphate - abundant available phosphate retards NO_3-N absorption.

These conclusions are corroborated by Wright and Davidson (1964).

The toxic level of NO_3-N in plants is regarded as over 1.5% KNO_3 equivalent of dry weight or 2078 ppm N. Among the food and feed plants observed to attain toxic NO_3-N levels are: -

Human consumed vegetables:
- Beets
- Broccoli
- Celery
- Cucumber
- Carrot
- Kale
- Kohlrabi
- Lettuce
- Parsnips
- Rutabaga
- Radish
- Squash
- Spinach
- Turnip

Animal consumed forages:	- Barley	- Sugar beet
	- Corn	- Soybean
	- Mangel	- Swan grass
	- Oats	- Sorghum
	- Orchard grass	- Rye
	- Fescue	(Tucker 1961; Murphy et al 1967)

Brown and Smith (1967) assembled the known dose response evidence of NO_3-N for humans and livestock in food and/or water as: -

	NO_3-N
Acute toxic dose - humans	0.70 g
Chronic toxic daily dose - human adults	0.56 g
Acute toxic dose - cattle	13000 ppm B.W.
Maximum tolerance - human infants	20 ppm B.W.
U.S.P.H.S. - water standard tolerance	10 ppm

However, SATTELMACHER (1962) reviewing some 249 references, concludes the maximum allowable NO_3-N level in human drinking water is 30 ppm.

The recent criticism of nitrogenous fertilizing of food crops has been specifically directed at those vegetables which are processed into baby foods particularly, beets, carrots, snapbeans and spinach. Infants are exquisitely sensitive to NO_3-N toxemia, and a number of "blue baby" cases have been attributed to excessive NO_3-N in their food. (Walton 1951; Wilson 1949; Sattelmacher 1962; Whitehead et al 1962)

Critical field studies in Missouri, on ten vegetable crops, where nitrogen fertilizer applications ranged up to 400 lbs N/A as ammonium nitrate indicated that beets, spinach, lettuce, kale, turnip and mustard greens all tended to accumlate NO_3-N in direct linear response to the nitrogen applied; while radish, snapbeans, carrots and swisschard revealed a guadratic response to nitrogen fertilizer, as the NO_3-N accumlated leveled off at from 100 to 200 lbs N/A. There were indications that phosphate deficiencies enhanced NO_3-N accumulation in beet, turnip, kale, and leaf lettuce, but the observed data failed to be confident @ $P \leq 05$. (Brown and Smith 1966 & 1967).

A survey of fresh vegetables grown in five different states from California to Florida sold in grocery stores in Columbia Mo. between July and December 1964, indicated wide ranges of nitrate content between kinds of vegetables and production areas and as much as a 19 fold range for the same product from the same state. There was, however, no seasonal trend observed, nor any source differences. There were marked and rather consistent differences between kinds of vegetables.

Among those which showed NO_3-N readings above the danger limit (0.2% of D.wt.) were: - celery, endive, lettuce, squash, radishes, spinach and turnips among the fresh vegetables assayed and green beans, carrots, beets, squash, and spinach among the processed baby foods tested. (Brown & Smith 1967).

Modest normal intakes of any of these foods by adults would not elicit hazardous response from the NO_3-N. For infants, however, there is the possibility of approaching the toxic limit if such vegetable foods were consistently and predominently fed, particularly in combination with water containing upwards of 30 ppm NO_3-N. Unlikely as this coordination of circumstances may seem, the fact remains it can and indeed has occurred albeit very infrequently.

We must therefore take every precaution for reviewing and revising the fertilizer recommendations to vegetable growers and to monitoring NO_3-N in foodstuffs on a consistent and valid statistical sampling basis. Actually few vegetable crops will significantly respond on most soils in terms of yield to more than 200 lbs of N/A applied at one time. Therefore a restrained approach to nitrogen fertilization for at least those vegetable crops which tend to accumulate nitrate is just simple common sense, for such a program would be more economical, safer for the consumer, and would protect the aquifers against sudden insertions of nitrates.

PESTICIDE CONTAMINATION OF WATERS

As water is an essential component of all life, and as if usually flows great distances, any significant contamination of water constitutes not only a hazard at the point of insertion but often for extended distances down stream and for prolonged periods thereafter.

There are, however, three important mitigating factors which are generally either ignored or discounted by the critics of pesticides. First there is tremendous dilution as the compound courses the gathering waters, second the most persistent pesticides are exceedingly insoluble in water, and third even the most persistent pesticides undergo varying degrees of decay into less toxic derivatives. Each of these factors plays an important role in the detoxifying of agriculturally applied pesticides, and collectively they reduce the total impact of these necessary compounds on the aquatic environment.

Where serious incidents of water contamination have occurred they can invariably be traced either to accidental or irresponsible dumping of residual pesticides into streams, or, on occasion, to an unexpected severe wash-off by torrential rains immediately following a dust or granular application of a persistent insecticide to control soil insects, or, in a few cases to the ill-advised application of an unrecommended persistent pesticide directly to a lake or stream.

The often cited Clear Lake incident in California is an example of the latter. It is seldom mentioned however, that when the correct insecticide was employed, the fish rapidly repopulated, the grebes returned and the hoards of eye gnats, which had originally rendered the resort areas by Clear Lake virtually uninhabitable to humans, were suppressed to tolerable levels.

The argument raised to negate the dilution factor is that the phyto-and zoo-plankton and other biota of open waters rapidly reconcentrate the pesticide from the ambient water successively over the series of aquatic flora and fauna up the scale to the economically important fauna, such as fish and amphibians, to the extent that this so-called food chain results in magnification of the pesticide to the level where it becomes acutely or at least critically toxic to a favorable or desirable species. Equipped with the fantastically sensitive analytical apparatus currently available (Lamar et/al 1964; Rosen et al 1959; Skinde et al 1962; Wolfe 1963) a number of workers have indeed, been able to demonstrate successfully that certain aquatic species in the contaminated waters do indeed pool organo-chlorine compounds many fold. (Vance et al 1969; Sweeney 1968; Brocksen et al 1967; Crosby D. G. et al 1968).

Thus blue-green algae were reported to increase Dieldrin to 180 X, DDT to 268 X, Aldrin to 225 X, and Endrin 222 X, and certain green algae showed corresponding increases of

127 X, 270X, 143X and 156 X respectively for each of these organo-chlorine pesticides concentrating the compound from the ambient water, when the initial level of each was 1 ppm. This certainly appears to be a formidable magnification, but the level of 1 ppm also appears to be far above what would generally occur in drainage waters in the field under normal recommended agricultural use.

Thus levels of organo-chlorine insecticides reported in some 7 different rivers and streams draining agricultural areas in such widely separated states as California, Michigan, Texas and Ohio revealed dieldrin ranging from less than 10 ppt in Texas up to 70 ppt, in California, aldrin ranging from 10 ppt in Texas to 20 ppt in Ohio, endrin ranging from 20 ppt in Texas to 40 ppt in Ohio, heptachlor from below 10 ppt in Michigan to 10 ppt in Ohio. The highest single observation noted was for toxaphene in the Brazos River which drains the heavily sprayed cotton lands of east Texas, this ran 1.1 ppb. (Lamar 1965).

Clearly as these and many other actual determinations range from 3 to 5 orders of magnitude below the level tested in the studies of algae magnification quoted (Vance et al 1969) the actual increases reported are not particularly meaningful. Furthermore, as pointed out by Chadwick (1969) uptake is a direct function of concentration, so that the substantial algae levels reported are in fact more a reflection of the exaggerated concentrations employed than an indication of the reality of field occurrence.

In the case of the aquatic Daphnia magna Crosby and Tucker (1968) reported a 16,000 X concentration of DDT from non-flowing ambient medium of 8 ppb and 23,000 X from that of 50 ppb. during a 24 hour exposure under laboratory conditions. The maximum accumulation amounted to 1150 ppm of body weight which presumably would have been lethal were it not for the fact the bulk of the DDT was absorbed to the exoskeleton.

It was computed that the median sub-acute lethal level of DDT for <u>Daphnia magna</u> was 1170 ppm, an astonishingly high level, as the LD_{50} for mammals (<u>rat, mouse, rabbit</u>) lies from 150 to 300 ppm of body weight. From this Crosby and Tucker estimate that <u>Daphnia</u> exposed to 10 ppb of DDT in waters would accumulate sufficient insecticide such that ingestion of 10 mg of <u>Daphnia</u> would kill a 1 gm fish - i.e. a dose of 1.5 ppm.

Brockson et al (1967) examined the build-up of DDT and its metabolites in the food chain in the Rattlesnake Creek, drainage channel in the Ochoco and Malheur National Forest prior to and following the recommended level (1 lb/A) of DDT for the control of an outbreak of Douglas-fir tussock moth.

Over a period of 12 months from May 1965, (two months prior to application), through July & October 1965 to February and May 1966 post-application DDT totals in the ambient water assayed less than 15 ppb with no significant difference due to the DDT application apparent at any time observed. Algae increased from 19 ppb prior to spraying to 87 ppb posttreatment by October 1965 and fell back to 10 ppb by May 1966. Herbivorous insects assayed 80 ppb prior to treatment rose sharply almost 10-fold to 770 ppb immediately post-spraying in July 1965, fell to 145 ppb by October 1965 and to 98 ppb by May 1966. Carnivorous insects, however, rose from 53 ppb prior to 320 ppb immediately postspraying, - only a 6-fold increase, but were still 140 ppb by May 1966 - a 2.5-fold rise. Dace rose from 76 ppb in May 1965 to 1015 ppb by July 1965 - a 13-fold increase, fell back to 180 ppb by February 1966, but rose again by May 1966 to 1060 ppb. The top of the chain species, trout, however, rose from 34 ppb in May 1965 to 1197 ppb by July - a 35-fold increase fell to 570 ppb by October and to 265 ppb by February 1966 and up again slightly to 487 ppb by May 1966.

Although there was unquestionably a distinct increase in concentration of DDT and its metabolites as the food chain ascended, it did not follow in these studies the consistent course and extend to the gross magnification often alleged in the lay press.

There is no question that the algae tended to pool DDT from 2 to 8-fold from their ambient medium in the Oregon studies and that the degree of concentration was related to the incidence of spraying the insecticide. It also appears that such pooling occurs among herbivorous insects and to a generally lesser extent among carnivorous insects. Dace (a carp-type fish) also tended to pool DDT from its diet to about the same extent as the more advanced trout. However, as the maximum concentration of DDT noted in trout was 1.2 ppm which was approximately 100 fold increase over the water level, the question still remains whether this degree of magnification actually comprises hazard either to man or to the proliferation of the trout, for the level of DDT declined markedly thereafter.

Studies by Chadwick (1969) on the relative quantities of the organo chlorine pesticide dieldrin accumulated by Steelhead from ambient water, and/or food, when raised in specially designed and controlled laboratory aquaria indicated that rate of uptake from the ambient medium was directly related to the concentration of dieldrin in the medium, and that at all levels tested from 0.017 ppb to 8.6 ppb accumulation approached a steady state level also directly related to the exposure concentration in the medium.

In other experiments (Freed et al 1968) fed tubificid worms, an intermediate organism in the food chain, containing varying levels of dieldrin to fish and found that virtually all the dieldrin was retained by the fish fed worms carrying from 0.5 to 25 ppm of dieldrin. When, however, the level of dieldrin in the worms was increased above 25 ppm, the per cent absorbed by the fish progressively declined, again indicating the approach to the steady state from ingested sources.

This agrees with the responses noted when increment levels of other organo-chlorine pesticides are fed to terrestial vertebrates, such as rats, chickens and humans (Quinby et al 1965) there does remain the question as to what the steady state level is for each species of fish and for each pesticide at which no toxic effect occurs. Certainly it would be expected to occur at a lower level for dieldrin, endrin, chlordane, heptachlor and toxaphene than it would for DDT or methoxychlor.

Chadwick (1969) found that sculpins held in controlled laboratory streams containing 0.5 ppb of dieldrin and fed midge larvae with and without dieldrin accumulated the pesticide up to the steady state at essentially the same rate. From these data he concludes that the uptake of the dieldrin from the ambient water and the food chain is not additive but complementary. In fact the contribution of dieldrin from the food source was estimated to be only 15% of the total uptake after 21 days of continuous exposure.

They conclude that although the primary step-algae-in the food chain may have accumulated relatively high concentrations of dieldrin directly from contaminated waters, actually up to 85% of the dieldrin accumulated by fish at the top of the food chain was derived directly from the water through their epithelial surfaces. The pesticide in fact was absorbed from the water by the algae and other aquatic vegetation which served to compete with the higher vertebrates for the pesticide and actually reduced the immediate local danger rather than magnified it. (Freed et al 1968).

The problem then remains as to whether under field conditions there actually is a significant magnification of pesticides eluted or washed from the treated soils to the extent that they attain lethal or toxic levels in the ambient water or the food of fish.

Certainly the annual reports of the unnatural fish kill in the U.S. published formerly by the U.S. Public Health Service and recently by the USDI - FWPCA - have indicated for many years that all agricultural chemicals combined account for less than 3% of the total of all kills reported. Industrial and municipal sewage effluents continue to be responsible for over 75% of the total kill reported each year.

There also remains the important question as to what subtle sublethal effects occur among desirable aquatic flora and fauna as a result of continuous low level exposure to agricultural chemicals. Ferguson (1969)has reported significant increases in resistance to organochlorine compounds among several species of fish and also among cricket frogs. He suggests these introduced factors in the environment may well be exerting a significant selective effect upon the evolution of new genetic strains and species of aquatic life.

The use of herbicides in forested watershed management has now become essential to remove undesirable underbrush particularly along stream banks and utility rights-of-way. Even where riparian objectives exceed those of timber production it has been determined that discriminative control of wild brush verdure enhances the water economy. (Pierce 1967) (Reigner et al 1968).

The question of possible contamination of aquifers derived from such herbicidally treated watersheds has been carefully examined in a number of studies, by "before" and "after" assays of issuing waters. Compounds tested include AMMATE (ammonium sulfamate) 2-4-D (2,4, dichlorophenoxyacetic acid-esters) and 2-4-5-T (2,4,5, trichlorophenoxyacetic acid esters). The general conclusions were that discriminative applications of these herbicides were effective in reducing undesirable underbrush and stream bank clogging weed growth without inducing injurious or deleterious contamination of flowing or storage aquifers. In all cases maximum concentrations of applied herbicides were below 0.1 ppm, and rapidly dissipated and degraded. (Reinhart 1965; Krammes & Willets 1964; Reigner et al 1964; Paine 1959; Winston & Ritty 1961; USDA 1961).

Despite the rather overwhelming evidence that the phenoxy-acetic herbicides effectively improve riparian forest management by suppressing unwanted brush and weeds there still persists the contention that these compounds when so used contaminate potable waters, elicit objectionable tastes and odors (Baker 1961) and induce undetermined and unestablished chronic ills in man (Carson 1962).

Actually, phenols occur frequently in forest waters and are derived almost entirely from natural sources - e.g. oaks - and are carried into potable water treatment plants where during chlorination they become halogenated into various chlorinated phenols which are primarily responsible for the medicinal tastes and odors reported (Faust 1969).

There is actually no evidence that chlorinated phenoxy acid herbicides applied at approved herbicidal levels persist at pharmacologically significant levels in potable waters delivered to the public. On the contrary there is ample evidence that these useful compounds degrade rapidly in both forest and cultivated soils (Goerlitz et al 1967, Newman & Thomas 1950, Alexander 1965, Aly et al 1963, Reigner et al 1968, Reinhart

1965). It has been frequently claimed that pesticides, particularlythe chlorinated hydrocarbons, persist in the soil, the water and the general environment indefinitely. (Woodwell 1961, 1964) (Riseborough 1969). There is, however, ample evidence that DDT, usually the primary maligned culprit is in fact degraded in nature (Spencer 1967).

As pointed out by Lichtenstein et al (1959) the half life of chlorinated hydrocarbon insecticides in the soil depends considerably upon the environmental factors of moisture, temperature, soil texture, microflora etc., and that it is by no means indefinite. (Chisholm et al 1959).

On the other hand, percolation of organo-chlorine compounds is exceedingly slow and limited, and most of the pesticide which reaches flowing waterways does so through soil erosion and run-off during heavy rains (Smith 1968). As these compounds are lipophyllic they tend to remain attached to organic soil particles and when entering a water way remain so attached and tend to settle as sediments (Breidenbrach et al 1963), obviously they cannot at once remain in the soil and also simultaneously be dispersed into waters without undergoing some dilution. In addition, at least part may be vaporized and another part metabolized. All these factors tend to reduce the ultimate levels which can accrue in the waterways.

In general, assays of DDT and related analogues in the major river systems Mississippi, Missouri, Ohio, Columbia that drain millions of acres of arable pesticide treated lands do not show toxic levels in the ambient waters (Nicholson et al 1959 and 1964), (Grzenda et al 1964) and continuous monitoring surveys in both river and estuarine waters and benthic deposits have revealed no significant trend that would suggest accumulation. (Brown et al 1967), (Miller et al 1967), (Bugg et al 1967), (Casper 1967), (Barthel et al 1969). There has been no evidence of pesticides of any chemical group within the waters or benthic deposits of the estuarine waters of the major drainage channels of the country as monitored over the past 5 to 7 years.

There is also no evidence that any pesticide or its derivatives is increasing in concentration in the national food market basket (Duggan 1966, 1967_a, 1967_b, 1969),(Corneliussen 1969), nor in the bodies of the people (Hayes et al 1958), (Ortellee 1958), (Hayes 1960), (Maier-Bode 1960), (Hunter et al 1963), (Hoffman et al 1964_a), (- 1964_b), (Hayes et al 1965), (Hoffman et al 1967), (Quinley et al 1965), (Zavon et al 1965), (Wasserman et al 1965), (Robinson et al 1965), (Dale et al 1966), (Brown G.R. 1967), (Davies et al 1968).

On the basis of the overwhelming evidence that pesticides, including DDT and its analogues, are not accumulating in our water ways or potable water supplies, nor in our foods, nor in our bodies, and that ubiquitous as they may appear to be there is no valid evidence that pesticides are significantly impairing the reproductive capacity of either humans, livestock or terrestial wildlife.

CONCLUSION

Despite the recent furious clamor that agricultural chemicals, specifically fertilizer nitrogen and phosphorus, and pesticides, particularly the chlorinated hydrocarbons, are spreading invidiously through our environment our food and our bodies and that they are accumulating rapidly to the point where they will separately and collectively aggregate to a chronically injurious level, there is no valid experimental or observational evidence to sustain this gloomy contention.

The incidence of increasing levels of nitrate nitrogen in the aquifers and waterways is recognized and although it must be continuously monitored, the present levels are safe except for the localized and isolated instance. Such cases are generally identifiable as to source and indicate that municipal industrial, septic tank and animal waste effluents and soil erosion are the principal causes. There is little secure evidence that recommended levels of field applied fertilizer nitrogen are responsible for significant or serious levels of nitrates in aquifers.

The necessity for soil nitrogen is directly related to the rising need for protein and therefore the use of nitrogenous fertilizers will have to increase with the population to maintain and enhance the standard of living. Such increments of fertilizer nitrogen must be monitored and methods of application developed to reduce prospective leaching of nitrates into the aquifers.

The contamination of the waterways by pesticides as a result of their use in agriculture and forestry is minimal and of little or no importance in injury to mammalian or avian wildlife, however, there have been instances of damage to economically important fish. Such injury appears to be related more to direct contact in the ambient waters than through alleged food chains.

The available evidence on unnatural fish kills indicates that kills attributable to all agricultural chemicals is of minor importance compared to the kills directly related to municipal and industrial effluents.

Long term monitoring surveys of major river and estuarine waters and their benthic deposits reveal no significant trends of accumulation or toxicities for any group of pesticidal compounds or for any one pesticide.

Similarly there is no evidence from extensive market basket surveys nor from surveys of blood analyses or fat and tissue biopsies that any pesticide or group of pesticides is escalating in either the food or the bodies of the people.

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CONTROLLING YELLOW NUTSEDGE IN MINNESOTA

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Yellow nutsedge (*Cyperus esculentus* L.), sometimes called nutgrass, is a grass-like plant with yellowish-green leaves that is on the increase in Minnesota. It can be easily recognized by the triangular stem and triangular leaf arrangement. It spreads by seeds but once established in a field, large numbers of nutlike tubers are produced underground during the summer. These tubers that sprout in the spring are the major means of persistence of the infestation and of increasing the stand density. Tillage has been the only method of control in the past. However, recent studies have indicated that several chemical weed killers are useful for the control of this weed. We have examined fourteen herbicides during the past three years to determine their possibilities for yellow nutsedge control. For yellow nutsedge in corn,alachlor (Lasso) and butylate (Sutan) have given fair to good control. Preplant soil incorporation of alachlor appears to be the best method of application for this compound and butylate must be incorporated in the soil. Atrazine and oil in a single postemergence application did not give satisfactory nutsedge control. However, split applications of atrazine and oil with the second application made two weeks after the first appears promising though some corn injury may develop from the split application. EPTC (Eptam), evaluated only in 1970, gave excellent nutsedge control with minor injury to the corn. Atrazine, EPTC, and several other compounds need further study to determine their consistency of nutsedge control and their safety to the corn. For soybeans, alachlor has shown the most promise for yellow nutsedge control. As for corn, preplant soil incorporated applications to soybeans appear to give more consistent yellow nutsedge control than preemergence applications of this compound.

DEVELOPMENTS IN CONTROLLING WILD SUNFLOWER

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Morris, Minnesota

Wild sunflower is a serious weed in western Minnesota. Some of the general weed control herbicides for corn and soybeans do not control wild sunflower. A study was initiated in 1970 to determine more fully the effectiveness of certain herbicides on the control of wild sunflower. A field severely infested with wild sunflower was located near Hancock, Minnesota.

Separate corn and soybean trials were designed. Since the wild sunflowers were not uniformly distributed over the area, the individual treatments were arranged with a check plot adjacent to each treatment. The average infestation of wild sunflowers in the check plots was 1 plant for each 3 square feet in the corn area and 1 plant for each square foot for the soybean area. No yields were taken because of only 2-row plots and because other weeds also greatly affected yields. Wild sunflower control was determined by counting sunflower plants in each treatment and by comparing with the 2 nearest check plots.

On May 19 the preplant herbicides were applied and incorporated. The corn and soybeans were planted May 19 and the preemergence herbicides were also applied May 19. Both corn and soybeans emerged on June 1. Wild sunflowers continued to emerge from June 3 until about June 30. Early postemergence application dates and temperatures were June 5 at 80°F for corn and June 10 at 85°F for soybeans. Late postemergence treatments were applied June 15 at 70°F for both corn and soybeans. This low temperature may have been a factor in the effectiveness of some herbicides. Also on June 15 the largest wild sunflowers had only 4-8 leaves and therefore most were still quite small. All treatments were applied broadcast with a bicycle sprayer without drop nozzels. Frequent rain showers with over 2 inches in 7 showers from May 19-31 and with 3 inches in 5 showers from June 11-19 at Morris were adequate to activate the herbicides.

A summary of the data from this corn and soybean study is presented in tables 1-4.

Suggestions and assistance in this study from R. N. Andersen, ARS, USDA, St. Paul; and R. Behrens and G. Miller, Dept. of Agronomy and Plant Genetics, University of Minnesota, St. Paul, are gratefully acknowledged.

Table 1. Corn preplant and preemergence herbicides applied May 19.

Herbicide	Rate	Sunflower Control June 3	Sunflower Control Aug. 11
	lb/A	percent	percent
Preplant herbicides			
Atrazine	4	41	99
SD 15418	4	33	97
Butylate	4	2	1
Preemergence herbicides			
Atrazine	4	31	100
Linuron	2½	52	92
SD 15418	4	28	100
C 6313	4	32	100
B 2903-H	4	44	38
Propachlor	5	14	6
	LSD_{05}	NS	4
	LSD_{01}	NS	9

Table 2. Corn early and late postemergence herbicides applied June 5 and 15.

Herbicide	Rate	Corn Damage June 17	Sunflower Control Aug. 11
	lb/A	0-10	percent
Early post herbicides			
S-6115	1	0	100
Atrazine + Oil	2 + 1 g.	0	100
2,4-D	1/2	0	90
2,4-D + Dicamba	1/4 + 1/8	0	100
Late post herbicides			
Atrazine + Oil	2 + 1 g.	0	100
Atrazine + Oil	1 + 1 g.	0	98
Atrazine + Oil	2 + 2 g.	0	100
Atrazine + Oil	3 + 3 g.	0	100
S-6115	1	0	100
S-6115	2	0	100
2,4-D + Dicamba	1/4 + 1/8	5	100
2,4-D + Dicamba	1/2 + 1/4	7	100
2,4-D	1/2	4	100
2,4-D	1	5	100

Table 3. Soybean preplant and preemergence herbicides applied May 19.

Herbicide	Rate	Soybean Height June 25	Emergence Delay	Sunflower Control June 3	Sunflower Control Aug. 11
	lb/A	inches	days	percent	percent
Preplant herbicides					
Vernolate	3	10	1	0	7
Alachlor	3	10	0	2	10
Trifluralin	1	10	1	5	0
Amiben-	3	9	1	0	0
Weed Free		10	0	100	100
Preemergence herbicides					
Naptalam and Chlorpropham	3 + 3	9	1.5	84	66
Naptalam and Chlorpropham	4 + 4	8	2	72	59
Amiben	3	9	1	38	20
RP 17623	2	8	2.5	45	0
RP 17623	3	6	4	78	5
C 6989	4	8	2	82	49
Weed Free		10	0	100	100
			LSD_{05}	7	10
			LSD_{01}	14	18

Table 4. Soybean early and late postemergence herbicides applied June 10 and June 15.

Herbicide	Rate	Soybean Height June 25	Sunflower Control Aug. 11
	lb/A	inches	percent
Early post herbicides			
Chloroxuron + WA	1½	5	85
Linuron + WA	½	7	97
Dinoseb	3	5	85
Weed Free		10	100
Late post herbicides			
Chloroxuron + WA	1½	8	19
Chloroxuron + WA	3	8	52
Chloroxuron + WA	4½	7	68
Linuron + WA	½	7	6
Dinoseb	3	8	65
Dinoseb	6	6	100
C 6989	4	8	15
C 6989	8	6	8
Weed Free		10	100
		LSD_{05}	7
		LSD_{01}	15

Some of the regular corn herbicides did a good job of controlling wild sunflower. As a group, the triazines gave better wild sunflower control than the other herbicides. The recommended rates of 2,4-D and 2,4-D plus Dicamba also were effective against the wild sunflower. Since most wild sunflowers were still quite small at the late post treatments, this data cannot be used to indicate the effectiveness of 2,4-D, Dicamba or other post treatments for larger wild sunflowers.

None of the preplant and preemergence soybean herbicides used in this study gave as good control as the most effective herbicides used in the corn experiment. Some of the soybean herbicides applied postemergence in this study gave some control. These herbicides generally are temperature sensitive, may cause leaf burn, and may cause delayed maturity. From this data it appears that Chloroxuron could be used for emergency control of wild sunflower, provided that the Chloroxuron was applied early and at a proper temperature. Some of the other postemergence treatments used in this soybean study are not registered for postemergence applications. It would be better to plant corn rather than soybeans in a sunflower infested field as some of the herbicides used in the corn experiment were very effective in the control of wild sunflower. Although these results do generally agree with other Minnesota research results and with farmer observations, it must be remembered that these are only one year's results at one location.

Table 5 lists both the common and trade names for each of the chemicals used in this study. Inclusion of a trade name does not imply endorsement and exclusion does not imply nonapproval. Also some treatments are not registered.

Table 5. Herbicides used in study.

Common Name	Trade Name	Common Name	Trade Name
Alachlor	Lasso	Dinoseb	Several Mixtures
Amiben	Amiben	Linuron	Lorox, Mixtures
Atrazine	AAtrex	Naptalam	Alanap
Butylate	Sutan	Propachlor	Ramrod
B-2903-H	Basomaize	RP-17623	
C-6313	Maloran	SD-15418	Bladex
C-6989	Preforan	S-6115	
Chloroxuron	Tenuran	Trifluralin	Treflan
Chlorpropham	Chloro IPC	Vernolate	Vernam
Dicamba	Banvel, Mixtures	2,4-D	Several Mixtures

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Cultural and Chemical Weed Control in Field Crops-1970. Extension Folder 212, Agricultural Extension Service, University of Minnesota.

MUSK THISTLE CONTROL

Kent Ringkob, Extension Agent

Musk Thistle is a dangerous new weed in Minnesota. It has been declared a noxious weed and law requires all persons help prevent the spread of it. It has made entry into Minnesota in both the Southwest and Southeast corners.

The research work described here was conducted in Rock County, in the very Southwest corner of the State by Gerald Miller, Oliver Strand, George Holcomb and Kent Ringkob.

The Musk Thistle is a bienniel. Seedlings may emerge any time during the growing season. It spends the first year as the flat, low-growing rosette and starts the second year as the rosette. Because of this low-growing habit, mowing is almost useless as a control measure.

About June of the second year, the plant sends up stems and produces flowers and seeds. The plant grows up to six feet in height. It is mainly a problem in pastures and ditches.

The thorns or spines are unusually sharp. Cattle will not graze where there are a lot of Musk Thistle growing.

If we are going to win our battle against Musk Thistle we are going to have to emphasize from the beginning that early spraying is imperative. Spraying before June 15 is necessary and before June 1 is ideal. Early spraying can also mean a carefully timed fall spraying to stop this bienniel.

In our research, we found the 1# acid equivalent of 2,4-D applied June 15 did an excellent job. The same amount applied July 10 caused the thistles to wilt, but lots of seeds were produced <u>and</u> the thistles had already smothered the grass.

Two pounds acid equivalent 2,4-D applied June 5 did an excellent job <u>but</u> no better than 1#. Two pounds on July 10 is better than a pound, but is just simply too late.

One pound 2,4-D plus 1/2 pound Dicamba also worked very well when applied June 5. I will say that Dicamba does act much quicker and more thoroughly. I could see the Dicamba treated plants turn brown much quicker.

To wait until the pasture takes on a purple color from the thistle flowers before moving in with a sprayer is not the way to do it. Early control is the way to go.

HOW TEMPERATURE, RELATIVE HUMIDITY AND LIGHT AFFECT 2,4-D PERFORMANCE

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The widespread use of 2,4-D is largely due to its ability to control broadleaved weeds under a wide variety of conditions. However, many researchers have shown that environment can have a pronounced influence on plant response to the herbicide. It has generally been accepted that high temperatures and high humidities increase the susceptibility of most plants to 2,4-D. Considerable evidence has been collected supporting these generalizations as far as the influence of environment after treatment is concerned. However, there is little data available showing the influence of pretreatment environment on plant response to the herbicide. Therefore, a study was undertaken to determine the influence of pretreatment light, relative humidity and air temperature conditions on plant response to 2,4-D.

Peas (field peas, var Stroll and garden peas, var Alaska) and velvetleaf were preconditioned under several light, air temperature, and relative humidity regimes from emergence until they reached the 5-node and fourth true leaf stages, respectively. After treatment with 2,4-D amine or 2,4-D ester all plants were exposed to a common environment for 10 days. Reduction in dry weight from untreated plants grown under the same environments as the treated plants was used as an indicator of response.

In light studies, plant responses to 2,4-D were compared when plants were preconditioned under artificial lights or sunlight. The light source caused no difference in the response of peas to 2,4-D. Velvetleaf preconditioned under sunlight responded 10 to 20% more than when preconditioned under artificial lights prior to treatment.

Pretreatment air temperature (50°, 59°, 68° and 77° F) and pretreatment relative humidity (25 to 35% vs. 85 to 100%) did not influence the response of peas to 2,4-D. The response of velvetleaf plants when preconditioned at 59° F prior to treatment was 10 to 15% less than when preconditioned at 68°, 77° and 86° F. Similarily, velvetleaf preconditioned under a high humidity (85 to 100%) responded slightly more than when preconditioned under a low humidity (25 to 35%) prior to treatment.

These studies indicate that considerable variations in the pretreatment growing conditions have a relatively minor influence on the response of peas and velvetleaf to 2,4-D.

EFFECTIVENESS OF VEGETABLE OILS AND OTHER ATRAZINE SPRAY ADDITIVES

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Atrazine has been consistently improved in Minnesota trials as an early postemergence herbicide on corn by the addition of a petroleum oil to the spray mix. Vegetable oils and several other surfactants and combinations of oils and emulsifiers have not been thoroughly tested for use with atrazine on corn. The purpose of this study was to evaluate available additives and emulsified linseed, soybean and sunflower oil with early postemergence applications of atrazine to determine weed control and crop injury effects on corn.

After preliminary greenhouse studies to determine an effective range of atrazine and additive rates, a field experiment was conducted at Rosemount Agricultural Experiment Station during 1970 to evaluate four petroleum oils, three vegetable oils, two combination oils and four surfactants as atrazine adjuvants.

Predominant weed species were green foxtail (Setaria viridis) and yellow foxtail (Setaria glauca). Scattered redroot pigweed (Amaranthus retroflexus) were also present. Experimental design was a randomized complete block with three replications. Plots were two 30 inch rows wide and 30 feet long. Two untreated check rows were left adjacent to each plot for observation purposes. Herbicide spray treatments were applied on June 8 at the rate of 23 gpa when corn was in the three to four leaf stage and foxtail was in the two to three leaf stage and less than 1 1/2 inches tall. Plots were not cultivated. Over 1 inch of rain fell within one week after the herbicides were applied and another inch fell during the second week. Percent weed control ratings were made June 17 (nine days after application) by comparison with adjacent untreated checks. These early evaluations agreed closely with the dry weed yields that were harvested on July 28 and reported in Table 1. There was no visible corn injury in any of the trials.

Examination of the data in Table 1 suggests that, within each rate of atrazine, the higher rate of oil or surfactant was more effective in reducing weed yields than was the lower rate of the additive. However, in a few instances, the lower rate of one additive was as effective as the higher rate of another additive.

When weed yields from the field study are averaged over the two rates of atrazine and two rates of adjuvants to determine the main effects of adjuvants, the relative rank of adjuvant performance can be listed as shown in Table 2. The vegetable oils (linseed, soybean and sunflower) were not statistically different from each other in performance and ranked among the best additives in effecting lower weed yields with atrazine. Petroleum oils were not greatly different from one another, and were also very similar in performance to the vegetable oils. One combination oil ranked high and another ranked low in performance. Oils as a group improved atrazine phytotoxicity more than did surfactants as a group. However, one surfactant gave as good results as several of the oil additives. All additives improved weed control as compared to atrazine alone.

Table 1. Effect of atrazine-adjuvant combinations on early postemergence weed control in corn, Rosemount, Minnesota, 1970.

	Dry weed yields, lb/A			
	3/4 lb atrazine/A		1 1/2 lb atrazine/A	
	(Oil)			
Adjuvant	1 qt/A	1 gal/A	1 qt/A	1 gal/A
Sun 11-E[a]	863	384	544	395
Amoco[a]	816	619	720	352
Orchex-795[a]	784	685	611	384
KM-524+[a]	848	720	544	479
Soybean[b]	841	464	656	224
Linseed[b]	661	557	524	240
Sunflower[b]	689	671	640	352
Elin[c]	976	880	864	683
Agri-oil+[d]	809	480	499	368
	(Surfactant)			
	1/2 pt/A	1 pt/A	1/2 pt/A	1 pt/A
Tronic[e]	1083	800	720	448
Surfol[f]	801	751	609	512
L.O.C.[g]	1341	896	912	801
Bestline concentrate[h]	1120	1002	803	753
No adjuvant	1268	1076	1120	961
LSD (.05)		198		
Untreated check		2438		

a/ Commercially available petroleum crop oils each containing 1-2% emulsifier: Sunoco Oil Company, Marcus Hook, Pennsylvania, American Oil Company, Chicago, Illinois, Esso Research and Engineering Company, Baytown, Texas, (Humble Oil and Refining Company product) and, Mutual Dealers, St. Paul, Minnesota (Kerr-McGee base oil 524) respectively.

b/ Crude soybean, linseed and sunflower oil with 5% TH-AO_2 emulsifier added. Raw linseed from Minnesota Linseed Oil Company, Minneapolis degummed soybean and crude sunflower oil from Mutual Dealers, St. Paul. Emulsifier from Thompson-Hayward Chemical Company, Minneapolis.

c/ Emulsified linseed oil plus petroleum oil. Sunoco Oil Company, Marcus Hook, Pennsylvania.

d/ Gordon Corporation, Kansas City, Kansas (Atlas Chemical Industries, Inc. product)

e/ Colloidal Products Corporation, Sausalito, California.

f/ Castle Chemical Company, Savage, Minnesota.

g/ Amway Corporation, Ada, Michigan.

h/ Bestline Products, San Jose, California.

Table 2. Effect of adjuvants on atrazine phytotoxicity as reflected in dry weed yields in corn. Rosemount 1970 (average of all treatments)

Adjuvant	Lbs dry weeds/A
Linseed oil	496
Agri-oil +	539
Soybean oil	546
Sun 11-E oil	546
Sunflower oil	588
Orchex-795 oil	616
Amoco oil	627
Kerr McGee oil	648
Surfol surfactant	668
Tronic surfactant	763
Elin combination	851
Bestline surfactant	920
L.O.C. surfactant	988
No adjuvant	1106
LSD (.05)	99
Untreated check	2438

THE HERBICIDE CLEARANCE SITUATION

Gerald R. Miller[1]

On December 2, 1970, a newly created federal government agency, the Environmental Protection Agency (EPA) assumed responsibility for pesticides registration. Those divisions of the U. S. Department of Agriculture; Department of Health, Education, and Welfare; and U. S. Department of Interior previously involved with pesticides clearance including the Pesticides Regulation Division of the USDA and the Food and Drug Administration (FDA) of HEW were transferred to the new agency. The USDA will continue its research programs on pest control and pesticides. The new agency will be operating under the same legislation that has been in effect, i.e. the Federal Insecticide, Fungicide, and Rodenticide Act as amended and the Food, Drug, and Cosmetic Act as amended.

After December 31, 1967, registrations of herbicides that had been cleared on a zero or no tolerance basis were subject to cancellation unless: (1) finite tolerances or exemptions from the requirements of tolerances were established with the FDA or (2) progress reports were submitted to the USDA showing that studies were being conducted to obtain data to support finite tolerances.

Herbicides which do not yet have tolerances established or exemptions from tolerance requirements are subject to cancellation December 31, 1970. Some clearances have previously been temporarily extended, but the USDA has informally agreed to extend clearances after this year only if manufacturers have presented to FDA a fully documented petition for the establishment of a negligible residue tolerance. Action will now depend on EPA policies.

Most of the major herbicide uses in Minnesota have tolerances established. However, there are some herbicide uses for which petitions are submitted that have not been acted on and some uses will likely be dropped because the cost of establishing tolerances is not justified by the market.

Also, there are several herbicides including phenoxy compounds (2,4,5-T, 2,4-D, MCPA, silvex), amitrole, diallate, and cacodylic acid under intensive study for possible cancerous or embryo-malformation effects in laboratory animals. Herbicides showing these effects are considered potentially hazardous to people and uses may be cancelled. Some uses of 2,4,5-T have already been cancelled, but it can still be used for weed and brush control in pastures, forests, rights-of-way, and other non-agricultural lands.

Since clearances are subject to further change, it is important that you keep informed on the current status of clearances by checking with the University, county extension agents, or manufacturers.

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NEW DEVELOPMENTS FOR WEED CONTROL IN SUGARBEETS

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As development and label clearance for new pesticides become more expensive and more difficult, a decline in the number of new pesticides becoming available seems inevitable. This will be especially true in crops such as sugarbeets with smaller acreages and therefore smaller potential profits. If a herbicide for sugarbeets costs 6 million dollars to develop, which is a realistic estimate, the developing company would have to realize a profit of four dollars on each of the approximately 1.5 million acres of sugarbeets in the United States just to break even.

At present, the herbicides available for weed control in sugarbeets are far from ideal. No individual herbicides are available with good broad spectrum weed control and excellent selectivity between the weeds and the sugarbeets. Since new herbicides are not likely to be forthcoming and the available herbicides have certain weaknesses, the use of herbicide combinations to obtain better broad spectrum weed control with a minimum of crop damage appears to be necessary.

In 1970 several herbicides and herbicide combinations were applied at three locations in the Red River Valley and four locations in Southern Minnesota. Weed control and sugarbeet retardation ratings were taken at all locations.

When Eptam, Ro-Neet, TCA, Betanal, or Pyramin Plus were used individually, very little sugarbeet retardation was observed; but when Eptam or TCA were used, preplant incorporated and preemergence respectively and then followed by a postemergence application of Betanal or Pyramin Plus, considerable sugarbeet retardation occurred. Ro-Neet used preplant incorporated and followed by a postemergence herbicide gave less sugarbeet retardation than Eptam or TCA followed by a postemergence herbicide.

When sugarbeet yields at Glyndon, Minnesota were compared to sugarbeet retardation ratings, the ability of sugarbeets to recover from early season sugarbeet retardation was evident. The yield reduction from the use of TCA or Eptam followed by Betanal or Pyramin Plus was only about two tons per acre while the early-season visual evaluations indicated 35 to 50 percent retardation.

The weed control from the use of Eptam, TCA or Ro-Neet followed by a postemergence application of Betanal or Pyramin Plus was superior to the weed control from any of the herbicides used individually. The weed control was generally very good from the use of all the combinations. Some variations on individual species was observed with combinations containing Betanal more effective on wild mustard and combinations containing Pyramin Plus (pyrazon + dalapon) more effective on grassy weeds.

Herbicide combinations should be used with caution until experience or research has shown that the combination is effective and safe. Some suggestions to minimize possible sugarbeet retardation from the use of herbicide combinations follow: when Eptam or TCA will be followed with Betanal or Pyramin Plus, the rate of Eptam should be no greater than 2.5 lb/A on the very heavy soils and no greater than 2 lb/A on the lighter soils. The rate of TCA should be limited to 6 lb/A. Betanal should be used at no more than 1 lb/A following any preemergence or preplant incorporated herbicide.

CHEMICAL WEED CONTROL IN POTATOES

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Nine herbicide treatments were applied to potatoes grown at three locations in each of three years. The locations were characterized by widely different soil types--silty clay loam, sandy loam, and muck--and by differences in rainfall and temperatures during the growing season. None of the herbicide treatments applied pre-emergence gave adequate weed control at all locations and/or in all years.

EPTC at 6 lb per acre (6.72 kg/ha) gave excellent weed control on both mineral soils but not on muck. Metabromuron at 4 lb per acre (4.48 kg/ha) gave excellent weed control only on the low organic matter sandy loam. Propachlor at 6 lb (6.72 kg/ha) and 2 lb amiben plus 3 lb propachlor (2.24 plus 3.36 kg/ha) gave variable weed control.

Four herbicides: 1 lb paraquat (1.12 kg/ha), 2 lb linuron (2.24 kg/ha), 6 lb dinoseb (6.72 kg/ha) 6 lb dinoseb plus 2.25 dalapon (6.72 plus 2.52 kg/ha) applied at potato plant emergence, when weeds were in the 2-6 leaf stage, also gave variable weed control but as a group generally gave better control than the pre-emergence herbicides particularly on muck soil. Their effectiveness was less affected by soil type than the latter but was affected by the degree of weed emergence.

On muck soil, weeds generally emerged well before "at emergence" herbicide treatments were applied. Tuber yields were not directly affected by the herbicides, but were reduced where weed control was inadequate. Tuber specific gravity and chip color were unaffected by the herbicides.

WHITE COCKLE CONTROL IN ESTABLISHED ALFALFA

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White cockle (Lychnis alba L.), a biennial or short-lived perennial in growth habit, is a serious weed problem in many established alfalfa fields in Minnesota. In an effort to determine the extent of white cockle control with available herbicides, white cockle infested alfalfa fields were located in Washington, Anoka and Isanti Counties with the cooperation of the County Extension Agents and Area Soils Agent, Curtis Klint, Anoka, Minnesota. The Washington County trial was located on the John Keller farm in May township. In the fall of 1969 a thick stand of both seedling and established white cockle was present in this second production year alfalfa-grass mixture. Scattered yellow rocket (Barbarea vulgaris) plants were also present. The Anoka County location, on the Caroll Broadbent farm in Lynwood township, was a two-year old stand of alfalfa infested with a uniform growth of established white cockle. The Isanti County trial was located on the Roman Jalacynski farm in Cambridge township in a thin stand of alfalfa-timothy-bromegrass which was infested with white cockle, common ragweed (Ambrosia artemisiifolia) and quackgrass (Agropyron repens). Fall treatments were applied on November 4 and 5, 1969, when alfalfa was dormant and after a killing frost with a bicycle wheel sprayer delivering 17 gpa. Plot size was 10 feet wide by 30 feet long with a 6 2/3 foot strip sprayed down the center of each plot. Weed control results were evaluated in each plot by comparison with the adjacent unsprayed strips and with check plots included in the randomized complete block design. Three replications were used.

Identical treatments were applied the following spring, while alfalfa was still dormant in the same manner as the fall applications, on adjacent areas of the Washington and Anoka County fields. The Isanti County location was abandoned because of poor alfalfa survival. Injury index ratings for all treatments were recorded on May 26, 1970 and are reported in table 1.

Observations in the fall applied Isanti County trial indicated that timothy was injured more than smooth bromegrass by all the herbicides used and smooth bromegrass was injured more than quackgrass. RH-315 gave the most consistent grass control of all the herbicides used in both the Isanti County and Washington County trials. Simazine, GS-14254 and Terbacil all controlled white cockle seedings effectively in the Washington County trial and also suppressed established white cockle in all three trials about equally. However, GS-14254 was rated lowest on alfalfa injury in all three trials. Terbacil gave most injury to established alfalfa of any of the chemicals when used at the high rate of application.

Table 1. White cockle control and crop injury in established alfalfa, 1970.

Treatment	Rate lb/A*	Injury index** Anoka County Established cockle	Anoka County Alfalfa	Washington County Established cockle	Washington County Seedling cockle	Washington County Alfalfa	Washington County Grass
		(Fall application)					
Simazine (Princep)	1	3	1	1	6	1	2
Simazine	2	5	4	6	10	3	6
GS-14254 (Sumitol)	2	5	2	5	10	1	3
GS-14254	3	7	3	7	10	1	6
Terbacil (Sinbar)	1/2	4	2	1	10	2	3
Terbacil	1	7	6	7	10	4	4
RH-315 (Kerb)	1	0	0	0	0	0	7
RH-315	2	0	0	0	0	0	9
Check (no treatment)	-	0	0	0	0	0	0
		(Spring application)					
Simazine	1	3	2	2	6	3	5
Simazine	2	4	3	7	10	7	8
GS-14254	2	5	2	3	7	1	5
GS-14254	3	7	3	7	10	2	8
Terbacil	1/2	5	4	4	9	6	5
Terbacil	1	7	8	7	10	8	7
RH-315	1	0	0	0	0	0	6
RH-315	2	0	0	0	0	0	9
Check	-	0	0	0	0	0	0

* Active ingredient/A
** 0 = no injury; 1, 2, 3 = slight injury; 4, 5, 6 = moderate injury; 7, 8, 9 = severe injury; 10 = complete kill

GRASS PASTURE IMPROVEMENT IN MINNESOTA WITH 2,4-D AND NITROGEN FERTILIZER

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Minnesota has about two million acres of unimproved native grass pasture. Economic returns from these acres are generally very low with many farmers considering these areas to be virtually wasteland. Weeds and low fertility appear to be the major reasons for low pasture yields when rainfall is not a limiting factor. In an attempt to learn more about pasture improvement, a typical weedy, unimproved grass pasture area was selected on the Ken Albers farm near St. Cloud with the cooperation of Stearns County Extension Agents Francis Januschka and David Hart. The specific objective of the study was to determine the effect of broadleaf weed control and nitrogen fertilization on grass yields.

Phosphorous and potassium levels in the pasture experiment area were determined to be adequate by soil test. The principal grass specie in the pasture was Kentucky bluegrass, but scattered timothy and smooth bromegrass plants were present as well. The principal weed species in the experimental area were common yarrow (Achillea millefolium), absinth wormwood (Artemisia absinthium), bull thistle (Cirsium vulgare) and Canada thistle (Cirsium arvense). One pound per acre (one quart) of 2,4-D low-volatile ester was applied with a boom sprayer to one-third of the plot area during the last week of May, 1970. A second one-third of the area was sprayed with 2 pounds per acre of 2,4-D low-volatile ester during the last week in June and the last one-third of the area was left as an untreated check. Ammonium nitrate fertilizer at 100 pounds per acre was broadcast on one-half of the plot area at right angles to the 2,4-D applications during the third week in May. Plot layout was a split plot design as follows:

	No nitrogen	100 lbs ammonium nitrate
1 pound 2,4-D, early		
2 pounds 2,4-D, late		
No treatment		

Grass and broadleaf weed yields were determined on the early application of 2,4-D and untreated check areas on June 15 from an ungrazed portion of the plots by cutting two 10 square foot quadrats in each treatment with a hand sickle and separating grass and weeds by hand sorting. Green weight of broadleaf weeds and grass were converted to pounds per acre and are reported in table 1.

Both broadleaf weed control and nitrogen fertilizer improved grass yields over the untreated check. However, the combination of both treatments was necessary to give really profitable grass yield increases.

Table 1. Early determination of grass and weed yields (June 15) from Stearns County pasture trial, 1970.

Treatment	Green weight, lb/A Grass	Broadleaf weeds	Total
2,4-D ester, 1 lb/A	3,485	436	3,921
Nitrogen, 33.5 lb/A	3,049	4,792	7,841
2,4-D + nitrogen	8,276	-	8,276
Untreated check	871	3,049	3,920

The 2 pound per acre rate of 2,4-D applied late in June failed to control weeds adequately. Rainfall was somewhat limiting in the St. Cloud area in July and August so additional nitrogen was not applied. A second grass and broadleaf weed yield determination was made on July 17, from a previously unharvested or ungrazed portion of the plots in the same manner as in the first harvest. Yields are given in table 2.

Table 2. Late determination of grass and weed yields (July 7) from Stearns County pasture trial, 1970.

Treatment	Green weight, lb/A Grass	Broadleaf weeds	Total
Early applied 2,4-D, 1 lb/A	2,614	-	2,614
Nitrogen, 33.5 lb/A	2,396	3,485	5,881
Early applied 2,4-D + nitrogen	5,663	-	5,663
Untreated check	1,525	1,307	2,832
Late applied 2,4-D, 2 lb/A	1,307	1,742	3,049
Late applied 2,4-D + nitrogen	2,614	3,049	5,663

Direct yield comparisons cannot be made between data presented in table 1 and data given in table 2 because moisture content of harvested plants decreased with maturity.

Late applications of 2,4-D resulted in much less weed control and consequently grass yields were reduced. It is also significant to note that composition of the grass plots changed somewhat in response to nitrogen fertilization. In the untreated check plots and plots receiving 2,4-D only, the grass stand was almost all Kentucky bluegrass. In the nitrogen fertilized plots in the study, however, a much higher percentage of timothy and smooth bromegrass plants were in evidence.

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Corn and Soybean Weed Control Demonstration Results
1970

Oliver Strand and Gerald Miller, Extension Agronomists

Tables 1 to 9 summarize results of weed control demonstrations conducted by Minnesota county extension agents and extension specialists. These data are the average results from a large number of trials on various soil types and under different weather conditions. They may assist in evaluating herbicides, but for information on herbicides, rates, and methods of use for specific situations, refer to University of Minnesota Extension Folder 212, Cultural and Chemical Weed Control in Field Crops, 1971.

Chemicals were applied on 1/100-acre plots either preplanting and incorporated (before planting and disked in), preemergence (after crop planted but before crop or weed emergence), or postemergence (after crop and weeds emerged) as specified in the tables. Preemergence treatments were not incorporated. All chemicals were applied as sprays with a knapsack sprayer. Plots were located across eight crop rows. One-half of each plot was cultivated once or twice as needed, the other half was left uncultivated. Several check plots with no chemical applied were left in each trial.

Early postemergence applications of atrazine (AAtrex) alone or with petroleum or soybean oil, cyprozine (Outfox), and the atrazine-dalapon (Dowpon)-oil mixture on corn were made when weeds were less than 1 1/2 inches tall. Propachlor (Ramrod) was applied preemergence to corn to control grasses before the postemergence treatments of 2,4-D or dicamba. Trifluralin (Treflan) was applied preplanting to control grasses in soybeans before chloroxuron (Tenoran) or dinoseb (DNBP) were applied. The early postemergence treatment of chloroxuron was applied when weeds were less than 1 1/2 inches tall and when soybeans were in the first trifoliolate leaf stage. Dinoseb was applied just as the soybeans were emerging. Trifluralin was applied preplanting on soybeans before the preemergence application of chlorpropham (Chloro IPC) or linuron (Lorox).

Weed control was visually evaluated 3 to 8 weeks after chemicals were applied (early evaluations) and again near the end of the growing season (late evaluations). Control is rated "good" if more than 75 percent of the weeds were controlled, "fair" if 50 to 75 percent of the weeds were controlled, and "poor" if less than 50 percent of the weeds were controlled. "Grasses" in the tables refers to annual grasses such as foxtails, barnyardgrass, and crabgrass. "Broadleafs" refers to annual broad-leaved weeds such as redroot pigweed, lambsquarters, pennsylvania smartweed, common ragweed, cocklebur, velvetleaf, wild mustard, etc. Perennial weeds such as Canada thistle and quackgrass were not included in the evaluation.

Table 1 summarizes early evaluations of herbicides that have been included for two or more years. These results are from uncultivated plots. Tables 2 to 9 are 1970 results. Each table specifies uncultivated or cultivated and early or late evaluations.

Table 1. Weed Control Demonstration Results, Several Year Summary. Early Evaluations, Uncultivated.

Chemical	Pounds per acre A.I. or A.E.* broadcast	Years in trial	Number of trials: Grasses	Number of trials: Broad-leaved weeds	Percent of trials in each class: Grasses Poor	Grasses Fair	Grasses Good	Broad-leaved weeds Poor	Broad-leaved weeds Fair	Broad-leaved weeds Good
			CORN							
Preemergence										
Atrazine (AAtrex)	3	1959-70	613	588	8	16	75	5	9	86
Propachlor (Ramrod)	5	1965-70	283	278	6	12	81	32	28	40
Atrazine + linuron (Lorox)	1 1/2 + 1 1/2	1965-70	271	270	6	16	78	4	11	84
Atrazine + propachlor	1 1/2 + 3	1967-70	147	158	1	13	86	2	9	88
Linuron + propachlor (Londax)	1 1/2 + 3	1968-70	99	98	5	8	87	9	14	76
Alachlor (Lasso)	2 1/2	1969-70	58	57	2	9	90	38	18	44
SD 15418 (Bladex)	3	1969-70	58	57	3	14	83	10	18	72
Preemergence followed by postemergence										
Propachlor and 2,4-D	4 + 1/2	1967-70	143	151	6	9	85	9	9	75
Propachlor and 2,4-D + dicamba (Banvel)	4 + 1/4 + 1/8	1967-70	140	148	6	11	84	8	12	80
Early postemergence										
Atrazine	3	1961-67	398	374	12	14	73	6	7	87
Atrazine + oil	2 + 1 1/2 gal	1966-70	222	221	4	8	88	2	4	94
Atrazine + dalapon (Dowpon) + oil	1 + 3/8 + 1 1/2 gal	1969-70	56	55	11	21	68	4	5	91
			SOYBEANS							
Preplanting (disked in)										
Trifluralin (Treflan)	1	1965-70	129	122	2	12	87	16	23	61
Preplanting followed by preemergence										
Trifluralin and chlorpropham (Chloro IPC)	3/4 + 3	1969-70	37	36	0	8	92	3	22	75
Preemergence										
Amiben	3	1959-70	387	374	10	16	74	8	17	74
C 6989 (Preforan)	4 1/2	1968-70	67	63	3	21	76	14	11	75
Linuron (Lorox)	2	1962-70	298	289	23	26	51	15	21	64
Propachlor (Ramrod)	5	1965-69	145	138	6	13	81	25	36	39
Alachlor	2 1/2	1969-70	43	42	7	2	91	19	26	55
Norea + amiben (Noraben)	1 1/5 + 1 1/2	1969-70	42	40	7	19	74	12	25	62
Preplanting followed by postemergence										
Trifluralin and chloroxuron (Tenoran) + "Adjuvan-T"	3/4 + 1 1/2 + 0.5%	1968-70	56	52	2	5	93	4	6	90

* A.I. = active ingredient: A.E. = acid equivalent

Table 2. Corn Weed Control Demonstration Results, 1970. Early Evaluations, Uncultivated.

Chemical	Pounds per acre A.I. or A.E.* broadcast	Number of trials: Grasses	Number of trials: Broad-leaved weeds	Percent of trials with each degree of control: Grasses Under 50%	Grasses 50-75%	Grasses 75-95%	Grasses Over 95%	Broad-leaved weeds Under 50%	Broad-leaved weeds 50-75%	Broad-leaved weeds 75-95%	Broad-leaved weeds Over 95%
Preplanting (disked in)											
Alachlor (Lasso)	2 1/2	21	20	14.3	23.8	57.1	4.8	50.0	20.0	15.0	15.0
Atrazine (AAtrex)	3	21	20	4.8	19.0	52.4	23.8	0.0	5.0	35.0	60.0
SD 15418 (Bladex)	3	21	20	19.0	19.0	52.4	9.5	15.0	15.0	35.0	35.0
Preemergence											
Atrazine	3	24	23	4.2	29.2	29.1	37.5	0.0	0.0	30.4	69.6
Atrazine + linuron (Lorox)	1 1/2 + 1 1/2	24	23	8.3	12.5	50.0	29.2	0.0	13.0	21.7	65.2
Propachlor (Ramrod)	5	25	24	0.0	4.0	48.0	48.0	20.8	29.2	37.5	12.5
Atrazine + propachlor	1 1/2 + 3	25	24	0.0	16.0	48.0	36.0	0.0	4.2	25.0	70.8
Linuron + propachlor (Londax)	1 1/2 + 3	24	23	4.2	4.2	58.3	33.3	4.3	17.4	43.4	34.8
Alachlor	2 1/2	25	24	0.0	12.0	52.0	36.0	37.5	16.7	33.4	12.5
SD 15418	3	25	24	0.0	16.0	64.0	20.0	8.3	16.7	41.7	33.3
Atrazine + alachlor	1 1/2 + 2	25	24	0.0	8.0	52.0	40.0	0.0	8.3	33.3	58.3
Linuron + alachlor	1 1/2 + 2	24	23	0.0	8.3	50.0	41.7	4.3	8.7	34.7	52.2
Preemergence followed by postemergence											
Propachlor and 2,4-D	4 + 1/2	23	19	13.0	4.3	52.2	30.4	0.0	10.5	57.9	31.6
Propachlor and 2,4-D + dicamba (Banvel)	4 + 1/4 + 1/8	23	20	13.0	8.7	47.8	30.4	5.0	10.0	55.0	30.0
Postemergence											
Atrazine + oil	2 + 1 1/2 gal	24	24	12.5	16.7	33.3	37.5	0.0	4.2	25.0	70.8
Atrazine + dalapon (Dowpon) + oil	1 + 3/8 + 1 1/2 gal	25	24	16.0	16.0	60.0	8.0	0.0	12.5	25.0	62.5
Atrazine + soybean oil	2 + 1/2 gal	25	24	12.0	20.0	40.0	28.0	0.0	8.3	25.0	66.7
Cyprozine (Outfox)	1	25	24	12.0	8.0	56.0	24.0	0.0	4.2	29.2	66.7

* A.I. = active ingredient; A.E. = acid equivalent.

Table 3. Corn Weed Control Demonstration Results, 1970. Early Evaluations, Cultivated.

Chemical	Pounds per acre A.I. or A.E.* broadcast	Number of trials: Grasses	Number of trials: Broad-leaved weeds	Percent of trials with each degree of control — Grasses: Under 50%	Grasses: 50-75%	Grasses: 75-95%	Grasses: Over 95%	Broad-leaved weeds: Under 50%	Broad-leaved weeds: 50-75%	Broad-leaved weeds: 75-95%	Broad-leaved weeds: Over 95%
Preplanting (disked in)											
Alachlor (Lasso)	2 1/2	20	19	10.0	0.0	55.0	35.0	21.1	21.1	26.4	31.6
Atrazine (AAtrex)	3	20	19	0.0	10.0	25.0	65.0	0.0	0.0	31.6	68.4
SD 15418 (Bladex)	3	20	19	10.0	15.0	25.0	50.0	5.3	21.0	15.8	57.9
Preemergence											
Atrazine	3	24	23	0.0	8.3	41.7	50.0	0.0	0.0	17.3	82.6
Atrazine + linuron (Lorox)	1 1/2 + 1 1/2	23	22	4.3	4.3	47.8	43.5	0.0	4.5	18.2	77.3
Propachlor (Ramrod)	5	24	23	0.0	0.0	33.3	66.7	8.7	8.7	39.1	43.5
Atrazine + propachlor	1 1/2 + 3	24	23	0.0	8.3	33.3	58.3	0.0	4.3	13.0	82.6
Linuron + propachlor (Londax)	1 1/2 + 3	23	22	0.0	4.3	47.8	47.8	4.5	9.1	36.4	50.0
Alachlor	2 1/2	24	23	0.0	8.3	41.7	50.0	8.7	26.1	30.4	34.8
SD 15418	3	24	23	0.0	8.3	41.7	50.0	0.0	13.0	30.4	56.5
Atrazine + alachlor	1 1/2 + 2	24	23	0.0	4.2	29.2	66.7	0.0	4.3	21.7	73.9
Linuron + alachlor	1 1/2 + 2	23	22	0.0	4.3	26.0	69.6	4.5	0.0	22.7	72.7
Preemergence followed by postemergence											
Propachlor and 2,4-D	4 + 1/2	22	19	9.1	4.5	31.8	54.5	0.0	0.0	26.4	73.7
Propachlor and 2,4-D + dicamba (Banvel)	4 + 1/4 + 1/8	22	19	9.1	4.5	27.2	59.1	5.3	0.0	21.1	73.7
Postemergence											
Atrazine + oil	2 + 1 1/2 gal	23	22	4.3	13.0	26.1	56.5	0.0	0.0	27.3	72.7
Atrazine + dalapon (Dowpon) + Oil	1 + 3/8 + 1 1/2 gal	24	23	4.2	20.8	25.0	50.0	0.0	0.0	21.7	78.3
Atrazine + soybean oil	2 + 1/2 gal	24	23	0.0	16.7	16.6	66.7	0.0	0.0	21.7	78.3
Cyprozine (Outfox)	1	22	23	4.5	9.1	27.2	59.1	0.0	0.0	26.0	73.9

* A.I. = active ingredient; A.E. = acid equivalent

Table 4. Soybean Weed Control Demonstration Results, 1970. Early Evaluations, Uncultivated.

Chemical	Pounds per acre A.I. or A.E.* broadcast	Number of trials		Percent of trials with each degree of control							
				Grasses				Broad-leaved weeds			
		Grasses	Broad-leaved weeds	Under 50%	50-75%	75-95%	Over 95%	Under 50%	50-75%	75-95%	Over 95%
Preplanting (disked in)											
Trifluralin (Treflan)	1	21	21	0.0	4.8	47.6	47.6	9.5	28.6	48.6	14.3
Alachlor (Lasso)	2 1/2	21	21	0.0	9.5	47.6	42.9	28.6	19.0	38.1	14.3
Preplanting (disked in) followed by preemergence											
Trifluralin and chlorpropham (Chloro IPC)	3/4 + 3	21	20	0.0	9.5	47.7	42.9	0.0	15.0	65.0	20.0
Trifluralin and linuron (Lorox)	3/4 + 1 1/2	21	20	0.0	4.8	42.8	52.4	0.0	0.0	60.0	40.0
Preplanting (disked in) followed by postemergence											
Trifluralin and chloroxuron (Tenoran) + "Adjuvan-T"	3/4 + 1 1/ 2 + 0.5%	20	19	0.0	10.0	55.0	35.0	10.5	0.0	31.6	57.9
Trifluralin and dinoseb (DNBP)	3/4 + 2 1/4	21	20	0.0	19.0	57.1	23.8	5.0	25.0	40.0	30.0
Preemergence											
Linuron	2	21	20	19.0	28.6	47.6	4.8	0.0	30.0	25.0	45.0
Amiben	3	22	21	4.5	4.5	50.0	40.9	4.8	9.5	52.3	33.3
C 6989 (Preforan)	4 1/2	21	20	0.0	28.6	28.6	42.9	0.0	10.0	70.0	20.0
Alachlor	2 1/2	22	21	0.0	0.0	40.9	59.1	9.5	19.0	52.4	19.0
Norea + amiben (Noraben)	1 1/5 + 1 1/2	21	19	0.0	14.3	57.1	28.6	0.0	21.1	63.1	15.8
Naptalam + chlorpropham (Solo)	3 + 3	21	20	33.3	28.6	38.1	0.0	0.0	25.0	45.0	30.0

* A.I. = active ingredient; A.E. = acid equivalent

Table 5. Soybean Weed Control Demonstration Results, 1970. Early Evaluations, Cultivated.

Chemical	Pounds per acre A.I. or A.E.* broadcast	Number of trials: Grasses	Number of trials: Broad-leaved weeds	Grasses: Under 50%	Grasses: 50-75%	Grasses: 75-95%	Grasses: Over 95%	Broad-leaved weeds: Under 50%	Broad-leaved weeds: 50-75%	Broad-leaved weeds: 75-95%	Broad-leaved weeds: Over 95%
Preplanting (disked in)											
Trifluralin (Treflan)	1	18	18	0.0	0.0	11.1	88.9	0.0	5.6	38.9	55.6
Alachlor (Lasso)	2 1/2	18	18	0.0	11.1	27.8	61.1	5.6	5.6	50.0	38.9
Preplanting (disked in) followed by preemergence											
Trifluralin and chlorpropham (Chloro IPC)	3/4 + 3	18	17	0.0	0.0	22.2	77.8	0.0	0.0	41.2	58.8
Trifluralin and linuron (Lorox)	3/4 + 1 1/2	18	17	0.0	0.0	27.8	72.2	0.0	0.0	23.5	76.5
Preplanting (disked in) followed by postemergence											
Trifluralin and chloroxuron (Tenoran) + "Adjuvan-T"	3/4 + 1 1/2 + 0.5%	17	16	0.0	0.0	23.5	76.5	0.0	0.0	12.5	87.5
Trifluralin and dinoseb (DNBP)	3/4 + 2 1/4	18	17	0.0	0.0	50.0	50.0	0.0	5.9	47.1	47.1
Preemergence											
Linuron	2	18	17	11.1	0.0	50.0	38.9	0.0	5.9	29.4	64.7
Amiben	3	19	18	0.0	0.0	21.0	78.9	0.0	5.6	38.9	55.6
C 6989 (Preforan)	4 1/2	18	17	0.0	5.6	38.9	55.6	0.0	0.0	47.1	52.9
Alachlor	2 1/2	19	18	0.0	0.0	10.5	89.5	5.6	5.6	33.3	55.6
Norea + amiben (Noraben)	1 1/5 + 1 1/2	18	17	0.0	5.6	50.0	44.4	0.0	11.8	35.3	52.9
Naptalam + chlorpropham (Solo)	3 + 3	18	17	16.7	16.7	33.3	33.3	0.0	5.9	47.0	47.1

* A.I. = active ingredient; A.E. = acid equivalent

Table 6. Corn Weed Control Demonstration Results, 1970. Late Evaluations, Uncultivated.

Chemical	Pounds per acre A.I. or A.E.* broadcast	Number of trials: Grasses	Number of trials: Broad-leaved weeds	Grasses: Under 50%	Grasses: 50-75%	Grasses: 75-95%	Grasses: Over 95%	Broad-leaved weeds: Under 50%	Broad-leaved weeds: 50-75%	Broad-leaved weeds: 75-95%	Broad-leaved weeds: Over 95%
Preplanting (disked in)											
Alachlor (Lasso)	2 1/2	13	12	30.8	23.1	38.5	7.7	33.3	41.7	8.3	16.7
Atrazine (AAtrex)	3	13	12	23.1	7.7	38.5	30.8	0.0	0.0	58.3	41.7
SD 15418 (Bladex)	3	13	12	15.4	15.4	53.9	15.4	0.0	16.7	58.3	25.0
Preemergence											
Atrazine	3	14	13	14.3	21.4	28.6	35.7	0.0	7.7	30.8	61.5
Atrazine + linuron (Lorox)	1 1/2 + 1 1/2	14	13	28.6	7.1	28.6	35.7	0.0	0.0	23.1	76.9
Propachlor (Ramrod)	5	14	13	0.0	14.3	57.1	28.6	15.4	23.1	53.9	7.7
Atrazine + propachlor	1 1/2 + 3	14	13	7.1	21.4	50.0	21.4	0.0	0.0	30.8	69.2
Linuron + propachlor (Londax)	1 1/2 + 3	14	13	21.4	14.3	35.7	28.6	15.4	0.0	38.5	46.2
Alachlor	2 1/2	14	13	0.0	14.3	57.2	28.6	23.1	15.4	53.9	7.7
SD 15418	3	14	13	7.1	21.4	50.0	21.4	15.4	15.4	38.5	30.8
Atrazine + alachlor	1 1/2 + 2	14	13	0.0	7.1	64.2	28.6	0.0	0.0	38.5	61.5
Linuron + alachlor	1 1/2 + 2	14	13	0.0	14.3	35.7	50.0	7.7	0.0	46.2	46.2
Preemergence followed by postemergence											
Propachlor and 2,4-D	4 + 1/2	14	13	21.4	7.1	57.1	14.3	7.7	0.0	46.2	46.2
Propachlor and 2,4-D + dicamba (Banvel)	4 + 1/4 + 1/8	14	13	21.4	7.1	50.0	21.4	7.7	7.7	38.5	46.2
Postemergence											
Atrazine + oil	2 + 1 1/2 gal	14	13	21.4	7.1	35.7	35.7	0.0	7.7	15.4	76.9
Atrazine + dalapon (Dowpon) + oil	1 + 3/8 + 1 1/2 gal	14	13	28.6	7.1	50.0	14.3	0.0	0.0	23.1	76.9
Atrazine + soybean oil	2 + 1/2 gal	14	13	21.4	14.3	35.7	28.6	0.0	0.0	15.4	84.6
Cyprozine (Outfox)	1	14	13	21.4	14.3	42.8	21.4	0.0	0.0	23.1	76.9

* A.I. = active ingredient; A.E. = acid equivalent

Table 7. Corn Weed Control Demonstration Results, 1970. Late Evaluations, Cultivated.

Chemical	Pounds per acre A.I. or A.E.* broadcast	Number of trials: Grasses	Number of trials: Broad-leaved weeds	Percent of trials with each degree of control: Grasses Under 50%	Grasses 50-75%	Grasses 75-95%	Grasses Over 95%	Broad-leaved weeds Under 50%	Broad-leaved weeds 50-75%	Broad-leaved weeds 75-95%	Broad-leaved weeds Over 95%
Preplanting (disked in)											
Alachlor (Lasso)	2 1/2	13	12	0.0	15.4	53.9	30.8	8.3	8.3	50.0	33.3
Atrazine (AAtrex)	3	13	12	0.0	0.0	38.5	61.5	0.0	0.0	33.3	66.7
SD 15418 (Bladex)	3	13	12	0.0	0.0	46.2	53.8	0.0	8.3	41.7	50.0
Preemergence											
Atrazine	3	14	13	0.0	7.1	35.8	57.1	0.0	0.0	23.1	76.9
Atrazine + linuron (Lorox)	1 1/2 + 1 1/2	14	13	0.0	7.1	35.8	57.1	0.0	0.0	23.1	76.9
Propachlor (Ramrod)	5	14	13	0.0	0.0	42.8	57.1	0.0	15.4	38.5	46.2
Atrazine + propachlor	1 1/2 + 3	14	13	0.0	7.1	21.4	71.4	0.0	0.0	23.1	76.9
Linuron + propachlor (Londax)	1 1/2 + 3	14	13	0.0	7.1	42.8	50.0	0.0	15.4	30.8	53.8
Alachlor	2 1/2	14	13	0.0	0.0	50.0	50.0	0.0	15.4	38.5	46.2
SD 15418	3	14	13	0.0	7.1	28.6	64.3	0.0	7.7	23.1	69.2
Atrazine + alachlor	1 1/2 + 2	14	13	0.0	0.0	28.6	71.4	0.0	0.0	30.8	69.2
Linuron + alachlor	1 1/2 + 2	14	13	0.0	7.1	21.4	71.4	7.7	0.0	23.1	69.2
Preemergence followed by postemergence											
Propachlor and 2,4-D	4 + 1/2	14	13	14.3	0.0	28.5	57.1	7.7	0.0	30.8	61.5
Propachlor and 2,4-D + dicamba (Banvel)	4 + 1/4 + 1/8	14	13	7.1	0.0	42.9	50.0	7.7	7.7	15.4	69.2
Postemergence											
Atrazine + oil	2 + 1 1/2 gal	14	13	0.0	7.1	28.6	64.3	0.0	7.7	7.7	84.6
Atrazine + dalapon (Dowpon) + oil	1 + 3/8 + 1 1/2 gal	14	13	0.0	14.3	35.7	50.0	0.0	0.0	15.4	84.6
Atrazine + soybean oil	2 + 1/2 gal	14	13	0.0	7.1	21.4	71.4	0.0	0.0	15.4	84.6
Cyprozine (Outfox)	1	14	13	0.0	7.1	28.5	64.3	0.0	0.0	15.4	84.6

* A.I. = active ingredient; A.E. = acid equivalent

Table 8. Soybean Weed Control Demonstration Results, 1970. Late Evaluations, Uncultivated.

Chemical	Pounds per acre A.I. or A.E.* broadcast	Number of trials: Grasses	Number of trials: Broad-leaved weeds	Grasses: Under 50%	Grasses: 50-75%	Grasses: 75-95%	Grasses: Over 95%	Broad-leaved weeds: Under 50%	Broad-leaved weeds: 50-75%	Broad-leaved weeds: 75-95%	Broad-leaved weeds: Over 95%
Preplanting (disked in)											
Trifluralin (Treflan)	1	15	13	0.0	0.0	60.0	40.0	7.7	15.4	61.6	15.4
Alachlor (Lasso)	2 1/2	15	12	0.0	0.0	66.7	33.3	8.3	16.7	58.3	16.7
Preplanting (disked in) followed by preemergence											
Trifluralin and chlorpropham (Chloro IPC)	3/4 + 3	15	13	0.0	6.7	46.7	46.7	7.0	15.4	61.6	15.4
Trifluralin and linuron (Lorox)	3/4 + 1 1/2	15	13	6.7	13.3	33.3	46.7	0.0	0.0	46.2	53.8
Preplanting (disked in) followed by postemergence											
Trifluralin and chloroxuron (Tenoran) + "Adjuvan-T"	3/4 + 1 1/2 + 0.5%	15	13	0.0	6.7	73.3	20.0	0.0	15.4	53.9	30.8
Trifluralin and dinoseb (DNBP)	3/4 + 2 1/4	14	12	7.1	14.3	42.8	35.7	8.3	33.3	25.0	33.3
Preemergence											
Linuron	2	15	13	20.0	13.3	53.4	13.3	7.7	23.1	38.5	30.8
Amiben	3	15	13	0.0	6.7	40.0	53.3	0.0	15.4	46.2	38.5
C 6989 (Preforan)	4 1/2	15	13	0.0	26.7	40.0	33.3	0.0	23.1	38.5	38.5
Alachlor	2 1/2	15	13	0.0	0.0	40.0	60.0	15.4	7.7	46.2	30.8
Norea + amiben (Noraben)	1 1/5 + 1 1/2	14	12	0.0	14.3	57.2	28.6	0.0	8.3	50.0	41.7
Naptalam + chlorpropham (Solo)	3 + 3	14	12	14.3	21.4	64.3	0.0	0.0	25.0	41.7	33.3

Percent of trials with each degree of control (Grasses and Broad-leaved weeds columns).

* A.I. = active ingredient; A.E. = acid equivalent

Table 9. Soybean Weed Control Demonstration Results, 1970. Late Evaluations, Cultivated.

Chemical	Pounds per acre A.I. or A.E.* broadcast	Number of trials: Grasses	Number of trials: Broad-leaved weeds	Percent of trials with each degree of control — Grasses: Under 50%	Grasses: 50-75%	Grasses: 75-95%	Grasses: Over 95%	Broad-leaved weeds: Under 50%	Broad-leaved weeds: 50-75%	Broad-leaved weeds: 75-95%	Broad-leaved weeds: Over 95%
Preplanting (disked in)											
Trifluralin (Treflan)	1	12	12	0.0	0.0	16.7	83.3	0.0	0.0	58.4	41.7
Alachlor (Lasso)	2 1/2	12	12	0.0	8.3	33.4	58.3	0.0	25.0	33.4	41.7
Preplanting (disked in) followed by preemergence											
Trifluralin and chlorpropham (Chloro IPC)	3/4 + 3	12	12	0.0	0.0	25.0	75.0	0.0	8.3	58.3	33.3
Trifluralin and linuron (Lorox)	3/4 + 1 1/2	12	12	0.0	8.3	33.3	58.3	0.0	0.0	25.0	75.0
Preplanting (disked in) followed by postemergence											
Trifluralin and chloroxuron (Tenoran) + "Adjuvan-T"	3/4 + 1 1/2 + 0.5%	12	12	0.0	0.0	50.0	50.0	0.0	0.0	50.0	50.0
Trifluralin and dinoseb (DNBP)	3/4 + 2 1/4	11	11	0.0	9.1	36.4	54.5	0.0	9.1	36.4	54.5
Preemergence											
Linuron	2	12	12	8.3	0.0	33.3	58.3	0.0	8.3	25.0	66.7
Amiben	3	12	12	0.0	0.0	8.3	91.7	0.0	8.3	33.3	58.3
C 6989 (Preforan)	4 1/2	12	12	0.0	0.0	33.3	66.7	0.0	0.0	33.3	66.7
Alachlor	2 1/2	12	12	0.0	0.0	8.3	91.7	0.0	8.3	33.3	58.3
Norea + amiben (Noraben)	1 1/5 + 1 1/2	11	11	0.0	9.1	18.2	72.7	0.0	0.0	36.4	63.6
Naptalam + chlorpropham (Solo)	3 + 3	11	11	0.0	9.1	54.6	36.4	0.0	0.0	54.6	45.5

* A.I. = active ingredient; A.E. = acid equivalent

HERBICIDES FOR CORN AND SOYBEANS

Gerald R. Miller[1]

The following tables giving suggested herbicide uses for corn and soybeans and the effectiveness of the herbicides on certain weed species are taken from "Cultural and Chemical Weed Control in Field Crops - 1971," Extension Folder 212. This publication which gives detailed information on herbicides will be available from County Extension Agents in January. Clearances for some herbicide uses are subject to cancellation and some new clearances are likely by planting time. New information will be available from County Extension Agents as changes occur.

Chemicals not cleared now but for which clearance is anticipated by planting time are SD-15418 (Bladex) and S-6115 (Outfox) on corn and C-6989 (Preforan) for soybeans. SD-15418, chemically similar to atrazine, has given good control of annual grasses and most annual broadleafs when applied preemergence. Pigweed has not been consistently controlled. Corn has good tolerance to SD-15418. Research indicates that SD-15418 does not leave a soil residue the following season. Suggested rates are 2 to 4 pounds active ingredient per acre, the higher rates are required on soils higher in organic matter and finer textured. SD-15418 has performed better under moderate to heavy rainfall than under dry conditions. Formulations of SD-15418 are an 80 percent wettable powder and a 4 pounds per gallon water dispersible liquid. Preplanting applications have not been as effective as preemergence. Postemergence treatments have sometimes injured corn.

S-6115 (Outfox), chemically similar to atrazine, has effectively controlled annual grasses and broadleafs when applied as an early postemergence treatment in corn. Suggested rates are 3/4 to 1 pound active ingredient per acre. Some corn stunting and leaf burn have occurred, but the corn appeared to recover satisfactorily. Soil residues do not appear to be a problem from the above rates. S-6115 is formulated as a 1 pound per gallon water dispersible liquid.

C-6989 (Preforan) is a recently developed preemergence herbicide for soybeans that controls annual grasses and some broadleafs. C-6989 has usually given good control of pigweed, smartweed, and foxtails; fair control of barnyardgrass, common ragweed, lambsquarters, and wild mustard; and poor control of giant ragweed, cocklebur, and velvetleaf. Soybeans have good tolerance to C-6989. Suggested rates are 3 3/4 to 4 1/2 pounds active per acre applied preemergence without incorporation. Formulations of C-6989 are a 3 pounds per gallon emulsifiable concentrate and 15 percent granules. At this time, C-6989 is cleared only for soybeans grown for seed for planting.

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Table 1. Suggestions for chemical control of weeds in corn.

Chemical	Rate: lb/A of active ingredient/acid equivalent broadcast	Time of application	Remarks
alachlor (Lasso)	2 to 3	Preemergence	
atrazine (AAtrex)	1 to 4	Preplanting, preemergence, or early postemergence	Atrazine may injure some crops the following year
butylate (Sutan)	4	Preplanting, incorporated	Grass weeds only
propachlor (Ramrod)	4 to 5	Preemergence	Grass weeds only
atrazine and alachlor	1 to 2 + 1 1/2 to 2 1/2	Preemergence	
atrazine and butylate	1 to 1 1/2 + 3 to 4	Preplanting, incorporated	
atrazine and linuron (Lorox)	1/2 to 1 1/2 of each	Preemergence	Do not use on sandy soils
atrazine and propachlor	1 to 1 1/2 + 2 to 3 3/4	Preemergence	
linuron and propachlor	1 to 1 1/2 + 2 to 3	Preemergence	Do not use on sandy soils
2,4-D amine	1/4 to 1/2	Postemergence -two-leaf stage to layby	For 2,4-D, use drop nozzles after corn is 8 inches tall
2,4-D ester	1/6 to 1/3		
2,4-D amine	1/2 to 1	After layby	
2,4-D ester	1/3 to 2/3	After layby	2,4-D controls only broadleafs

Table 2. Effectiveness of herbicides on major weeds in corn.

	Preplanting		Preemergence				Postemergence		
	Butylate (Sutan)	Atrazine (AAtrex)	Alachlor (Lasso)	Atrazine (AAtrex)	Propachlor (Ramrod)	Linuron (Lorox)	2,4-D	Dicamba (Banvel)	Atrazine and oil
Corn tolerance	G	G	G	G	G	F	G	G	G
Grasses									
Giant foxtail	G	F	G	F	G	F	N	N	F
Green foxtail	G	G	G	G	G	F	N	N	G
Yellow foxtail	G	G	G	G	G	F	N	N	G
Barnyardgrass	G	F	G	F	F	F	N	N	F
Crabgrass	G	P	G	P	G	G	N	N	P
Panicum	G	P	G	P	F	G	N	N	P
Nutsedge	G	P	G	P	F	P	N	N	F
Quackgrass	N	G	N	G	N	N	N	N	G
Broadleafs									
Cocklebur	P	F	N	F	P	P	G	G	G
Lambsquarters	P	G	F	G	P	G	G	G	G
Mustard	P	G	P	G	P	G	G	F	G
Pigweed	F	G	G	G	F	G	G	G	G
Ragweed	P	G	P	G	P	G	G	G	G
Smartweed	P	G	P	G	P	F	P	G	G
Velvetleaf	F	F	P	F	P	F	G	G	F
Wild sunflower	P	P	P	P	P	P	F	G	G
Canada thistle	N	P	N	P	N	N	F	G	F

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

Table 3. Suggestions for chemical control of weeds in soybeans.

Chemical	Rate: lb/A of active ingredient or acid equivalent broadcast	Time of application	Remarks
alachlor (Lasso)	2 to 3	Preemergence	
chloramben (Amiben)	3	Preemergence	
chlorpropham (Chloro IPC)	2 to 3	Preemergence	For smartweed only
linuron (Lorox)	1/2 to 2 1/2	Preemergence	For medium textured soils with less than 4% organic matter
linuron and alachlor	1/2 to 1 1/2 + 1 1/2 to 3	Preemergence	
norea and chloramben (Noraben)	0.8 to 1.2 + 1 to 1 1/2	Preemergence	Do not use on sandy soils
trifluralin (Treflan)	1/2 to 1	Preplanting, incorporated	Must be well incorporated
vernolate (Vernam)	3	Preplanting, incorporated	Incorporate well immediately after application
chloroxuron (Tenoran)	1 to 1 1/2	Soybeans in first trifoliolate leaf stage, weeds less than 2 inches	Controls only certain broadleafs
2,4-DB	1/5	Postemergence	For cocklebur only

Table 4. Effectiveness of herbicides on major weeds in soybeans.

	Preplanting		Preemergence						Postemergence	
	Trifluralin (Treflan)	Vernolate (Vernam)	Alachlor (Lasso)	C-6989 (Preforan)	Chloramben (Amiben)	Chloramben and norea (Noraben)	Chlorpropham (Chloro-IPC)	Linuron (Lorox)	Chloroxuron (Tenoran)	2,4-DB
Soybean tolerance	F	F	G	G	G	F	G	F	F	P
Grasses										
Giant foxtail	G	G	G	G	G	G	P	F	P	N
Green foxtail	G	G	G	G	G	G	P	F	P	N
Yellow foxtail	G	G	G	G	G	G	P	F	P	N
Barnyardgrass	G	G	G	F	G	G	P	F	P	N
Crabgrass	G	G	G	G	G	G	P	G	P	N
Nutsedge	P	F	G	P	P	P	N	P	N	N
Broadleafs										
Cocklebur	P	P	P	P	P	P	P	P	P	F
Lambsquarters	G	G	F	F	G	G	P	G	F	P
Mustard	P	F	P	F	F	F	F	G	G	P
Pigweed	G	G	G	G	G	G	P	G	F	P
Common ragweed	N	P	P	F	G	G	P	G	P	P
Smartweed	P	F	P	G	F	F	G	F	P	P
Velvetleaf	P	F	P	N	F	F	P	F	P	P
Wild sunflower	N	P	P	-	P	P	P	P	F	P

G - Good
F - Fair
P - Poor
N - None
\- - Inadequate information

Aerodynamic Improvements for Agricultural Aircraft

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FOR THE PAST FIVE years, the Dept. of Aerophysics and Aerospace Engineering of Mississippi State University has been closely involved in research relating to aerial application and agricultural aircraft. A portion of this work, which was funded by the Aircraft Development Service of the Federal Aviation Administration, was designed to determine the performance characteristics of existing agricultural aircraft and to delineate methods of improving their performance and safety in aerial application operations. During the course of this program, the performance and aerodynamic characteristics of five different aircraft were evaluated. This paper presents a brief summary of the results for three typical types and sizes of aircraft (Figs. 1-3) and discusses some of the modifications that were made to the aircraft to improve their flight characteristics or safety in agricultural operations. In addition, several other proposed modifications are discussed.

DESCRIPTION OF TEST PROGRAM

The flight test program consisted of the measurement of the level flight and climb performance of the test vehicle in the clean or basic configuration and in both the spray and granular distributor configurations. In addition, the performance characteristics were determined at a low gross weight corresponding to full fuel, oil, and pilot and at a normal gross weight which would correspond to the basic aircraft with a full hopper of material. Special techniques and instrumentation were used to investigate the wing stall patterns, the airflow about the aircraft, and to determine the various aerodynamic characteristics of the aircraft such as skin-friction drag, pressure drag, and boundary layer characteristics.

Upon receipt of the aircraft from the manufacturer, all flight and power instruments were removed and calibrated or replaced with precision flight test instrumentation. In addition to the standard airspeed system in the aircraft, a second airspeed system was installed using a Kiel tube total head and a neutral static source located on the aircraft's fuselage. The second airspeed system was dynamically balanced and calibrated using a trailing static sonde and a third calibrated airspeed indicator. Brake horsepower requirements were determined from engine manifold pressure and rpm data and all performance data were reduced to standard sea level conditions.

All climb and level flight performance data were obtained under near calm wind conditions and under very stable atmospheric conditions. The sawtooth climbs were con-

ABSTRACT

During the past four years, the Dept. of Aerophysics and Aerospace Engineering conducted evaluations of five agricultural aircraft to determine their performance, handling characteristics, and modifications to improve their safety and economy. As a result, several modifications were made to the basic aircraft to improve its performance. Reevaluation of the modified aircraft's performance showed that these modifications were beneficial.

The evaluations showed that the greatest impediment in obtaining increased safety and performance is usually the dispersal systems used to distribute seed, fertilizer, and chemicals. Some effort was devoted to designing improved dispersal systems with lower power requirements. Results of the evaluation tests are represented.

Fig. 1 - Aircraft "A"

Fig. 2 - Aircraft "B"

Fig. 3 - Aircraft "C"

ducted over an altitude range of 1000 ft with altitude-time data being taken every 100 ft. All climb tests were terminated at or below 2000 ft MSL. Level flight performance tests were conducted at or below 3000 ft MSL during the entire program. As stated previously, all of the data have been reduced to standard atmospheric conditions.

RESULTS OF EVALUATION ON AGRICULTURAL AIRCRAFT

The results of climb and level flight performance tests that were conducted on three of the agricultural aircraft are presented in Figs. 4-6. It may be observed that, in all

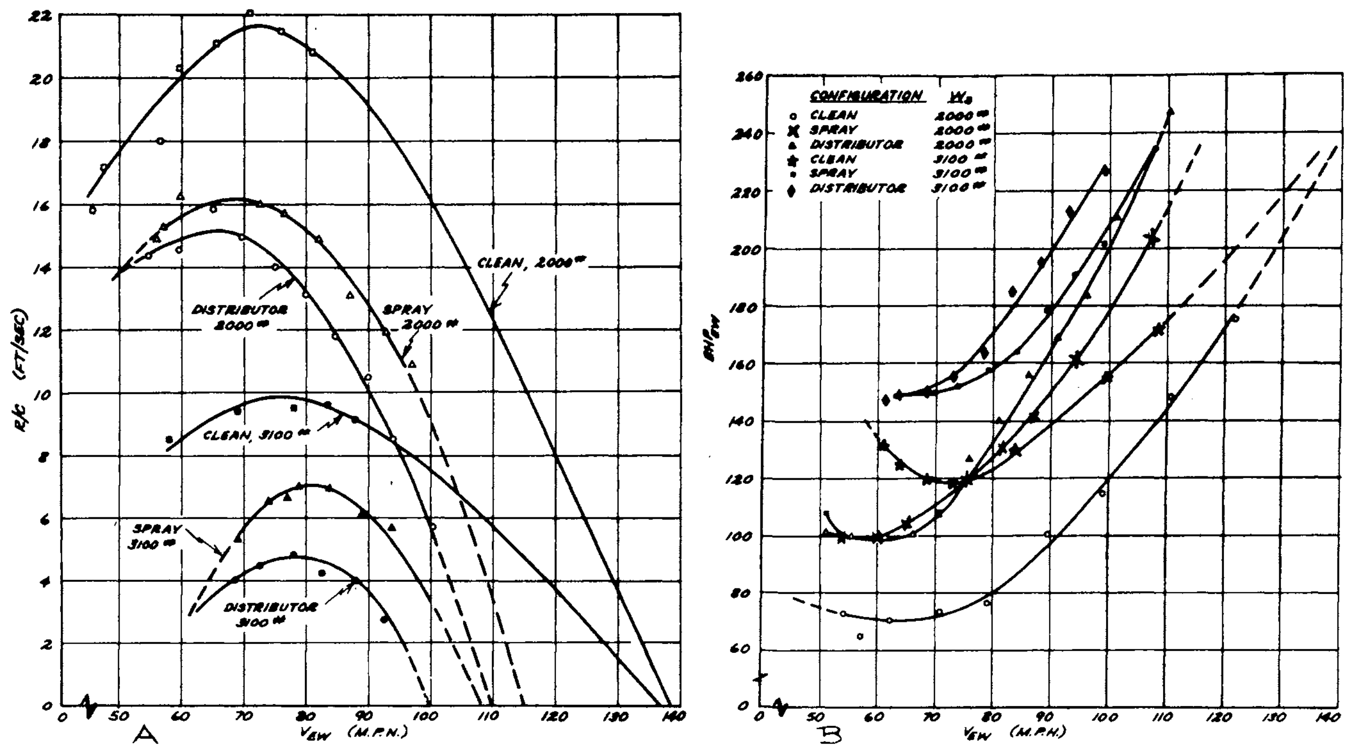

Fig. 4 - Aircraft "A" (A) climb performance data (B) level flight performance data

cases, the dispersal systems produce a significantly adverse effect upon the rate of climb of the airplane and that the power requirements of the dispersal system in some instances are almost as large as that of the basic aircraft.

The rate of climb of aircraft A at the 3100 lb gross weight and at a normal operating speed of 95-100 mph is comparable to that of the aircraft at its low gross weight with the dispersal systems attached. In addition, it may be noted that in both weight configurations the stall speed of the aircraft with the dispersal system attached was approximately 3.5-5 mph greater than that of the basic aircraft. Also, it can be observed that the rate of climb of the aircraft with the distributor system attached is approximately half of the maximum rate of climb of the clean airplane at 3100 lb gross weight. The power requirements of the spray and distributor system are considerable in both weight configurations. At 100 mph and 2000 lb gross weight, the power requirements of the spray system are approximately 1.5 times that of the clean aircraft and the requirements of the distributor system are approximately 1.7 times that required for the clean aircraft. It may be noted that the power required to fly the aircraft at the same airspeed with a 1200 lb load is only 1.3 times that of the basic aircraft at the lower gross weight.

The climb performance data for aircraft B is shown in Fig. 5A. At the 2900 lb gross weight, the spray dispersal equipment reduced the maximum rate of climb in excess of 20% while the addition of the distributor system reduced the maximum rate of climb by approximately 32%. At the 4800 lb gross weight, the maximum rate of climb in the spray configuration was reduced by approximately 32% and in the distributor configuration by approximately 46%. At the latter gross weight, the best rate of climb speed was reduced 6-8 mph for both the distributor and spray configuration. The power required data (Fig. 5B) also indicate the high power requirements of the dispersal systems. These data show that at the minimum gross weight of 2900 lb, the minimum required power was increased 11% by the addition of the spray equipment and 29% by the distributor system. At 90 mph the power required to fly the aircraft at the maximum gross weight is 159% of that required to fly the aircraft at 2900 lb gross weight.

The climb performance of aircraft C is shown in Fig. 6A. At the 4500 lb gross weight, the best climb speed was reduced by 3-9 mph, while at the 6900 lb gross weight, the dispersal equipment decreased the best climb speed by 2-1/2 to 4 mph. Due to the fact that the power loading of aircraft C was low as compared to the other agricultural aircraft, the equipment did not detrimentally affect the performance as much as it would if the power loading was substantially higher. The low minimum power requirement of the aircraft added considerably to its climb performance and is indicative of the aerodynamic advantage of a cantilever wing design. The level flight performance data are shown in Fig. 6B. At the 4500 lb gross weight and 110 mph airspeed, the power requirements of the spray system were approximately 1.17 times that of the clean aircraft while the power requirements of the distributor system were approximately 1.45 times that of the clean aircraft. It may be noted that at the same speed, the power required to fly the aircraft with the 2400 lb load was approximately 1.17 times that required to fly the empty aircraft. It is interesting

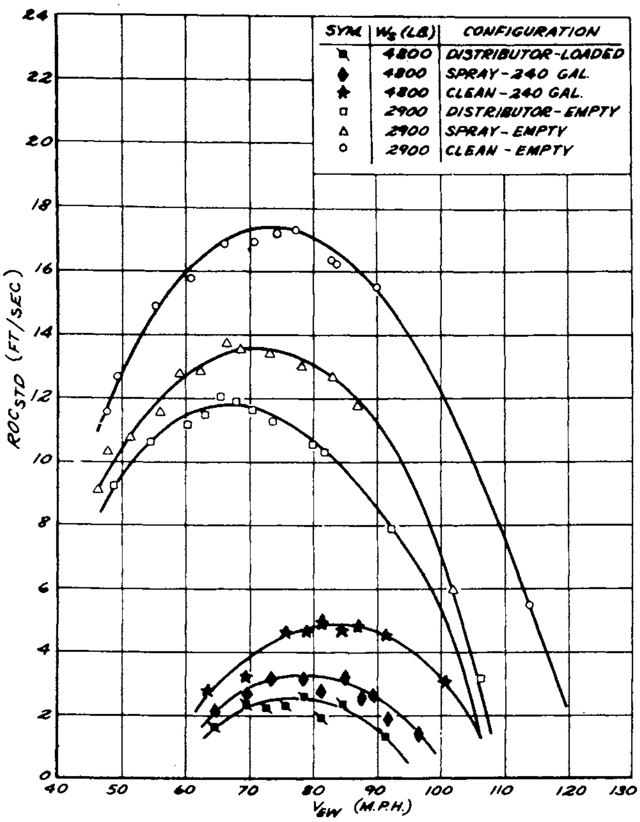

Fig. 5A - Climb performance data for aircraft "B"

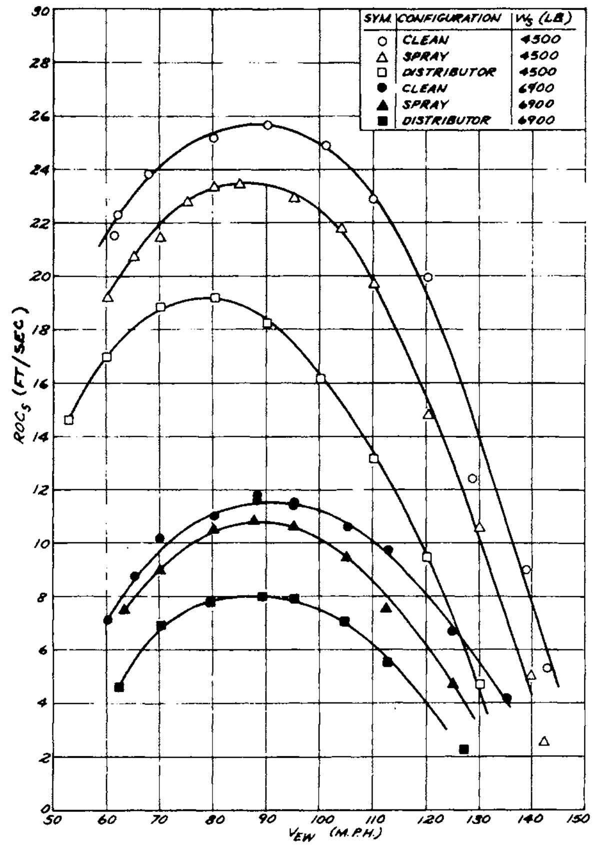

Fig. 6A - Climb performance data for aircraft "C"

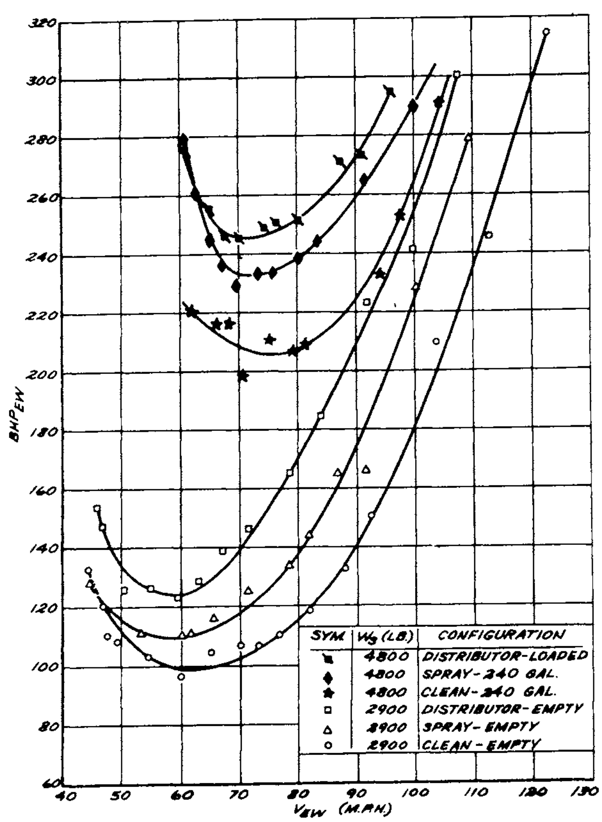

Fig. 5B - Level flight performance data for aircraft "B"

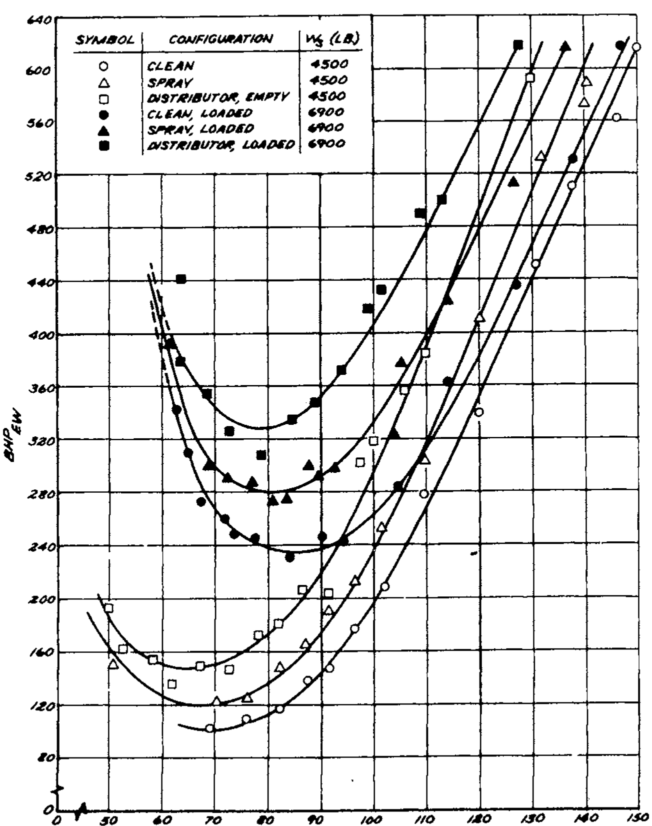

Fig. 6B - Level flight performance data for aircraft "C"

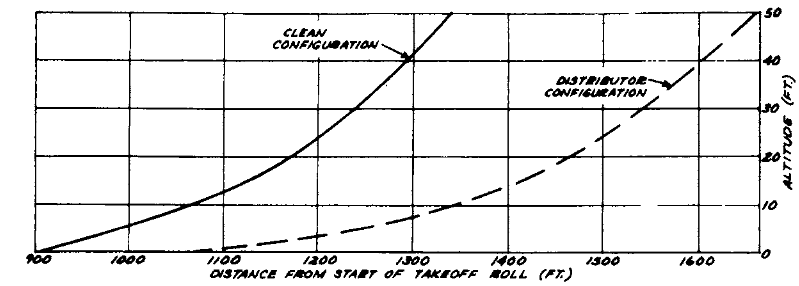

Fig. 7 - Effect of distributor system on takeoff trajectory, aircraft "A", W_s = 3100 lb, 0 deg flap

to note that in all cases the power requirements of the dispersal systems at the higher gross weight are larger than they are at the low gross weight. This is no doubt due to the higher velocities in the propeller slipstream and the fact that the major portion of the dispersal systems are designed to operate in the propeller slipstream.

All of the climb performance data and the power required data for the three aircraft indicate that the dispersal systems have a significantly adverse effect on performance. The dispersal systems reduce the maximum rate of climb at all airspeeds but particularly in the range of the normal operating speed. The increased profile drag caused by the systems reduced the best rate of climb which caused considerable increase in the induced drag at the higher gross weights and further tended to reduce the climb performance.

The dispersal systems reduce the airspeed at which minimum power is required to fly the aircraft and this result decreases the economy of operation by moving the minimum power speed further from the actual operating speed. These results can be noted by observing any of the level flight power curves. Ideally, the minimum power speed at gross weight would be slightly less than the normal operating speed in order to maximize both the economy of operation and the climb performance on pull-up from the field.

DISCUSSION OF EFFECT OF DISPERSAL EQUIPMENT ON LEVEL FLIGHT AND CLIMB PERFORMANCE

In all cases the power required to move the dispersal systems through the air is a considerable proportion of the power required to operate the basic aircraft. This additional power represents a considerable cost in terms of fuel consumption and accelerated engine deterioration. In some cases, it was necessary to operate the engine at full power during the takeoff and first few swath runs due to the extremely high power requirements of the dispersal system. Such extreme operating conditions are hazardous because of the increased probability of sudden engine failure, in addition to the decrease in performance.

Since climb performance is dependent upon the excess horsepower available, one might anticipate that good climb performance could be achieved by simply installing a higher powered engine. While an increase in engine power will usually increase the rate of climb, the increase is not directly proportional to the power increase because of the increased velocity in the slipstream causing higher drag on components of the dispersal systems mounted in the slipstream.

In general, all of the dispersal systems were approximately the same size and design. The power required to operate the spray systems ranged 33-65 bhp at the normal operating speeds for the test aircraft. These power requirements are very high as compared to those that could be obtained through aerodynamic refinement of the systems and by powering the systems directly from the aircraft engine. The reduction in horsepower that could be obtained by using an engine powered spray pump instead of a windmill powered system can be estimated by consideration of the power input required to drive a centrifugal spray pump from the aircraft engine.

Characteristic curves for a typical spray pump show that the input horsepower required for the application of 10 gal/acre at 100 mph on a 40 ft swath is nearly 4 shp. If the efficiency of the power transmission system is 65% (typical for a gear pump hydraulic system), then 6 shp will be required from the engine. In addition, drag calculations show that a cylindrical boom mounted in the free stream requires approximately 20-25 bhp from the engine to overcome the drag of the boom. A streamlined boom section with trailing edge nozzles requires only 12-15 bhp when mounted in the free stream but only about 7-8 bhp when it is mounted in the wake of the wing. Thus, if the pump was driven from the engine and the streamlined boom section was mounted in the wing wake, a complete system could be developed with a total power requirement of 10-15 bhp depending upon the liquid flow rate and spray pressure required.

In addition to the previously mentioned adverse effects which dispersal systems have on climb and level flight performance, they also produce other adverse effects which should be considered. Detailed measurements of the static thrust and take-off trajectories of various aircraft in various configurations indicate that the static thrust produced by the engine propeller system can be significantly reduced (up to 20%) due to the distributor or spray pump being mounted in the propeller slipstream. This reduction in thrust caused by proximity of the dispersal systems to the propeller disc causes an increased take-off run as is depicted in Fig. 7. In addition, the propulsive efficiency in both level flight and climb is considerably reduced due to the presence of the dispersal systems in the slipstream at velocities below the best rate of climb speed (Fig. 8).

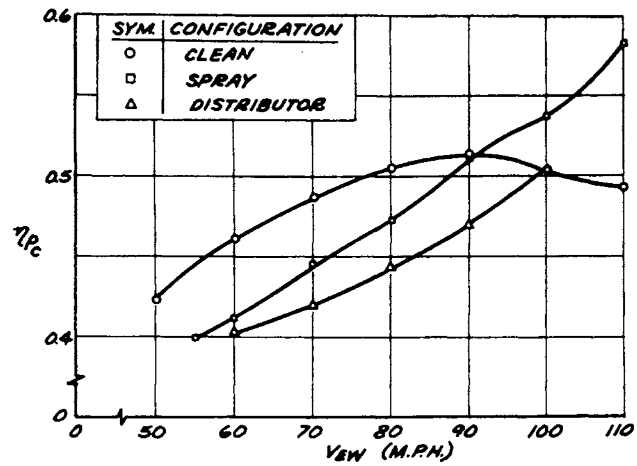

Fig. 8A - Propulsive efficiency of aircraft "A" in climb

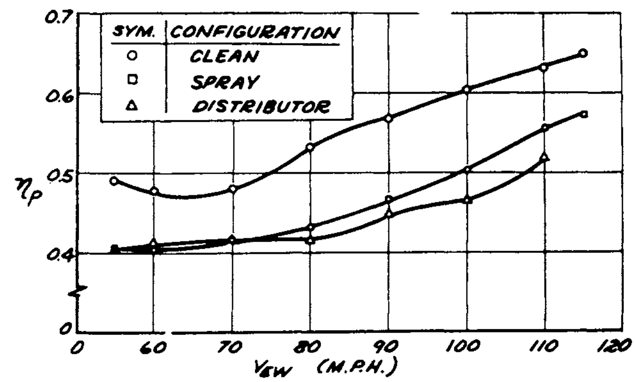

Fig. 8B - Propulsive efficiency of aircraft "A" in level flight

MISCELLANEOUS AERODYNAMIC TESTS

In order to determine if modifications to the various aircraft could improve the basic aerodynamic characteristics of the airplane, several additional tests were conducted. Flow visualization tests using both sublimation techniques and woolen tufts were conducted to determine areas of separated flow and to indicate the nature of the airflow over the aircraft surface. From these investigations, it was observed that considerable interference drag was created in the region of strut and wing intersections, wing and fuselage intersections, and in some cases, in the area of the engine cowl and the control surface-wing intersections. Several modifications to wing strut fairings and aileron gap configurations were made in order to improve the handling qualities of the airplane in low-speed flight and also to reduce the interference drag. The overall drag reduction that was achieved due to these modifications was small in terms of the total drag of the airplane although in certain cases reductions in stall speed of one to two miles an hour were observed. The details of these tests are given in Refs. 1-5.

In order to determine the aerodynamic characteristics of the wing, the chordwise pressure distributions were measured at various stations along the wing. From these data, the spanwise load distribution was determined and it was observed that struts, fairings, and other protuberancies produced a considerably detrimental effect on the spanwise lift distribution of the wing. The profile drag coefficient of the wing was determined by a wake survey technique and it was determined that the drag coefficient of most of the airfoils was considerably higher than the published two-dimensional data. This could possibly be due to construction techniques utilized in agricultural aircraft, in addition to the location of struts, protuberbancies, and attachment points on the wing surface. The drag coefficients of flapped airfoils was considerably higher than that of two-dimensional wind tunnel data. The skin-friction coefficient on the various wings was determined from boundary layer measurements and it was also determined that the boundary layer over a great portion of the airfoil was turbulent and that the skin friction was appreciably higher than would ordinarily be anticipated for airfoils operating at the Reynolds numbers characteristic of agricultural operations. Considerable improvement in the surface contour and the junction of control surfaces and flaps could aid in reducing the drag of the agricultural aircraft wing. However, the drag reduction that might be acquired by state-of-the-art wing construction is negligible as compared to the drag of the dispersal systems and other components such as canopies and engine cowls.

AERODYNAMIC IMPROVEMENT OF AGRICULTURE AIRCRAFT

As stated previously, the evaluation program showed that considerable improvement could be made in the performance of agricultural aircraft through modification of certain components of the aircraft and integration of the dispersal systems into the aircraft design. In order to test the validity of some of the proposed modifications, several modifications were made and evaluated to determine their effect on performance.

One such modification was to replace the open canopy on aircraft No. 3 with a closed canopy as shown in Fig. 9. The effect of this modification on the climb and level flight performance is shown in Figs. 10 and 11. The maximum rate of climb speed was increased approximately 7 mph. At a typical cruise speed of 120 mph, the level flight power required was reduced by 27%. In addition to the improvement in the climb and level flight performance, a significant reduction in the sound level within the cockpit was noted by the pilots, and fatigue over extended flight periods was considerably reduced. The installation of an engine cowling on both aircraft C and aircraft B should produce a similar improvement in performance as well as increase the engine cylinder head temperature to a more efficient level.

In order to demonstrate the savings in brake horsepower that can be accomplished through improved design of dispersal systems, an engine powered liquid dispersal system

Fig. 9 - Canopy modification on aircraft "C"

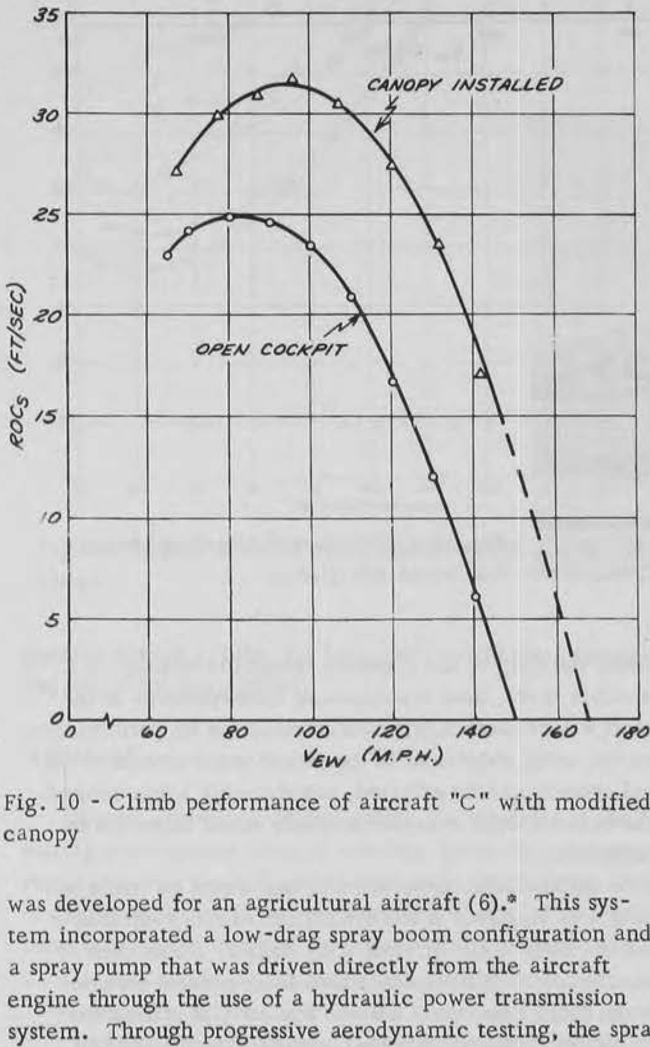

Fig. 10 - Climb performance of aircraft "C" with modified canopy

was developed for an agricultural aircraft (6).* This system incorporated a low-drag spray boom configuration and a spray pump that was driven directly from the aircraft engine through the use of a hydraulic power transmission system. Through progressive aerodynamic testing, the spray boom was located in the wing wake in such a manner that the drag of the boom and nozzle system was reduced from approximately 22 bhp to approximately 8 bhp. The engine powered spray system in its final configuration is shown in Fig. 12 and the power requirements of the external components of the spray system are shown in Fig. 13. The final configuration of the low-drag boom incorporated a streamline airfoil section for the boom and trailing edge nozzles.

It can be observed from the power required data that the drag of the streamline boom is less than that of the cylindrical spray boom; however, the drag reduction accomplished by putting the boom into the wing wake is far more important than the configuration of the boom itself. The power required to drive the spray pump was limited to 5 shp by a pressure relief valve in the hydraulic system; therefore, the total power required to drive the spray system would be approximately 5 hp or less than that shown in Fig. 13. The spray boom was designed to operate at approximately 95 mph and at this speed, the rate of climb of the modified aircraft was almost equal to that of the clean or basic aircraft and the level flight power required was estimated at approximately 10-12 hp for the total system at the maximum gross weight. At normal operating speeds, the rate of climb of the modified aircraft was within 10% of the basic aircraft (Fig. 14). Thus, by driving the spray pump from the engine and through the use of a streamline boom mounted in the wing wake, a complete system has been developed with a total power requirement of 10-12 bhp depending upon the flow rate and the spray pressure required for a particular job. The climb performance of the aircraft and its economy of operation in level flight were significantly increased by reducing the power requirement of the spray system from approximately 55 bhp to 10-12 bhp. The reduction of power required to operate the dispersal system permits the pilot to operate the aircraft engine at lower power settings which reduces engine wear and the possibility of sudden engine failure. Also the takeoff run and distance required to clear a 50 ft obstacle is greatly reduced and the rate of climb upon pull-up from the swath run is also increased.

Obviously, the performance of aircraft could be increased even more dramatically by effecting similar reductions in the power requirements of the solid materials distributor systems. Several different systems are currently being investigated, and it appears that a system can be developed which will require less than 15-25 bhp. In addition, these

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*Numbers in parentheses designate References at end of paper.

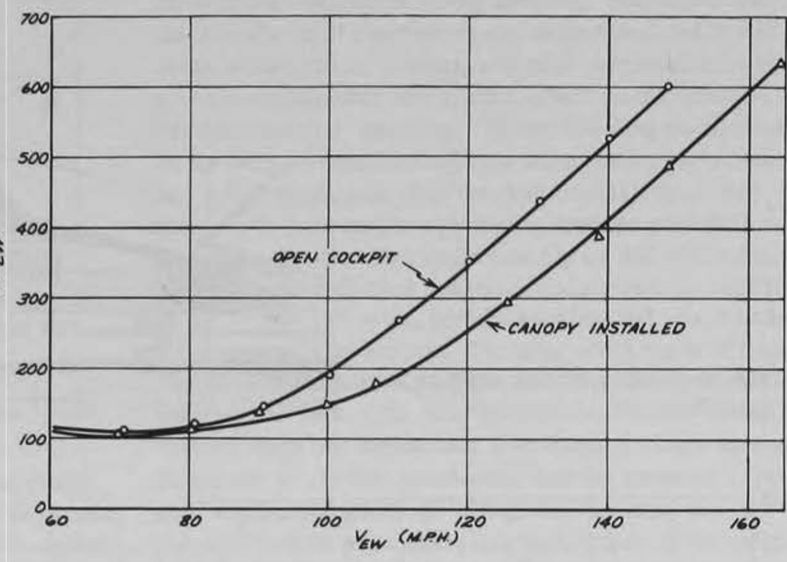

Fig. 11 - Level flight powered required, aircraft "C" with modified canopy

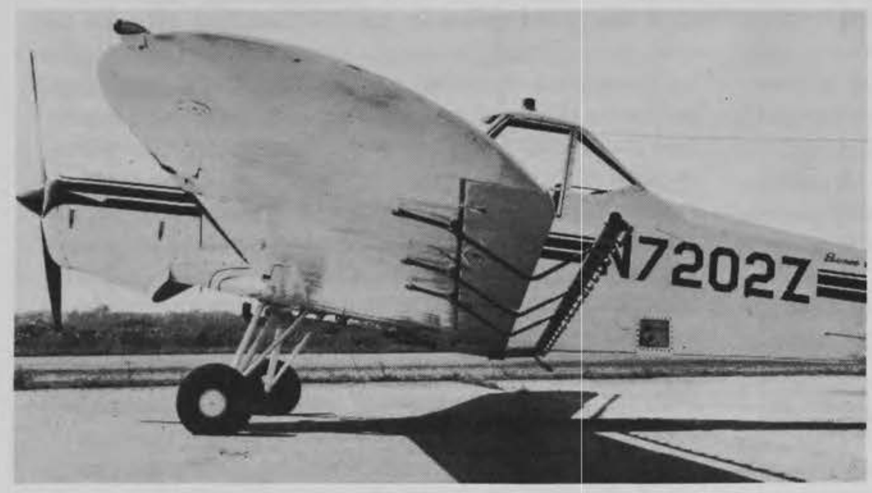

Fig. 12 - Side view of low-drag streamline boom installation

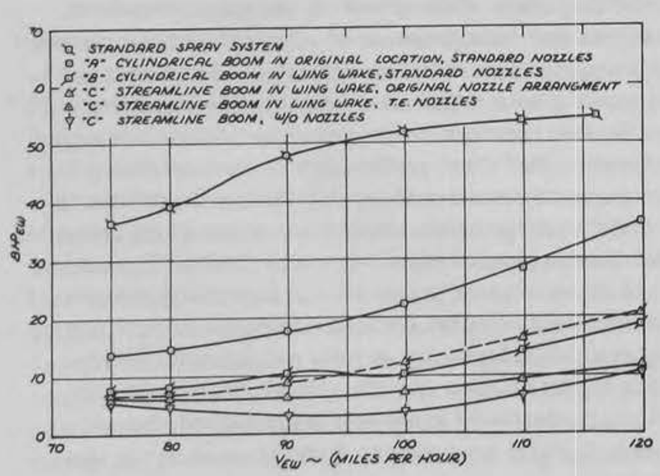

Fig. 13 - Power requirements of various spray boom configurations

systems show excellent promise of increasing the total and effective swath width that can be obtained and at the same time increase the uniformity of the distribution across the swath.

Once the drag of the dispersal systems is reduced to a reasonable level, then aerodynamic improvements in the aircraft will produce significant increases in its performance. However, until reductions in the power requirements of dispersal systems can be effected, aerodynamic improvement in the basic aircraft will produce only small increases in performance.

One aerodynamic improvement that could be made to agricultural airplanes is the utilization of more suitable airfoil sections in the aircraft wing design. Since current production aircraft have descended from general purpose aircraft, there has been a natural tendency to utilize the same airfoil sections. However, careful investigation of airfoil characteristics will indicate that considerably thicker airfoils in the 63_2, 63_3, or 63_4 series could be utilized in agricultural aircraft without a significant penalty in drag. By utilizing thicker airfoils, the maximum lift of the flapped wing would be greater and the stall characteristics would be more suitable to agricultural aircraft operations. In addition to the aerodynamic improvements that could be realized from the thick airfoil sections lighter wing structures and

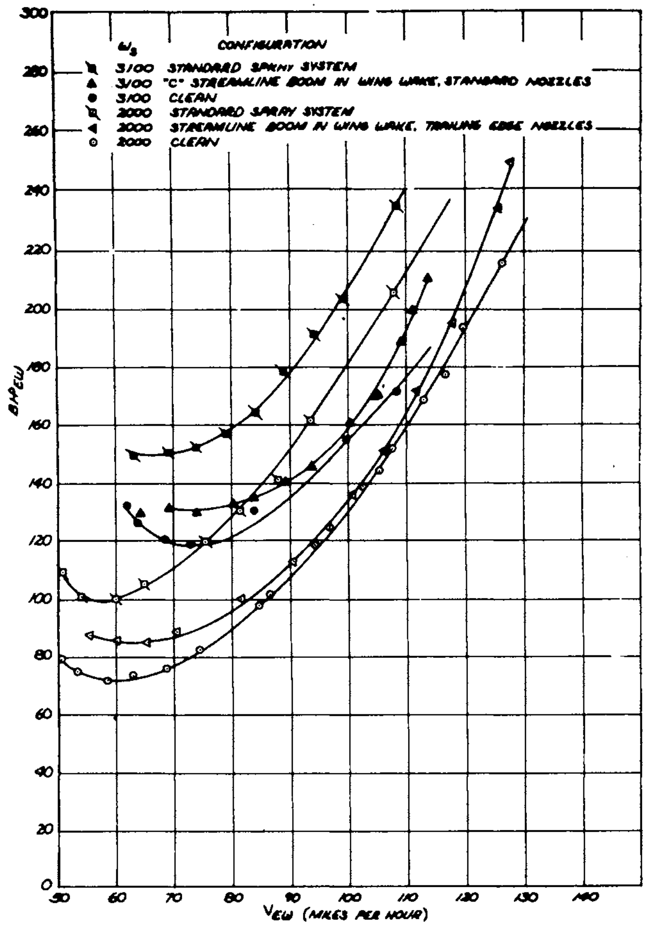

Fig. 14 - Comparison of power requirements of dispersal systems

greater storage volume for fuel could be realized through the use of thicker airfoils.

SUMMARY

Through systematic flight testing and analysis of the resulting performance data, it has been shown that the power requirement of most dispersal systems is much larger than it should be for optimum performance of aircraft in agricultural operations. Several modifications have been made to the basic aircraft to improve its aerodynamic characteristics and to increase its performance; however, in most cases, it has been shown that the increase in performance due to modification of the basic aircraft is small as compared to the increase in performance that can be obtained through improvement in the aerodynamic design of the dispersal systems. A low-drag, engine-powered, liquid dispersal system was designed which had a power requirement of less than 20% of typical spray systems. It is emphasized that through consideration of the dispersal system in the preliminary design of the aircraft and integration of the dispersal system into the aircraft, the performance of the aircraft can be increased in agricultural operations and that improved dispersal characteristics can be obtained from the dispersal systems.

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HAZARDS PRESENTED TO THE APPLICATOR BY INCREASED USE OF ORGANOPHOSPHATE PESTICIDES

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I. INTRODUCTION

Recent restrictions on the use of chlorinated pesticides will force agriculture to depend increasingly on the organophosphates for insect control.

Because the organophosphates are relatively unstable chemicals, their persistence in water or soil after dispersion is measured in hours or days, and the environment will almost certainly benefit from the substitution. Concern about the long-range effects of insecticides on the Nation's health should subside, because proper control of amount and timing of application to food crops can minimize or abolish the residue problem. In any event, these chemicals do not accumulate in animal tissues.

However, many of the most widely-used organophosphates are more toxic than the compounds they are slated to replace, and therefore present a greater hazard to the applicator who must handle them in concentrated form. Paradoxically therefore, unless the applicator becomes better informed, the incidence of poisonings is certain to increase. This trend may now be appearing in certain areas in which the use of organophosphates has increased sharply. We are particularly concerned about this trend, because many of these poisonings have occurred among aerial applicator personnel.

Safety in handling chemicals depends upon a proper respect for their toxicological properties. Applicators have a multiple responsibility in this regard because they are obligated to protect not only themselves and their employees, but the public as well. In these times it has become especially important to become familiar with the potential hazard of a chemical before it is used in any commercial operation.

II. TOXICOLOGY OF ORGANOPHOSPHATES

At least nine different types of phosphorus-containing chemicals are useful pesticides. They vary in toxicity from the relatively innocuous malathion to the highly-toxic tetraethyl pyrophosphate

(TEPP). Derivatives of phosphoric acid are active poisons in their original form. Derivatives of thiophosphoric acid must be converted to their oxygen analogs by enzymes present in both insects and higher animals before they acquire insecticidal or toxic properties.

All organophosphates share a common, primary mechanism of toxicity in animals, including man; inhibition of the enzyme, acetyl cholinesterase, which is essential to the function of the nervous system. As a result of this action there is a dramatic disturbance of function within the nervous system and in every organ of the body which is subject to control by the nervous system.

The onset of poisoning may be signalled by headache, nausea and vomiting. As absorption of the chemical continues, symptoms become progressively more severe. They usually include: intestinal cramping and diarrhea, excessive salivation and sweating, constriction of the pupil of the eye, "tightness" in the chest, leg cramps and spontaneous muscle contractions. If the dose is large and proper treatment is not given immediately, convulsions may occur, followed by coma and death due to respiratory arrest.

Unlike some cholinesterase inhibitors which are medically useful because their action is transient, the organophosphates are persistent or permanent inhibitors and actually destroy the enzyme. Although the symptoms of mild poisoning are suppressed by the familiar drug atropine, it should never be used other than as a first aid measure and the victim should be taken to a physician as soon as possible.

III. HOW POISONING OCCURS

With only a few exceptions, the organophosphates are readily absorbed through intact human skin. Absorption through the skin is usually slower and less complete than from the intestinal tract, and from 2 to 4 times the toxic oral dose must be applied to the skin to produce a comparable effect. Although the danger of inhalation of vapors, dusts and aerosols cannot be ignored, and some workers may be careless enough to carry toxic amounts of chemical to the mouth on food, cigarettes or contaminated hands, case histories show that most poisonings among professional applicator personnel result from dermal absorption.

Many of the most toxic organophosphates are available in formulations containing 50% or more, by weight, of the active chemical.

In the case of ethyl parathion, for instance, 1 ml of such a concentrate carries more than the estimated lethal dose for an adult human by either oral or dermal route, and a fraction of that amount could cause severe poisoning.

Many of the organophosphates cling to the skin tenaciously, and only vigorous scrubbing soon after contamination will remove them. A deceptive feature of some thiophosphates is the delayed reaction. Since absorption through the skin is slow, and activation to the toxic compound must occur in the liver, symptoms may appear hours after the last known contact. This feature, incidentally, points up the danger for the agricultural pilot who takes atropine to suppress symptoms and continues to fly; continued absorption and activation of the poison may overrun the protective effect of the antidote as the latter wears off and create an emergency situation.

Poisoning among professional applicators comes from two types of situations: (1) the catastrophic, seemingly-unavoidable accident, and (2) the thoughtless, careless act.

The first type of episode may involve the rupture of a pressure hose, a spill into the cockpit of an aircraft during loading or during flight, upset of an awkward or heavy container of concentrated material or an accident involving an aircraft or ground rig which drenches the operator with spray material.

Poisoning more frequently results from thoughtlessness, carelessness or haste. Each of the following types of action has been documented:
An applicator pilot cleans spray nozzles with bare hands and continues to work without thorough washing.
A pilot walks through spilled chemical and steps on the seat in boarding his plane.
A swamper carries food in his pocket while at work.
A swamper works in spilled chemical in canvas shoes or with holes in shoes or boots.
A swamper handles hoses wet with chemicals, without gloves.
A flagman moves too slowly in the field and becomes wet with spray.
A worker is poisoned from washing a contaminated aircraft with bucket and sponge.
An aircraft mechanic is poisoned from making repairs on an unwashed aircraft.

IV. CASE HISTORIES OF POISONINGS

As time permits, histories of actual poisonings among applicators will be reviewed.

DISTRIBUTION OF PESTICIDES FROM GRANULAR APPLICATORS

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Granular pesticides are recommended for control of many insect pests. For proper dispensation of these pesticides, granular applicators are required. If satisfactory pest control at a minimum cost is to be attained, these applicators must be calibrated easily and must deliver the pesticide uniformly throughout the field. If this precise and uniform application of pesticides is achieved, a minimal amount of pesticide can be applied and pesticidal residues can be reduced.

Although calibrations for various granular applicators are readily available or are easily determined, the pattern of distribution from pesticide applicators has not been studied. Generally, granular applicators have been calibrated for a given time interval or given distance (i.e. ounces per minute or ounces per 100 foot of row). Consequently, after calibration in this manner, the total amount of pesticide that was dispensed from the applicator closely agreed with calculated values. Unfortunately, these types of calibrations do not provide information on delivery during the time interval or distance over which the calibrations were made.

The results that are reported here have been obtained from experiments conducted by the Agricultural Engineering Department, Wooster, Ohio. My contribution to this project has been minimal.

The equipment that was used to determine the uniformity of distribution from granular pesticide applicators is shown in Figure 1. It consisted of a test stand, which supported the granular applicators, and a turntable which carried 75 sample containers. Each sample container was made of plastic and had a 4-inch square opening. The turntable driven by an electric motor, could be rotated at any speed to collect samples. For most of these tests, the turntable was rotated at a speed equivalent to a ground speed of 4 m.p.h. The rotors of the granular applicators were driven by an electric motor with a variable speed drive; therefore, any rotor speed could be maintained. The applicators were mounted on the test stand to dispense the granules from the applicator over the center line of the sample containers. Switches, solenoids, and microswitches provided precise control of the application procedure. A cam located on the side of the turntable contacted a microswitch which in turn activated a chute which directed the granules from the applicator into the sample containers. After one revolution of the turntable, this same mechanism

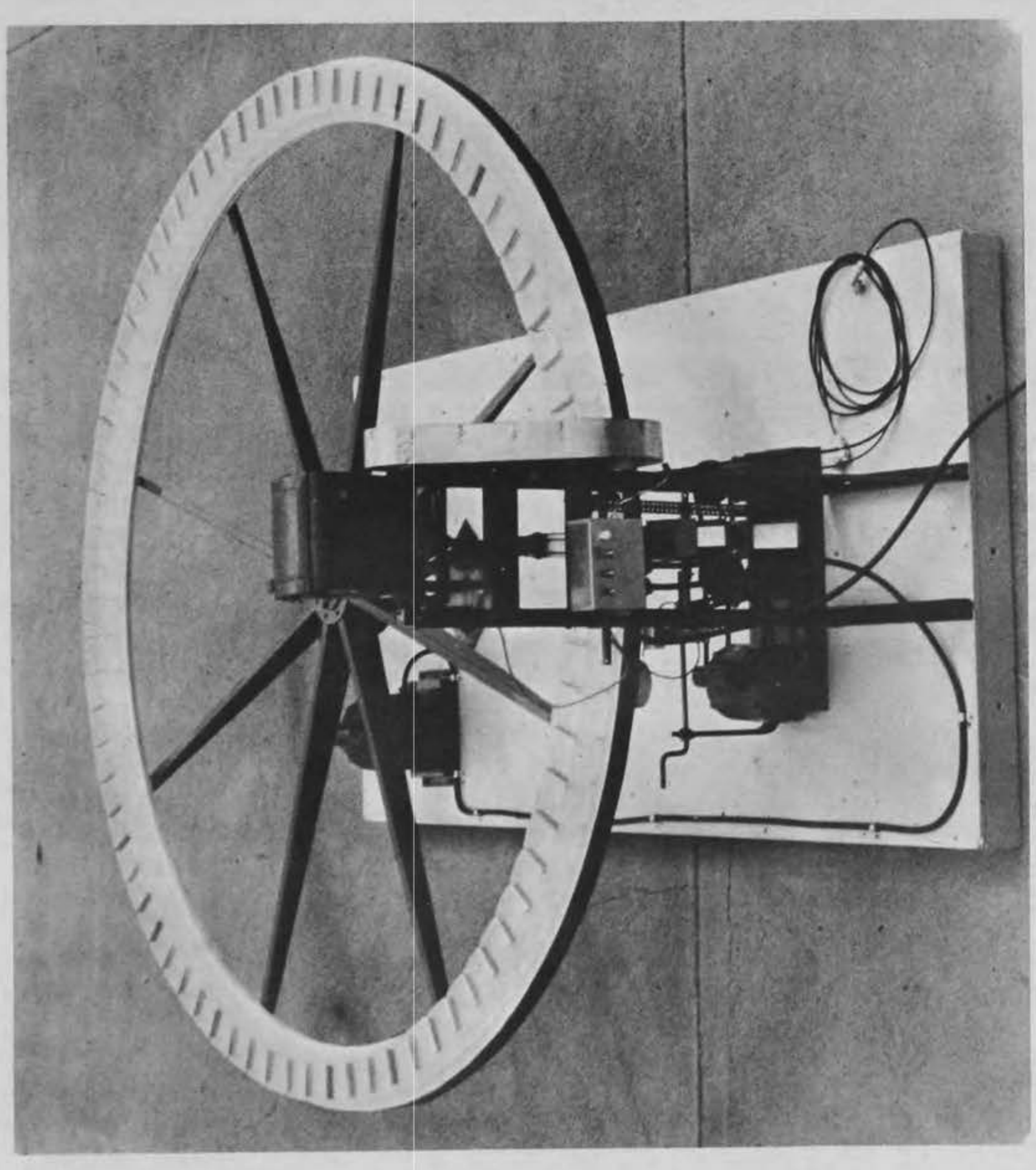


Figure 1. Test stand and turntable used for evaluation of distribution from granular applicators.

redirected the flow of granules from the sample container into a large container located along side of the turntable. One revolution of the turntable was equal to 25 feet of row. Various recording devices were operated, and from these recordings the exact rotor speed, turntable speed, and position of the rotor blades with respect to the outlet of the applicator could be determined.

US 20/40-mesh Florex (AA-LVM) granules were used. For all reported tests, the applicators were calibrated for each rotor speed to deliver 232 grams per minute or 20 pounds of granules per acre based on 38 inch rows at 4 m.p.h.

To illustrate the variation in delivery of granules from various applicators, 3 applicators (Figures 2A, 3A, and 4A) were used. In addition, the rotor within each of these applicators was operated at 2 different speeds. The rotor speeds were not constant from applicator to applicator, but were chosen to illustrate the effect of rotor speed on the delivery of granules from the various applicators. Commercial or trade names of the granular applicators will be omitted. They will be referred to as applicator A, applicator B, and applicator C.

APPLICATOR A

Applicator A and the rotor, which had 5 blades, are shown in Figure 2A and 2B, respectively. The manual that accompanies this applicator recommends that the rotor be operated at a speed of 7-20 r.p.m. Figure 2C shows the distribution of the granules from applicator A when set to deliver the calibrated rate at a rotor speed of 7 r.p.m. The horizontal line denotes the calibrated or average delivery rate for this r.p.m. This figure shows that consecutive samples 17-28 and 48-58 contained less than 75% of the mean sample weight or calibrated delivery rate. In addition, consecutive samples 2-9, 30-40 and 61-70 contained more than 125% of the mean sample weight or calibrated delivery rate. Consequently, only 31% of the row or treated area received within 25% of the calibrated delivery rate. For the remainder of the discussion, the exact sample distribution will not be stated. This information is readily available from the various figures.

In all tests a cyclic pattern in distribution of the granules was evident. From the recording devices previously mentioned, it was shown that the low points on each figure coincided with the rotor blade being centered over the opening of the applicator.

For applicator A, if the ground speed (i.e. turntable rotation) was increased from 4 to 6 m.p.h. and the rotor speed remained constant at 7 r.p.m., the length of row receiving less than 75% and more than 125% of the calibrated rate would be increased 50%.

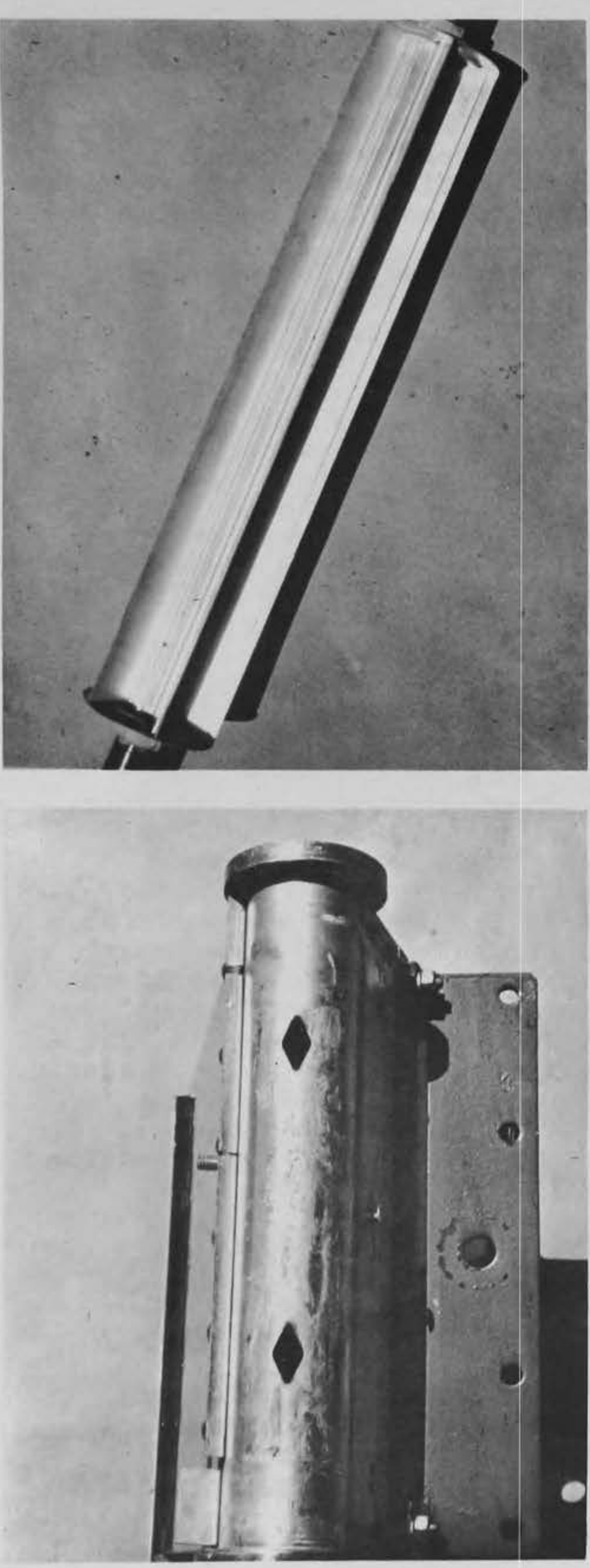


Figure 2. Applicator A results. 2A applicator; 2B – 5-bladed rotor of applicator A; 2C – sample distribution at a rotor speed of 7 rpm; and 2D – sample distribution at a rotor speed of 20 rpm.

Figure 2D shows the distribution of granules from applicator A set to deliver the calibrated rate at a rotor speed of 20 r.p.m. The horizontal line shows the calibrated rate. A comparison of the last two figures shows that the variation was less for the 20 r.p.m. rotor speed than for the 7 r.p.m. rotor speed. At 20 r.p.m. no sample container received less than 75% or more than 125% of the calibrated rate.

For applicator A it was shown that r.p.m. of the rotor was very critical in uniform delivery of the granules. A minimum of 15 r.p.m. was required for uniform distribution; however, 20 r.p.m. rotor speed appeared to be more uniform. Even with this rotor speed (20 r.p.m.) sample variation was between 15-20% of the calibrated rate.

APPLICATOR B

Figure 3A and 3B show applicator B and rotor (10 blades), respectively. The manufacturer indicated that a rotor speed of 25 r.p.m. was best.

Figure 3C presents the distribution of granules from applicator B when set to deliver the calibrated rate at a rotor speed of 15 r.p.m. Only 45% of the samples were within 25% of the calibrated rate. From figure 3C an increased number of high and low points is evident. This corresponds to the increased number of rotor blades. Each low point corresponds to positioning of the rotor over the opening.

Figure 3D presents the delivery from application B with the rotor operated at 25 r.p.m. At this speed only 68% of the row received within 25% of the calibrated rate.

In figures 3C and 3D the upper horizontal line denotes the calibrated rate, whereas, the lower one denotes 25% variation from this rate. With applicator B, no rotor speed tested (5 to 60 r.p.m.) dispensed granules within 25% of the calibrated rate. Uniformity increased with faster rotor speed. At high speeds a problem with attrition could be encountered.

When the rotor in applicator B was modified to correspond to the rotor in applicator A (i.e. 5 blades instead of 10), the distribution of granules from this applicator was within 25% of the calibrated delivery rate.

APPLICATOR C

Applicator C and rotor (6 blades) are shown in Figure 4A and 4B, respectively. No specification was given by the manufacturer for operational speed of this rotor.

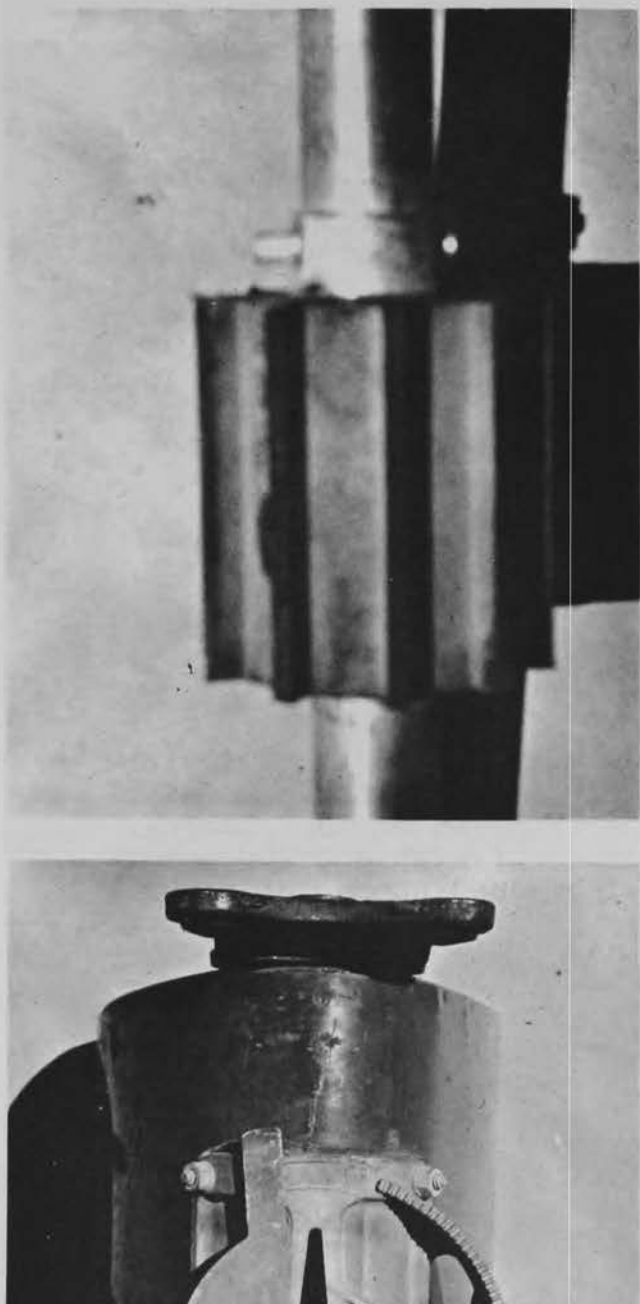


Figure 3. Applicator B results. 3A–applicator B; 3B–10 bladed rotor associated with applicator B; 3C–sample distribution at a rotor speed of 15 rpm; and 3D–sample distribution at a rotor speed of 25 rpm.

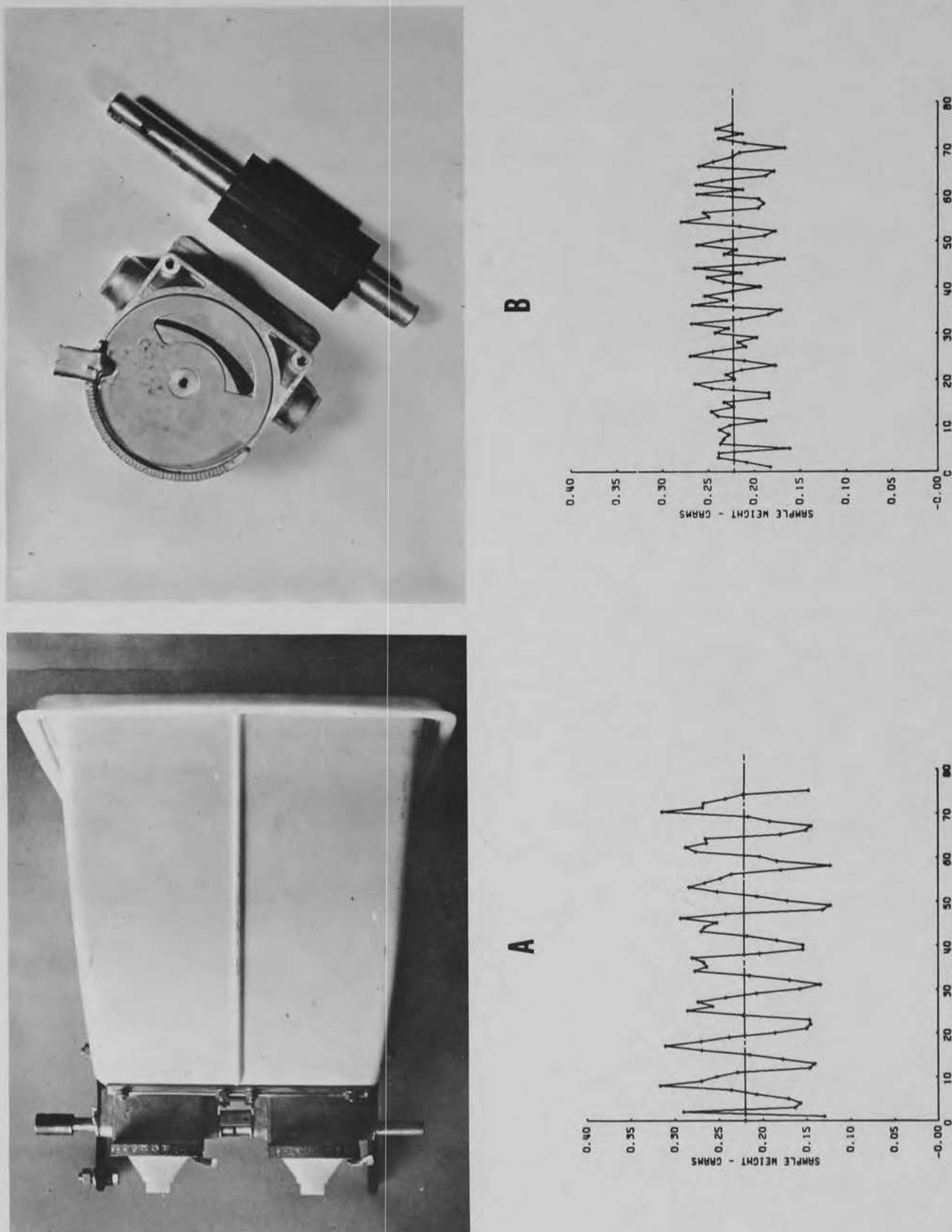


Figure 4. Applicator C results. 4A - applicator C; 4B - 6-bladed rotor associated with applicator C; 4C - sample distribution at a rotor speed of 20 rpm; and 4D - sample distribution at a rotor speed of 30 rpm.

Figure 4C shows the distribution from applicator C when set to deliver the calibrated rate at a rotor speed of 20 r.p.m. Only 44% of the samples of 33 samples received within 25% of the calibrated delivery rate. When the rotor speed was increased to 30 r.p.m., 95% of the samples or 71 samples received within 25% of the calibrated rate (Figure 4D).

With applicator C rotor speeds of 30 r.p.m. were necessary for optimal uniformity. The variation in distribution from this applicator was greater than applicator A but less than applicator B.

It was indicated earlier that several rotor speeds were evaluated. However, only selected rotor speeds have been discussed.

Figure 5A presents the results for all rotor speeds expressed in percent coefficient of variation (C.V.). The coefficient of variation (C.V.) expresses the relationship of the standard deviation to the mean. It measures the dispersion around the mean. In other words, as the coefficient of variation value decreases the more uniform the delivery rate. For instance, the coefficient of variation (C.V.) for applicator A at 7 r.p.m. was 35%, whereas, this value for the same applicator at 20 r.p.m. was 8%. From Figure 2A and 2B, the higher rotor speed was the most uniform.

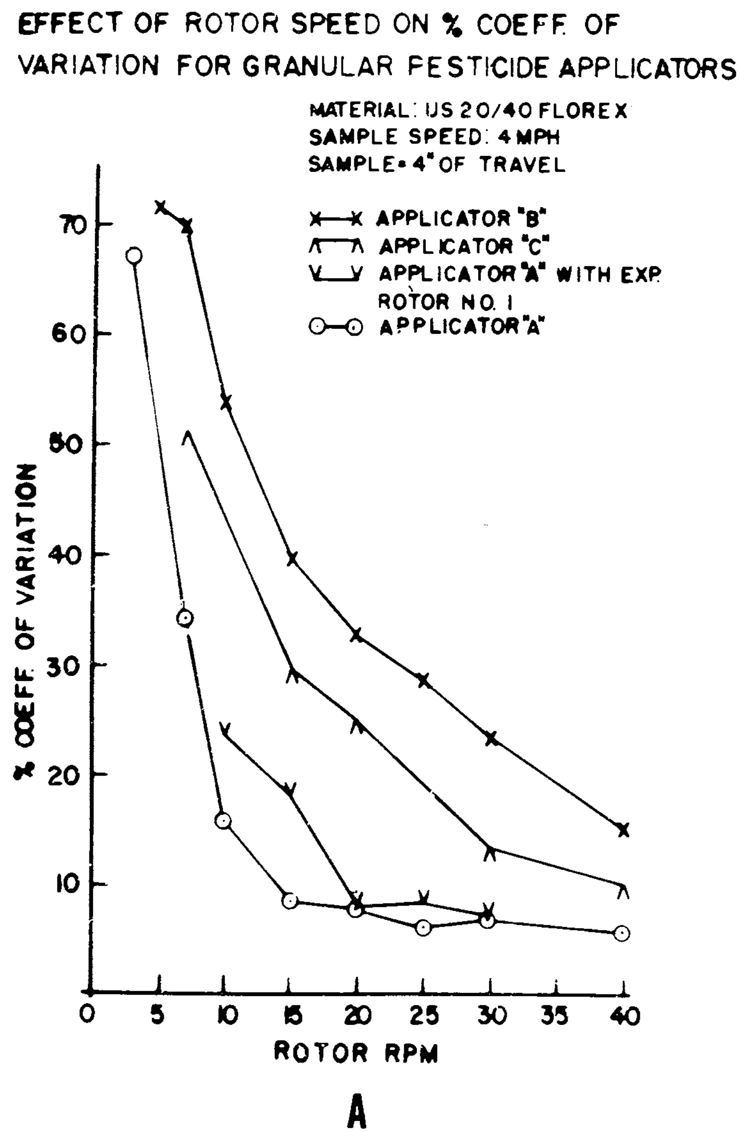
From Figure 5A, applicator A showed a linear decrease in C.V. values up to a rotor speed of 15 r.p.m. At rotor speeds in excess of 15 r.p.m. At rotor speeds in excess of 15 r.p.m., no real advantage was shown. Consequently, for maximum uniformity this applicator should be operated at 15 r.p.m.

For applicator B, a different result was shown. A decrease in C.V. corresponded to all increases in rotor speeds. This relationship appeared to be strongly linear.

For applicator C, the same type of pattern was shown. However, evidence indicates that rotor speeds in excess of 30 r.p.m. would not give any significant increase in uniformity.

Another important attribute for granular pesticide applicators is the relationship of rotor speed to delivery rate. The rotors within most applicators are chain-driven from a ground drive-wheel (i.e. presswheel on a planter). Consequently, rotor speed should be related directly to ground speed. Ideally, a change in ground speed should result in an equivalent change in delivery rate. If ground speed increases 10%, the delivery rate should increase 10%. Figure 5B shows this relationship to be far from the ideal. However, this relationship was dependent on the applicator. The solid unmarked line indicates the ideal relationship.

For applicator A the delivery rate increased sharply as the rotor speed was increased to 10 r.p.m. From 10 r.p.m. to 60 r.p.m., there



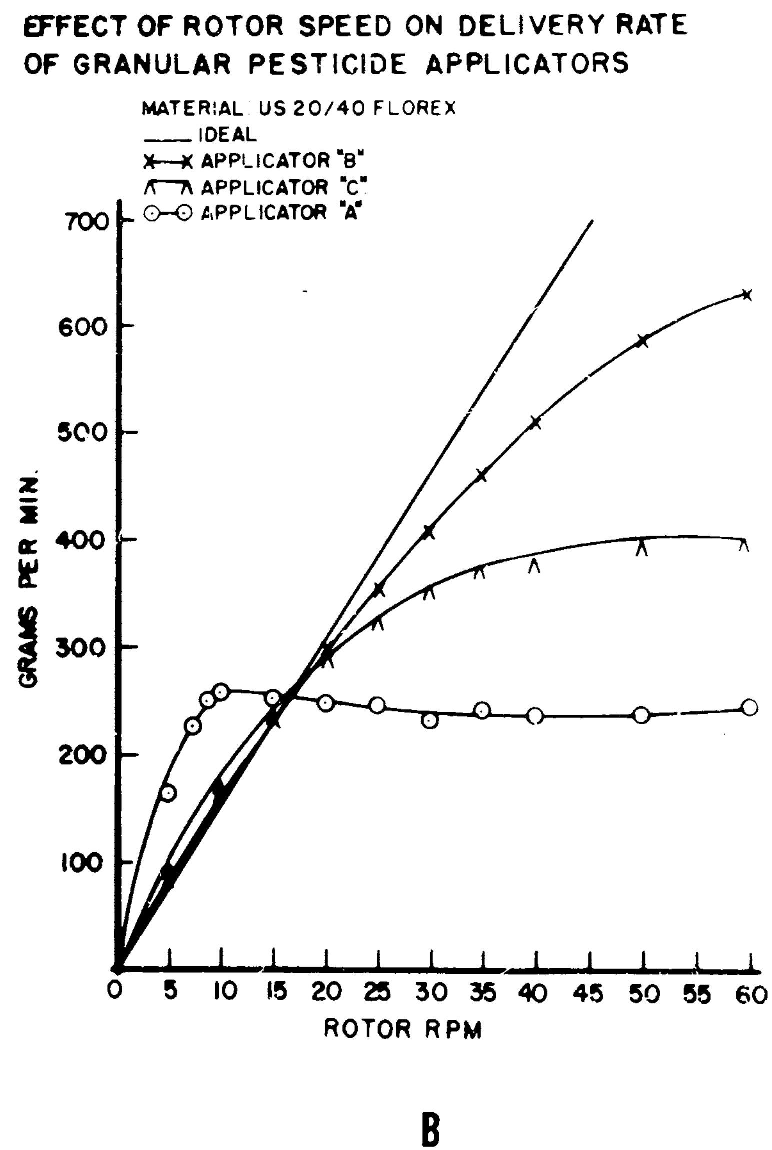


Figure 5. Sample distribution at various rotor speeds for the different applicators.
5A - effect of rotor speed on percent coefficient of variation for pesticide applicators
and 5B - effect of rotor speed on delivery rate of granular pesticide applicators.

was no change in the delivery rate with an increase in rotor speed.

For applicator B, the delivery rate closely followed the ideal rate up to a rotor speed of 30 r.p.m. Although there was an increase in delivery rate with increased rotor speeds above 30 r.p.m.. the delivery rate deviated from the ideal.

For applicator C the delivery rate was near ideal for rotor speeds up to 20 r.p.m. However, for rotor speeds above 20 r.p.m. the delivery rate, although increasing slightly with increasing rotor speeds, deviated significantly from the ideal rate.

It was concluded that calibrations are valid only for the ground speeds used in calibration. If ground speeds are changed, then a recalibration is necessary.

Grinding or attrition of granules for these various applicators was studied. For a rotor speed of 20 r.p.m. it was shown that the amount of material retained on a given size screen sieve was 93.4%, 89.8%, and 87.3% for applicators C, B. and A respectively. Applicator A and B showed about the same result. However, applicator C showed less attrition. In applicator C the rotor is short and in a compartment under the hopper. There is a baffle to direct granules to the side of the rotor; therefore, all material on the rotor is discharged soon after contact with the rotor.

Additional studies with these applicators, on different types of rotors, number of blades, mesh granules, etc. were studies. Some of the conclusions from these studies were:

1. distribution from applicators B and C always varied more than from applicator A.

2. testing with experimental rotors showed that thin-bladed rotors (similar to applicator A) always dispensed samples with the lowest coefficient of variation;

3. additional testing of rotors that were identical, except for the number of rotor blades, showed that 5-bladed rotors had lower coefficients of variation than 10-bladed rotors;

4. testing with other granular sizes showed that no applicator dispensed coarse granules (i.e. 8/16 mesh) as uniformly as fine granules (i.e. 20/40 mesh);

5. when flow rate (i.e. calibrated delivery rate) changed, the change in coefficient of variation (C.V.) was dependent on the applicator (i.e. applicator A - no change;

applicator B - very marked decrease in C. V. with decrease in flow rate); and

6. delivery rate from rotors with shallow blades remained closer to the ideal rate over a greater range of rotor speeds.

There are several general conclusions that can be made from this study. They are:

1. Pattern of distribution of pesticides from granular applicators is quite variable.

2. Distribution patterns for any applicator is dependent on the positioning of the rotor in the applicator, type of rotor, thickness of rotor blades, number of rotor blades, speed of rotor rotation (r.p.m.), particle size of granular pesticide, and flow rate of the pesticide.

3. Delivery rate from granular applicators is not, for the most part, proportional to rotor speed. However, the closest relationships were obtained with shallow rotors.

4. Attrition of granules at a rotor speed of 20 r.p.m. or less was not evident. However, at faster rotor speeds, it could become an important factor.

5. Finally, caution should be exercised in calibration of granular pesticide applicators. Recalibration should accompany any change in ground speed.

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ALFALFA WEEVIL, CORN ROOTWORM & EUROPEAN CORN BORER

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ALFALFA WEEVIL

This insect was found for the first time in Minnesota in Houston County on May 19th. Subsequent surveys in southeastern Minnesota added Winona, Fillmore and Wabasha Counties to the list of counties infested. No doubt other counties in southeastern Minnesota adjacent to both Iowa and Wisconsin have this weevil present in alfalfa. In the past in other states, alfalfa weevil has moved an average of 20 miles a year. On that basis, we can expect many more counties infested with this insect in a few years. Economic damage to alfalfa is not anticipated for a few years. In the future, we can expect that alfalfa weevil will be one of the most important economic pest in Minnesota.

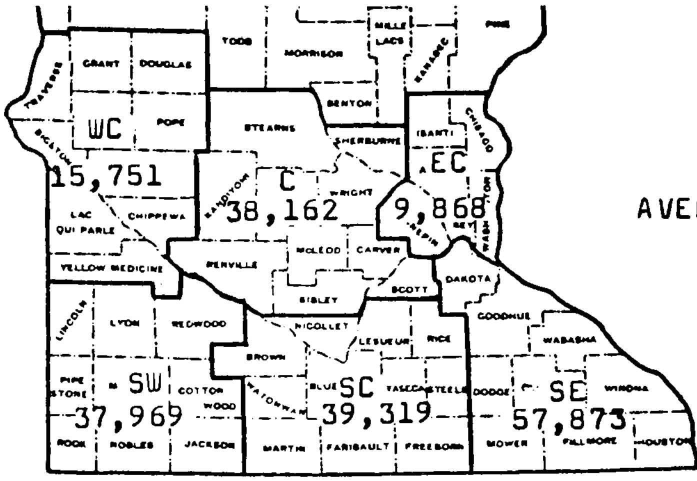
The following paragraph gives a brief description and life cycle of the alfalfa weevil: Alfalfa weevils are snout beetles, 3/16 inch long, brown in color with a broad band down the middle of their backs. Females lay from 600 to 800 eggs in alfalfa stems. The larvae hatch and migrate to the top of alfalfa plants and feed on leaves. Severe infestations cause shredding and drying of leaves, and fields appear gray; much like frost damage. The larvae are legless, light yellow to green, up to 1/4 inch long, have a white stripe down the middle of the back and have a shiny black head. The greatest damage from larvae is to the first crop of alfalfa. There is only one generation each year. The larvae pupate in June and July, adults do not become active until fall and then overwinter in the adult stage becoming active again in the spring.

CORN ROOTWORM SURVEY

Corn rootworm populations increased sharply in Minnesota during the 1970 season. In August, 54 counties in the major corn growing areas of the state were surveyed to determine the changing corn rootworm situation. This annual survey, now in its 7th year, indicates that corn rootworms have increased in all six reporting districts. Statewide the populations increased 128% this year.

Southwest District - Population counts increased in 7 out of the 9 counties. Counts averaged 37,969 beetles per acre in this district, an increase of 77%. Rock County had the highest populations in the southwest.

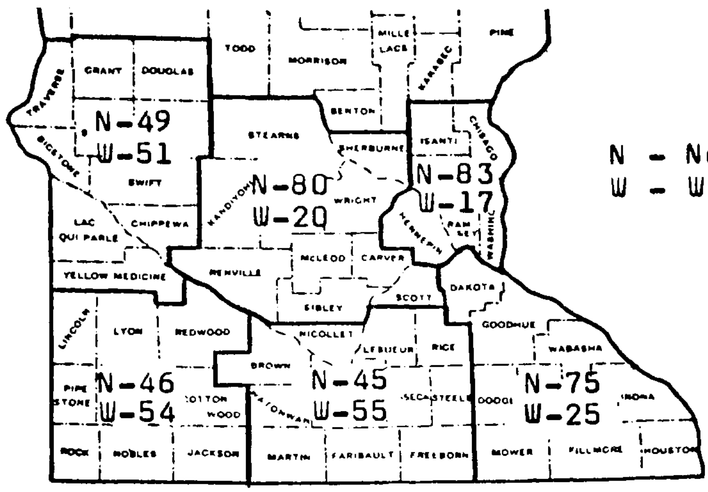
POPULATION COUNTS - (Both northern & western species)



AVERAGE NUMBER OF BEETLES PER ACRE

<u>South Central District</u> - Eight out of 11 counties had population increases. Counts averaged 39,319 beetles per acre, an increase of 164%. Watonwan County had the highest populations in the south central district.
<u>Southeast District</u> - Five out of 9 counties had population increases. Counts averaged 57,873 beetles per acre in this district, an increase of 48%. Houston County had the highest populations.
<u>West Central District</u> - All 11 counties surveyed in this district had population increases. Counts averaged 15,751 beetles per acre, an increase of 320%. Yellow Medicine County had the highest populations in this district.
<u>Central District</u> - Nine out of 10 counties had population increases. Counts averaged 38,162 beetles per acre, an increase of 425%. In the past only lightly scattered damage was noted; this year a great increase occurred throughout the district. Carver County had the highest populations in the district and also the highest populations in the state.
<u>East Central District</u> - All counties had population increases. Counts averaged 9,868 beetles per acre, an increase of 1,207%. Hennepin County had the highest populations in this district.

<u>Percent Northern & Western Corn Rootworm Beetles</u> - The percentage of western corn rootworm beetles increased in the SW, SC, SE, & C districts and remained about the same in the WC district. This species of rootworm is predominant now in the SW, SC, & WC districts. The northern corn rootworm is predominant in the SE, C & EC districts.



N - Northern Corn Rootworm
W - Western Corn Rootworm

<u>Cropping History and Rootworm Populations</u> - We again recorded the cropping history (last 2 years) of all the fields surveyed. The fields were divided into two classifications: (1) First year corn; (2) Corn grown 2 or more years. By relating the number of beetles counted to the cropping history of the fields, we found that 97.4% of the beetles were in fields that had been in corn 2 or more years. Only 2.6% of the beetles counted were in first year corn fields. This indicates rather strongly again that corn rootworm problems in Minnesota are in fields where corn follows corn.

<u>1971 Outlook</u> - Corn rootworm populations and damage will increase in 1971. As in the past, the SW, SC & SE districts will have the highest populations; however, some counties in the WC, C & EC districts will for the first time experience rootworm problems.

The cropping history of a particular field has a great effect on what will occur next season. Farmers should evaluate their own fields based on 1970 populations both locally and by district and the past cropping history of the field going into corn. The district figures on the map indicate on a general basis where rootworm problems will occur.

<u>EUROPEAN CORN BORER</u>

Populations increased this year in all but the northwest district. Increases were 12% in WC, 71% C, 115% SE, 122% SW, 256% EC and 455% SC.

District	Number of Borers per 100 plants 1969	1970
SW	111	246
SC	40	222
SE	62	131
WC	94	105
C	32	57
EC	25	89
NW	119	57

The increased populations were attributed to a large second generation borer population. The 2nd generation has been of minor importance in Minnesota for a number of years. This season's hot weather caused rapid development of the 1st generation allowing for an early and successful 2nd generation.

As is often the case with 2nd generation populations, stalk breakage was more prevalent. Most of the stalk breakage this past year was fortunately above the ears. However, enough stalk breakage below the ear took place to cause some difficulty in harvesting operations. Shank feeding causing ears to drop to the ground was quite important in some fields in the SW district. Much of the stalk breakage was due to a combination or association of corn borer feeding and stalk rot diseases.

1971 Outlook - We now have the highest overwintering corn borer populations in over 10 years. The potential for increased problems next year does exist, especially in the SW, SC, SE & WC districts. Weather conditions next season will determine the intensity of the infestation. If conditions are near normal, we can expect a higher 1st generation population next summer.

DISTRIBUTION AND ABUNDANCE OF GRASSHOPPERS IN MINNESOTA

Hart Graeber
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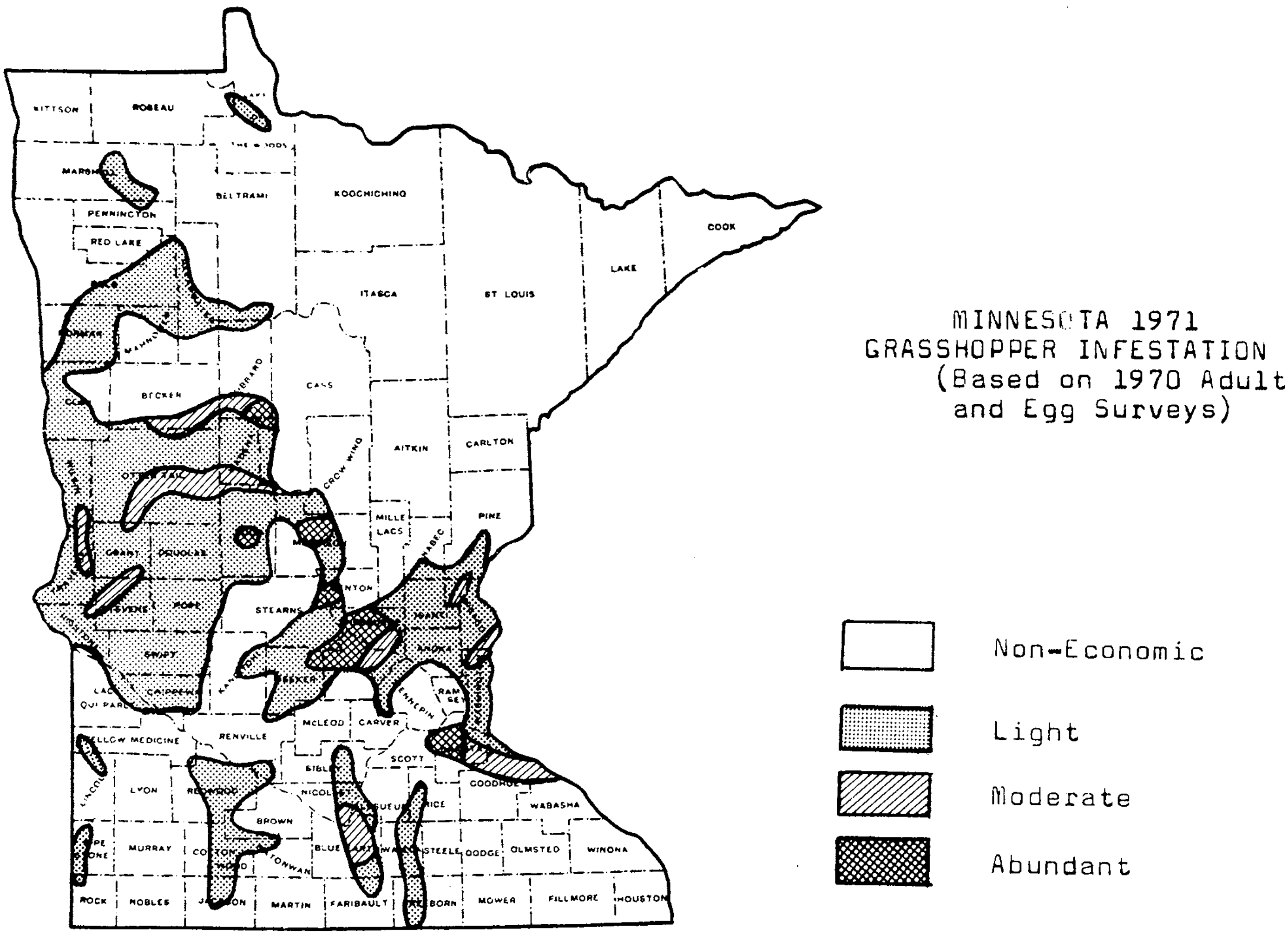

During the 1970 season, the areas in which most economic populations of 8 or more grasshoppers per square yard occurred were substantially the same as the past 3 years. However, populations in 1970 were considerably higher than those in 1969. An estimated 405,600 acres of forage crops had economic populations. This was an increase of 257,000 acres over the 1969 infestation.

A grasshopper egg survey conducted in October was confined to fields known to have had economic grasshopper populations during 1970. Results of this survey showed that 67% of the fields visited had grasshopper egg pods present. An average of 0.45 egg pods per square foot was found in these fields.

The dominant species throughout Minnesota continues to be the red-legged grasshopper. The two-striped and differential grasshoppers made population gains in the southern half of the state, but were predominant in only a few fields. The migratory, packard, and other grasshopper species were observed in many fields, but were of minor economic importance.

The outlook for the 1971 season as indicated by the grasshopper infestation map shows that moderate and abundant infestation areas lie in central Minnesota. Small areas are also found in south east and south central counties. It is expected that infestations will be dispersed throughout these areas. Primary host crops will be alfalfa and other forage crops. Field margins and roadsides will be important sources of infestation for other cropland. Light infestation areas indicated on the map may have widely scattered problems in some fields. Weather conditions at the time of egg hatch and early nymphal growth are very critical and could modify this outlook.

IMPORTANCE AND CONTROL OF INSECTS ON SOYBEANS

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Although several hundred different kinds of insects have been collected on soybeans (Balduf, 1923; Kretzschmar, 1948), most of these species do not become abundant enough to be of economic significance. Insect outbreaks on soybeans in Minnesota are usually limited to relatively few species of insects, outbreaks occur rather infrequently, and the outbreaks are often local in nature. However, because potential insect problems do exist, we need to become familiar with some of the most common insects and the types of injury which they cause.

One of the most conspicuous types of insect injury is defoliation. Common defoliators of soybeans include grasshoppers (Melanoplus femurrubrum and other species), larvae of the painted lady butterfly (Vanessa cardui), flea beetles (Systena frontalis and other species), and the green cloverworm (Plathypena scabra). Grasshoppers should be controlled if the nymphs become threatening along fence rows and roadsides. Usually damage to soybeans is most extensive along field margins, and treatment of field margins and crop borders to control grasshoppers may be preferable to treating entire fields. Control of the defoliating insects is probably not justified unless the insects become sufficiently abundant to cause 25% or more defoliation.

An experiment on control of the green cloverworm was conducted at Lamberton, Minn., in 1968. Both malathion and carbaryl proved to be effective (Table 1). Defoliation in the check plots averaged 14% on Aug. 28 and 18% on Sept. 10 as compared to 5 to 8% defoliation in plots treated with malathion or carbaryl. Differences in yields were not significant (Table 1).

Table 1. Results of an experiment on green cloverworms. Lamberton, Minn., 1968. Insecticides were applied on Aug. 22.

Insecticide	Rate/A.	Av. Cloverworms per ft. of row Aug. 22	Aug. 23	Aug. 28	Av. % Defoliation Aug. 28	Sept.10	Yield Bu./A.
Carbaryl	1.5 lb.	-	0	0	7.8	6.1	27.7
Malathion	1.0	-	0.1	0.1	7.8	5.0	30.8
Check	-	5.9	5.1	4.1	14.1	18.5	28.7

The bean leaf beetle (Cerotoma trifurcata) is primarily a defoliator, but the beetles may feed also on the developing seed pods. In an experiment on control of bean leaf beetles at Lamberton in 1970, carbaryl was effective and provided some reduction in beetle counts for about 2 weeks (Table 2). Malathion had no effect. Feeding injury was evident on over 20% of the soybean pods in the experimental plots. Most of this injury occurred between Aug. 25 and Sept. 5.

The application of carbaryl on Aug. 5 did not prevent the beetles from feeding on the pods in late August and September. Although there was an indication of a higher yield in the carbaryl plots, this difference did not reach the level of significance (Table 3). Neighboring fields had lower populations of bean leaf beetles, and there was little injury to the seed pods in these fields. Damage to seed pods as well as defoliation should be considered in making decisions concerning the need for insect control.

Table 2. Counts of bean leaf beetles in experimental soybean plots. Lamberton, Minn. Insecticides were applied Aug. 5, 1970.

Insecticide	Rate/A.	Av. Bean Leaf Beetles per 10 Sweeps					
		Aug. 5	Aug. 6	Aug. 11	Aug. 18	Aug. 25	Sept. 5
Carbaryl	1.25 lb.	-	0	6.0	11.0	32.2	5
Malathion	0.9	-	16.8	12.5	18.8	39.3	6
Check	-	17	20.5	15.5	20.2	42.0	5

Table 3. Comparisons of defoliation, injury to seed pods by bean leaf beetles, and yields in soybean plots. Lamberton, Minn. Insecticides were applied on Aug. 5.

Insecticide	Rate/A.	Est. % Defoliation		% Injured Pods	Av. Yield
		Aug. 18	Aug. 25	Sept. 5	Bu./A.
Carbaryl	1.25 lb.	2.5	2.5	20.5	31.4
Malathion	0.9	3.8	4.5	22.3	29.3
Check	-	5.8	7.5	27.9	28.5

The potato leafhopper (*Empoasca fabae*) was more abundant in 1970 than in several previous years. Feeding injury was evident as triangular yellowish areas along the leaf margins. Populations on soybeans reached a maximum of 945 per 100 sweeps at St. Paul on Aug. 10 and 450 per 100 sweeps at Lamberton on Aug. 11. The leafhoppers probably caused some reductions in yields. In Kretzschmar's studies in 1946, the potato leafhopper was the most abundant species on soybeans. Both carbaryl and malathion reduced numbers of leafhoppers for a period of 1 to 2 weeks in the 1970 experiment at Lamberton.

The alfalfa plant bug (*Adelphocoris lineolatus*) was present on soybeans at Lamberton during the entire month of August, 1970. It averaged from 50 to 65 bugs per 100 sweeps in the experimental plots and from 23 to 38 per 100 sweeps in other soybean fields at the Southwest Experiment Station. Alfalfa plant bugs feed on young growing tips, buds, and young seed pods. Relatively few insects may cause appreciable injury. Both carbaryl and malathion controlled alfalfa plant bugs for approximately 1 week.

Aphids do not usually become abundant on soybeans, and relatively few species breed on soybeans. (Some of those breeding on soybeans include the pea aphid, *Acyrthosiphon pisum*; the bean aphid, *Aphis fabae*; and the green peach aphid, *Myzus persicae*.) However, aphids from other host plants may feed temporarily on soybeans and transmit certain virus diseases. We have collected 20 different species of aphids on soybeans in Minnesota. More information is needed concerning the possible effects of various weeds and nearby crops on numbers of aphids in soybean fields.

Literature Cited

Balduf, W. V., 1923. The insects of the soybean in Ohio. Ohio Agr. Exp. Sta. Bul. 366

Kretzschmar, G. P., 1948. Soybean insects in Minnesota with special reference to sampling techniques. J. Econ. Entomol. 41:586-591

Corn Rootworm Control in 1970

J. A. Lofgren

Rootworms made a tremendous come back in 1970. Generally, treatments were effective in reducing losses but not in eliminating all lodging. Several reports of unsatisfactory results were received. Most of these were due to one or more of the following reasons:

1. Poor calibration of equipment resulting in low rates of application.

2. Faulty adjustment and operation of equipment resulting in poor placement and distribution of chemical.

3. Improper use of liquid formulations especially with liquid fertilizer solutions.

4. High moisture conditions in some areas immediately following early planting time treatments.

5. Very dry conditions in some areas at time of cultivation treatments.

6. Overwhelming numbers of rootworms with enough treatment survivors to cause damage.

There is no good evidence of resistance to presently suggested insecticides. Dr. L. K. Cutkomp continued his monitoring on field collected beetles. This work actually indicated more susceptibility in 1970 than in 1969.

2. Corn Rootworm Control in 1970.

LD/50s (Micrograms per gram), rootworm adults from 7 counties. Lower the number means greater the toxicity.

	Northern	Western
Diazinon		
1968	15.5	11.3
69	25.1	21.0
70	6.5	8.0
Thimet		
68	---	8.5
69	22.8	21.7
70	12.5	13.5

The same trends were observed with other materials.

3. Corn Rootworm Control in 1970

Results of Field Trials 1970

1. Planter Treatments, Southwest Experiment Station Lamberton, Minnesota. Planted May 7. Light to moderate infestation.

Treatment			Av. Root Rating (1 = light damage 5 = severe damage)	% lodged
Bux	10G	3/4 lb.	1.2	4
Dyfonate	20G	3/4 lb.	1.5	0
Furadan	10G	3/4 lb.	1.6	4
Dasanit	15G	3/4 lb.	1.8	4
Thimet	15G	1 lb.	1.9	4
Mocap	10G	3/4 lb.	1.9	2
Furadan	10G	(furrow)	2.0	4
Check			2.9	26

2. Cultivation Treatment, Southwest Experiment Station. Applied June 19
Planted May 7

Treatment			Av. Root Rating	% Lodged
Thimet	15G	1 lb.	1.4	8
Furadan	10G	3/4 lb.	1.5	2
Mocap	10G	3/4 lb.	1.5	4
Dasanit	15G	3/4 lb.	1.7	4
Bux	10G	3/4 lb.	1.8	4
Dyfonate	20G	3/4 lb.	1.8	18
Mocap	10G	1/2 lb.	1.9	6
Check			2.9	26

3. Planter Treatments, Rock County
D. Hengeveld Farm

Heavy infestation

Planted May 20

Treatment			Av. Root Ratings	% Lodged
Furadan	10G	3/4 lb.	1.6	0.0
Dyfonate	20G	3/4 lb.	1.6	1.5
Bux	10G	3/4 lb.	2.0	0.0
Mocap	10G	3/4 lb.	2.4	6.0
Thimet	15G	1 lb.	2.1	28.5
Dasanit	15G	3/4 lb.	2.6	14.0
Check			4.4	100.0

4. Planter Treatments - Rate and Placement Plots -
Brown County
Norman Moe Farm
Cooperators - L. Peichel, County Agent and
Niagara Chemical Division
Planted May 18

Treatment		Av. Root Rating	% Lodged
Furadan	2 lb. (furrow)	1.6	0
Furadan	1 lb. (furrow)	2.2	0
Furadan	1 lb. (band)	2.2	2
Furadan	3/4 lb. (band)	2.4	3
Furadan	3/4 lb. (furrow)	3.2	6
Bux	3/4 lb. (band)	2.8	7
Diazinon	3/4 lb. (band)	4.0	14
Check		4.2	91

5. Northcentral Regional Coop. Study, 1970
Average of results from Iowa, Kansas,
Nebraska and Ohio.

Treatment		Average Root Rating	
Furadan	3/4 lb.	1.91	a [1/]
Bux	1 lb.	2.19	b
Dasanit	1 lb.	2.22	bc
Thimet	1 lb.	2.25	bc
Mocap	1 lb.	2.37	bcd
Dyfonate	1 lb.	2.41	cd
Diazinon	1 lb.	2.56	d
Check		3.51	e

1/ Treatments with the same letter are not statistically different.

SUGGESTIONS FOR THE USE OF INSECTICIDES TO

CONTROL INSECT PESTS OF FIELD CROPS IN 1971.

Do not use after 1971.

Aldrin, DDT, dieldrin, endrin, heptachlor, lindane, and TDE (DDD) are classed as restricted-use pesticides in Minnesota. Dealers must have dealers' permits before they may sell these products and farmers must have users' permits before they can use them. The permits for specified uses are available from the MInnesota Department of Agriculture.

To help prevent illegal residues in livestock products it is suggested that the restricted use pesticides not be used for any purpose, except seed treatment, on dairy farms. If these pesticides are used as soil treatments on corn the crop should be harvested for grain only and dairy cattle or meat animals being finished for slaughter should not be allowed to graze in treated fields. Diary men, poultry producers and feeders should also be sure that purchased hay or other feed does not contain illegal residues.

If fields have received a soil treatment with a restricted use pesticide annually for 5 or more years, at least two years without treatment should elapse before planting soybeans or alfalfa.

Illegal residues may also occur in root crops (potatoes, sugar beets, carrots, etc.) grown in fields previously treated with these chemicals.

Unless residue tolerances for aldrin and heptachlor in corn are established by January 1, 1971, label registrations will be cancelled on that date and recommendations for these uses will be rescinded.

Carbaryl (Sevin), ULV malathion and parathion are very toxic to bees. Crops in bloom should not be treated and applications should not be made near bee yards or when bees are present in the field to be treated.

Demeton (Systox), disulfoton (Di-Syston), mevinphos (Phosdrin), methyl parathion, parathion, phorate (Thimet) and phosphamidon (Dimecron) are highly toxic chemicals and should be used only by persons acquainted with the necessary precautions for their safe use. The granular formulations are less hazardous to the operator than are the liquids. Avoid inhalation of dusts or vapors and contact with the skin. Follow directions on the labels for the use of protective clothing and other safety measures.

Crop	Insect	Insecticide	Dosage	Limitations, Remarks (Days before harvest)
Alfalfa	Alfalfa weevil	azinphosmethyl (Guthion)	½ - 3/4 lb.	21 days, one application per cutting
		methyl parathion	½ 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	3/4 lb. + 3/4 lb.	10 days - available as a ready-to-use mixture
		Cut first crop early to avoid most losses. Treat when over 50% of plant tips show feeding. Treat stubble if there are more than 8 larvae per sq. ft.		
	Aphids, Leafhoppers	demeton (Systox)	¼ lb.	21 days, one application per cutting
		diazinon	½ lb.	7 days
		malathion	1 lb.	No time limitations
		parathion	¼ lb.	15 days
		Control aphids when thick enough to cause wilting, usually during drought.		
Alfalfa, clover	Armyworm, Cutworms	carbaryl (Sevin)	1½ lb.	No time limitations
		Treat when over 5 per sq. ft.		
	Leafhoppers	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 - 12 inches and leafhoppers are over 2 per net sweep.		

Crop	Insect	Insecticide	Dosage	Limitations, Remarks (Days before harvest)
Alfalfa, clover	Grasshoppers	carbaryl	1 lb.	No limitations
		diazinon	½ lb.	7 days
		malathion	1½ lb. or 0.6 lb. technical as ULV by air	5 days, ULV No time limitations
		Control when there are over 8 'hoppers per sq. yd. in the field or treat margins after cutting at more than 20 per sq. yd.		
	Spittlebug	methoxychlor	1 lb.	7 days
		Apply on first crop when spittle masses average over one per stem.		
	Plant bugs	malathion + methoxychlor	3/4 lb. + 3/4 lb.	7 days
		diazinon + methoxychlor	½ lb. + 1 lb.	7 days
		Control seldom needed except on seed crop. Cut early to avoid injury.		
Alfalfa, clover (For Seed Only)	Plant bugs	endosulfan (Thiodan)	1 lb.	Do not harvest for forage or graze.
		toxaphene	2 lb.	
		Do not treat crop in bloom.		

Crop	Insect	Insecticide	Dosage	Limitations, Remarks (Days before harvest)
Corn, field	Aphids	malathion	1 lb.	5 days
		methyl parathion	4 oz.	12 days
		parathion	4 oz.	12 days
		phorate (Thimet)	1 lb.	Granules applied in the whorl just before tasselling. Do not use if phorate was also used as soil treatment.
		Chemical control of cornleaf aphids is seldom economically justified. If 10% of the plants have over 500 aphids per plant <u>prior</u> to tasselling treatment may pay.		
	Armyworm	carbaryl (Sevin)	1 to 2 lb.	No limitations
		Gardona	1 to 1 1/3 lb.	No limitations for grain; 5 days for forage.
		toxaphene	2 lb.	Do not feed stalks, leaves or husks. No limitation for grain.
		Treat when over 10% of the plants are infested. Higher rates for large worms.		
Corn	Corn rootworm larvae	Bux	1 lb.	Planting time application of granules in 7 inch band over the rwo. <u>Do not place in direct contact with the seed</u>. Band of granules should be covered lightly. Some liquid fertilizer formulations are registered but are suggested for trial use only.
		carbofuran (Furadan)	3/4 lb.	
		Dasanit	1 lb.	
		diazinon*	1 lb.	Cultivation time applications of materials registered for such use may be made after rootworm eggs hatch in June. Apply at base of stalks and cover with soil. At this time Bux, Dasanit, diazinon and phorate are so registered.
		Dyfonate	1 lb.	
		*diazinon will perform better as a cultivation treatment than as a planting time application on early planted corn.		Rates given are for 40 inch row spacing or for 13,200 ft. of row.

Crop	Insect	Insecticide	Dosage	Limitations, Remarks (Days before harvest)
Corn	Corn rootworm larvae	prophos (Mocap)	1 lb.	
		phorate (Thimet)	1 lb.	
		Treat corn following corn.		
	Corn rootworm adults	carbaryl	1 lb.	No time limitations
		malathion	1 lb.	5 days
		malathion ULV	4 to 8 oz. as technical by air	5 days
		Gardona	1 lb.	5 days for forage. No limitations for grain.
		EPN	¼ - ½ lb.	14 days
		Treat when beetles reach 10 per plant when fresh silks are present.		
	Cutworms	aldrin*	2 lb.	Apply broadcast and disk in before planting.
		chlordane	4 lb.	(same as above)
		heptachlor*	2 lb.	(same as above)
		diazinon	1 to 2 lb.	Apply in 7 inch band as for rootworms at planting time.
	Cutworms, Webworms	carbaryl	2 lb.	Post emergence spray to cover approximately 12 inch band at base of plants in at least 15 gal. total spray per acre. Limitations same as for armyworm, 28 days for trichlorfon.
		trichlorfon (Dylox)	1½ lb.	
		toxaphene	2 lb.	
		Apply post emergence spray when over 10% of the plants are infested.		

*Restricted use pesticide, see statement on page 1.

Crop	Insect	Insecticide	Dosage	Limitations, Remarks (Days before harvest)
Corn	European corn borer	carbaryl	1½ lb.	Spray or granules, no time limitations.
		diazinon	1 lb.	Granules. No time limitations.
		EPN	½ lb.	As spray or granules, 14 days.
		Gardona	1 lb.	As spray, 5 days for forage, no time limitations for grain.
		toxaphene	2 lb.	As granules. Use on corn for grain only.
		Bacillus thuringiensis		As labelled. No time limitations.
		Treat when 50 to 75% of whorl leaves show shot-holing for first brood; when egg mass count reaches 100 per 100 plants for second brood. Use granules before tassel emergence.		
	Grasshoppers	carbaryl	1 lb.	No time limitations.
		diazinon	½ lb.	No time limitations.
		malathion	1 lb. or 6 oz. technical as ULV	5 days
		toxaphene	1½ lb.	For grain only, no time limitations.
		Treat field margins early when 'hoppers are small.		
	Seed corn maggot Seed corn beetle Wireworms	aldrin*, dieldrin*, heptachlor*, lindane*, or diazinon	1 oz. per bu.	Seed treatment only. Will not control heavy wireworm infestation.

*Restricted use pesticide, see page 1.

Crop	Insect	Insecticide	Dosage	Limitations, Remarks (Days before harvest)
Corn	Wireworms, White grubs, Webworms, Seed-corn maggots, Seed-corn beetles	aldrin* chlordane heptachlor*	2 lb. 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.
	Wireworms	diazinon Dyfonate phorate	1 to 2 lb. 1 lb. 1 lb.	Band on the row as for corn rootworm.
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.		
	Armyworm, Cutworms	carbaryl (Sevin)	1 to 2 lb.	Do not apply after heads are visible. Higher rate for large worms.
		toxaphene	2 lb.	Use for grain only.
		malathion	1½ lb.	7 days.
		Treat when number of worms exceeds 5 per sq. ft.		
	Grasshoppers	carbaryl	1 lb.	Do not apply after heads are visible.
		malathion	1 lb. or 0.6 lb. as technical ULV by air.	7 days
		toxaphene	1½ lb.	Use for grain only.
		Treat when over 8 per sq. yd. in field or over 30 in margins.		

*Restricted use pesticide, see page 1.

Crop	Insect	Insecticide	Dosage	Limitations, Remarks (Days before harvest)
Small grains	Wireworms	aldrin*, dieldrin*, heptachlor*or lindane*	1 oz. per bu.	Seed treatment only.
Barley	Thrips	parathion or methyl parathion by air	6 oz.	15 days. Apply just at heading when there are 4 or more adult thrips per plant.
Soybeans	Bean leaf beetle, Flea beetles, Blister beetles	carbaryl (Sevin)	1 lb.	No limitations.
		Treat when defoliation exceeds 25% or when pod feeding is extensive.		
	Cutworms, Armyworms	carbaryl	2 lb.	No limitations.
		toxaphene	1½ lb.	21 days. Do not feed treated plants.
	Grasshoppers	carbaryl	1 lb.	No limitations.
		malathion	6 oz. technical as ULV by air.	7 days
		toxaphene	1½ lb.	21 days. Do not feed treated plants.
	Green clover-worm	carbaryl	1 lb.	No limitations.
		malathion	1 lb.	7 days
		Treat when defoliation exceeds 25%.		
	Leafhoppers	malathion	1 lb.	7 days

*Restricted use pesticide, see page 1.

Crop	Insect	Insecticides	Dosage	Limitations, Remarks (Days before harvest)
Sugar beets	Webworm	carbaryl (Sevin)	2 lb.	14 days, tops.
		endosulfan (Thiodan)	1 lb.	Do not feed tops.
		parathion	4 to 8 oz.	15 days
		toxaphene	3 lb.	60 days, do not feed tops.
		trichlorfon (Dylox)	1 lb.	14 days, beets 28 dyas, tops
		Treat when worms exceed 5 per sq. ft.		
	Cutworms	carbaryl	2 lb.	14 days, tops
		trichlorfon	1½ lb.	14 days, beets 28 days, tops
	Root maggots	disulfoton (Disyston)	1 lb.	Row treatment at seeding time. Place above seed in 5 to 7 inch band or as furrow treatment above seed.
		phorate (Thimet)	1 lb.	
		diazinon	2 lb.	
		Dasanit	1 to 2 lb.	
		(Carbofuran (Furadan) and Dyfonate may be registered for 1971 season).		
Potatoes	Aphids, Fleabeetles, Leafhoppers	disulfoton (Di-Syston)	2 to 3 lbs.	Row treatment in fertilizer bands at planting time. 75 days. Higher rate for heavy soils.
		phorate (Thimet)	2 to 3 lbs.	Row treatment in fertilizer bands at planting time only. Higher rate for heavy soils.
		carbofuran (Furadan)	2 to 3 lbs.	Apply to bottom of furrow at planting time.

Crop	Insect	Insecticide	Dosage	Limitations, Remarks (Days before harvest)
Potatoes	Aphids	demeton (Systox)	½ lb.	21 days
		dimethoate (Cygon)	½ lb.	No limitations
		endosulfan (Thiodan)	½ to 1 lb.	No limitations
		malathion	3/4 lb.	No limitations
		oxydemetonmethyl (Meta Systox R)	1/3 lb.	7 days
		phosphamidon (Dimecron)	3/4 lb.	7 days
	Cutworms	carbaryl (Sevin)	2 lb.	No limitations
		toxaphene	2 lb.	No limitations
	Colorado potato beetle	azinphosmethyl (Guthion)	½ lb.	7 days
		carbaryl	1½ lb.	No limitations
		endosulfan	½ to 1 lb.	No limitations
		toxaphene	3/4 lb.	No limitations
	Fleabeetles	azinphosmethyl	½ lb.	7 days
		carbaryl	1½ lb.	No limitations
		endosulfan	½ to 1 lb.	No limitations
		naled (Dibrom)	1 lb.	No limitations
		phosphamidon	¼ lb.	7 days
		toxaphene	3/4 lb.	No limitations
		DDT*	1 lb.	No limitations

*Restricted use pesticide, see page 1.

Crop	Insect	Insecticide	Dosage	Limitations, Remarks (Days before harvest)
Potatoes	Leafhoppers	carbaryl	1½ lb.	No limitations.
		demeton	½ lb.	21 days
		dimethoate	½ lb.	No limitations
		endosulfan	½ to 1 lb.	No limitations
		malathion	3/4 lb.	No limitations
		oxydemetonmethyl	½ lb.	7 days
		parathion	½ lb.	5 days
		DDT*	1 lb.	No limitations
	Wireworms	chlordane	4 lb.	Broadcast before planting.
		phorate	2 to 3 lb.	Band treatment at planting.
	White grubs, Cutworms	chlordane	4 lb.	Broadcast before planting.
Sunflowers	Sunflower moth larvae	endosulfan (Thiodan)	1 lb.	Not more than 3 applications. Do not feed treated plants. No limitations on use of seeds.
		methyl parathion	1 lb.	No more than 3 applications. 5 day intervals 30 days before harvest.
Mustard, rape seed	Fleabeetles	carbaryl (Sevin)	2 lb.	14 days
	Diamond back moth larvae	carbaryl	2 lb.	14 days
		malathion	2½ lb.	7 days

*Restricted use pesticide, see page 1.

Crop	Insect	Insecticide	Dosage	Limitations, Remarks (Days before harvest)
Wild Rice (in paddies)	Wild rice worm	malathion	1 to 1½ lb.	7 days after eggs appear in florets. Additional applications as needed.
Blue grass (for seed)	Plant bugs (capsus)	diazinon	½ lb.	No limitations
		malathion	3/4 lb.	No limitations.
		Treat as heads emerge when capsus bugs are detected or at first sign of silver top.		
Blue grass, Timothy (for seed)	Meadow plant bug	malathion	3/4 lb.	No limitations
		Treat at early heading stage when there is an average of two bugs per net sweep.		
	Armyworm	carbaryl	1½ lb.	No limitations
		malathion	1 lb.	No limitations
		Treat when there are 5 worms per sq. ft.		
Corn, sweet	Earworm	carbaryl	1½ lb.	No limitations before harvest. Highly toxic to bees. Do not apply as dust to pollinating corn. Aoivd treating while bees are in the field.
		diazinon	1½ lb.	2 days
		endosulfan (Thiodan)	1½ lb.	Not on corn for processing. Not more than 5 applications. Do not feed treated forage.
		Gardona	1 lb.	5 days, forage
		methomyl (Lannate)	¼ to ½ lb.	3 days, forage. May cause injury to some varieties.

Crop	Insect	Insecticide	Dosage	Limitations, Remarks (Days before harvest)
Corn, sweet	Corn rootworm larvae	Bux	See under field corn	
		diazinon		
		Dyfonate		
		phorate		
	Corn rootworm adults	carbaryl	1½ lb.	No time limitations, see bee precautions under earworm.
		malathion	1 lb. or 4 oz. technical as ULV	5 days
		EPN	¼ lb.	14 days
		parathion	¼ lb.	15 days
		Gardona	1 lb.	5 days for forage
	Cutworms, Armyworms	carbaryl	2 lb.	No limitations
		toxaphene	2 lb.	Do not feed or ensile treated plants.
	European corn borer	carbaryl	1 to 2 lb.	No time limitations; see bee precautions under earworm.
		diazinon	1 to 2 lb.	10 days for forage
		EPN	¼ lb. granular ¼ lb. spray	14 days
		Bacillus thuringiensis		As labelled
		Gardona	1 lb.	5 days, forage

Crop	Insect	Insecticide	Dosage	Limitations, Remarks (Days before harvest)
Corn, sweet	Wireworms	aldrin*, dieldrin*, heptachlor*, lindane*, diazinon	1 oz. per bu.	Seed treatment only.
		diazinon	1 to 2 lb.	
		Dy fonate	1 lb.	Band on the row at planting.
		phorate	1 lb.	
Peas	Aphids	demeton (Systox)	¼ lb.	21 days
		diazinon	½ lb.	1 day feeding of vines, 4 days hay.
		dimethoate (Cygon)	3 oz.	Do not feed or graze vines if mobile viner is used. 21 days if stationary viner is used.
		malathion	1 lb.	3 days. 7 days for forage.
		mevinphos (Phosdrin)	0.2 lb.	1 day
		naled (Dibrom)	1 to 2 lb.	4 days
		parathion	¼ lb.	10 days
	Loopers	carbaryl	1½ to 2 lbs.	No time limitations.
		parathion	½ lb.	15 days
		mevinphos	4 oz.	1 day

*Restricted use pesticide, see page 1.

FUNGICIDE SPRAYING OF CORN FOR CONTROL OF
SOUTHERN CORN LEAF BLIGHT

Herbert G. Johnson, Extension Plant Pathologist

Fungicide application to corn fields for control of Southern Corn Leaf Blight (SCLB) was used successfully in 1970 in areas south and southeast of Minnesota in seed corn fields. The cost, degree of control obtained, and value of the crop indicate that treatment of fields for production of feed is not economical. Information on results of treatment in 1970 has been difficult to obtain. A crash program was used. Many mistakes were made, and in the rush and panic of a new situation, check plots were often abandoned. The following information is available at this time:

1. Fungicides Registered for Corn Spraying

Common Name	Trade Name	Dosage lbs. actual per acre	Limitations
zinc ion plus maneb	Dithane M-45 Manzate 200	1.2	7 days
zineb	several	3.0	Do not feed forage to dairy animals or animals being finished for slaughter.
maneb (sweet corn only)	Dithane M-22 Special Manzate D	2.4	No time limitations. Do not feed treated forage to livestock.

2. Timing and Number of Applications

Since this situation was new in 1970, the timing of first application, interval between applications, and time of last application could only be estimated. First applications ranged from early July to mid August. It is generally believed now that treatment was started too late in most fields. For a field planted in "normal" season and with a corn line of average maturity for the area, a first application should be made about mid July or just before milk stage. Earlier applications may be needed if the disease develops beyond trace to light in severity. The interval between applications will vary depending upon weather. It may be increased during dry conditions to 14 days and shortened to 4 to 6 days during rainy periods. Last application should be made no later than early September. Some favorable results have been reported with two applications and as many as five were made.

3. Dosage

Most applications were made with 1½ lb. of fungicide formulation per acre. The maximum permissible dosage must be checked for each fungicide. A spreader-sticker at one ounce per acre is generally advisable.

4. Application Equipment

Most application was made by plane. A minimum of five gallons per acre should be applied for aerial application. High-clearance ground sprayers were also used and calibration of at least 40 gallons per acre and 150 lb. pressure is recommended.

5. Results - Fungicide Spraying of Seed Corn Fields for Control of Southern Corn Leaf Blight 1970, Reports of Three Fields from Iowa

1. Seven bushel increase of seed.

2. Percentage infected ears reduced:
   42% in check
   10% in treated

3. Five fungicide applications: July 1, July 23, August 3, August 11, and August 16. Yellow Leaf Blight and Southern Corn Leaf Blight present. T-cytoplasm corn.

   A. Treated 51 bushels
      Check 45 bushels

   B. Treated 48 bushels
      Check 39 bushels

   The yield increases may appear to be low, but this is seed corn with a relatively high value.

6. Minnesota 1970

The relatively light severity of SCLB in Minnesota resulted in very little fungicide spraying on seed fields. A few precautionary applications were made, but no results have been received. Presumably the disease was not severe enough to reduce yield in the checks.

7. 1971 Seed Crop

The near-total predicted conversion back to N-cytoplasm corn seed production in 1971 should reduce the need for fungicide application. However, even plants grown on N-cytoplasm are not immune to SCLB and the general severity of the disease will determine the need for fungicide application.

LIVESTOCK INSECTICIDES FOR 1971

David Noetzel, Extension Entomologist
University of Minnesota

Pest	Host	Insecticide	Dosage	Limitations
Cattle grubs	Beef cattle	coumaphos (Co-Ral)	0.5% spray 4% pour-on	None
Use but one of following treatments for grub control. Attempt to treat when animal is not under stress.		crufomate (Ruelene)	6.2% pour-on in water]	1 oz. 6.2% or 3/4 oz. 9.4% pour-on per 100 lb. not to exceed 8 oz/animal.
			9.4% pour-on in oil]	Do not repeat application within 28 days nor apply within 28 days before market.
			0.375% spray]	Not after Nov. 1st.
		famphur (Warbex)	13.2% pour-on	1 oz/200 lbs. bodyweight (do not exceed 4 oz.) Do not repeat treatment.
			0.199% feed pre-mix	4 oz. per 100 lb. daily for 10 days.
		fenthion (Tiguvon)	0.255% spray 0.051% spray	1 application per season. 2 applications per season. Do not use either within 45 days of slaughter.
		ronnel (Trolene)	0.6% in feed	0.3 lb. per 100 lbs. for 7 days.
		(Rid-Ezy)	0.26% in feed	0.3 lb. per 100 lbs. for 14 days.
		(Rid-Ezy) (Steer-Kleer)	5.5% in mineral block	For 75 days. Do not apply ronnel within 28 days slaughter.
		trichlorfon (Neguvon)	1% spray 8% pour-on	14 days before slaughter. 21 days before slaughter.
Cattle lice	Dairy cattle	crotoxyphos-dichlorvos (Ciodrin-Vapona, Ciovap)	0.25% spray	Do not apply oftener than once every 7 days.
		crotoxyphos (Ciodrin)	0.25% spray 3.0% dust	Every 14 days.
		synergized pyrethrins	0.05% - 0.1%	No time limitations.
		rotenone	2 lb. 5% powder per 100 gals.	

Pest	Host	Insecticide	Dosage	Limitations
Cattle lice	Beef cattle	carbaryl (Sevin)	0.5% spray	7 days before slaughter; not oftener than every 4 days.
		coumaphos (Co-Ral)	0.25% spray or dip	
		crotoxyphos (Ciodrin)	0.25% spray or 3% dust	
		crotoxyphos-dichlorvos (CioVap)	0.25% spray	
		crufomate (Ruelene)	5.0% pour-on in water] 0.375% spray] 9.4% pour-on in oil.]	28 days before slaughter.
		dioxathion (Delnav)	0.15% pour-on	Not oftener than 2 weeks.
		fenthion (Tiguvon)	1% in oil	On backrubber.
		malathion	0.5% dip or spray	7 days.
		methoxychlor	0.5% dip or spray 10% dust	No time limitations.
		ronnel (Korlan)	0.25% spray 1.0% in oil	8 weeks (spray). 14 days (backrubber).
		toxaphene	0.5% spray dip	28 days.
		trichlorfon (Neguvon	0.25% spray	14 days.
Mange and lice		lindane	0.06% spray or dip	60 days.

Pest	Host	Insecticide	Dosage	Limitations
Face flies	Dairy cattle	coumaphos (Co-Ral)	1% in oil	For face rubber (1 gal. per 20 ft. cable).
		crotoxyphos (Ciodrin)	1% oil solution]	Apply as mist spray daily at not over 2 oz per head.
		crotoxyphos-Vapona (Ciovap)	1 1/4 oil solution]	
		dichlorvos	1% oil solution]	
		pyrethrins + synergist	0.075% oil solution]	
		dichlorvos	0.5% baited spray. (1 tsp. to forehead) Once per day, morning preferable.	
	Beef cattle	Same as for dairy		
		or Ciodrin	2% oil solution]	On backrubber to permit face treatment.
		or ronnel	1% oil solution]	
		or toxaphene	5% oil solution]	
Flies (horn, stable, horse) and mosquitoes	Dairy cattle	Only limited control of horse, deer, and stable flies will be achieved using the following treatments.		
		dichlorvos (Vapona)	1% oil spray	Not over 2 oz. per animal daily as a mist.
		crotoxyphos (Ciodrin) (or combination of above, Ciovap)	1% oil spray	Not over 1 1/2 oz. per animal daily as a mist.
		coumaphos (Co-Ral)	1% on backrubbers 1% dust or as a dust bag.	

Pest	Host	Insecticide	Dosage	Limitation
Flies (horn, stable, horse) and mosquitoes	Dairy cattle	malathion	4 to 5% dust	At least 5 hrs. before milking.
		methoxychlor	50% W.P. as dust (1 tbsp.)	Apply after milking not oftener than 3 weeks.
		synergized pyrethrins (may also contain repellents).	0.05% to 0.1%	Not over 2 oz. per animal daily as a mist.
	Beef cattle	carbaryl (Sevin)	0.5% spray	7 days before slaughter; not oftener than every 4 days.
		coumaphos (Co-Ral)	0.25% spray 1% on backrubber 1% dust or as a dust bag.	
		crotoxyphos (Ciodrin)	1% spray 1% oil on backrubber 3.0% dust in dust bag.	
		crufomate (Ruelene)	9.4% pour-on solution in oil. 0.375% spray 6.2% emulsion as pour-on.	28 days before slaughter Horn flies only.
		dioxathion (Delnav)	0.15% spray or dip 1.5% in oil on backrubber.	Not oftener than 2 weeks.
		fenthion (Tiguvon)	1% in oil on backrubber	
		malathion	0.5% spray 2% in oil on backrubber. 0.6% lb. ULV* by air.	
		methoxychlor	0.05% spray, 5 or 6% in oil on backrubber.	
		ronnel (Korlan)	0.5% spray	8 weeks before slaughter.
			1% in oil on backrubber	14 days before slaughter.
		(Rid-Ezy Steer-Kleer)	5.5% in mineral	21 days. Horn fly only.

Pest	Host	Insecticide	Dosage	Limitations
Flies (horn, stable, horse) and mosquitoes	Beef cattle	toxaphene	0.5% spray	28 days.
			8.0% in oil on backrubber	
		trichlorfon (Neguvon)	1% spray	14 days before slaughter.
House flies	Milkhouse or food processing	pyrethrins	0.1% plus synergist	Space spray.
	Barns and animal housing areas	pyrethrins	0.1%]	Space spray with fogger, aresol or mist.
		dichlorvos	1.0%]	
		naled	0.3%]	
		diazinon*	1.0% 0.2% bait	Not in poultry houses.
		naled	0.5% bait	
		dichlorvos	0.5% bait	
		dimethoate	1.0% residual spray	
		Dimetilan (Snip)	Fly bands	Hang securely so animals cannot contact bands.
		malathion*	1% residual spray 1 to 2% bait	
		ronnel (Korlan)	0.5% to 1.0% residual spray	
		chlorfenvinphos (Compound 4072)	0.5% residual spray]	Do not use in poultry houses. Wear clean rubber gloves and a mask approved by the U. S. Department of Agriculture when spraying for prolonged periods.
		Rabon (Gardona)	1.0% residual spray]	
		Rabon (Gardona) + dichlorvos	1.0% + .25% residual spray]	
		trichlorfon (Dipterex)	1.0% bait	

Pest	Host	Insecticide	Dosage	Limitations
		fenthion (Baytex)	1.0% residual spray	
Poultry mites, lice	Chickens,** Turkeys	coumaphos (Co-Ral)	1/2% dust 0.25% spray (1 gal. per 100 birds).	
		malathion	0.5% spray] 4-5% dust]	No time limitations.
		carbaryl (Sevin)	5% dust (1 lb. per 100 birds) 0.5% water mist spray (1 gal. per 100 birds)	
Sheep Keds	Sheep	coumaphos (Co-Ral)	0.25% spray 1/2% dust	15 days 15 days
		dioxathion (Delnav)	0.15% spray or dip	Not oftener than 2 weeks
		diazinon	0.03 - 0.06% spray or 2% dust	14 days. 14 days.
		malathion	0.05% spray	No time limitations.
		methoxychlor	0.5% spray	
		ronnel (Korlan)	0.25% spray	84 days
Mange mites (Sarcoptic) and lice	Swine	lindane	0.06% as spray or dip 1.0% dust 0.2% in oil on backrubber	Do not treat before animals are 3 months old or sows within 2 weeks of farrowing; must be 30 days before slaughter, dips 60 days. If growth rates approach 200 lbs. in 150 days, another chemical should be used.
		malathion	0.06% spray or dip 0.5% on rubbing devices 5 to 6% dust	No time limitations.

Pest	Host	Insecticide	Dosage	Limitations
Mange mites (Sarcoptic) and lice	Swine	toxaphene	0.6% spray or dip] 5% dust] 8.0% on rub-bing devices]	Do not treat before animals are 3 months old. 28 days.
Lice only	Swine	coumaphos (Co-Ral)	0.25% spray	No animals under 3 months of age.
		carbaryl (Sevin)	0.5% spray	No oftener than once every 4 days.
		crotoxyphos (Ciodrin)	0.25% spray]	No oftener than once a week.
		crotoxyphos--dichlorvos (Ciovap)	0.25% spray]	
		dioxathion (Delnav)	0.15% dip or spray	No oftener than once in every 2 weeks.
		methoxychlor	0.5% dip or spray	No time limitations.
		ronnel (Korlan)	0.25% spray or dip.	No oftener than once in 2 weeks.
			5% granular to bedding at 1/2 lb. per 100 sq. ft.	Remove from treated bedding at least 2 weeks before slaughter.

÷ ULV = ultra low volume

* (If flies are not easily killed, resistance may be involved; newer materials with residual effect are dimethoate, ronnel, Compound 4072, and Rabon)

** Note: None of these materials has residue tolerance, other than zero, on eggs.