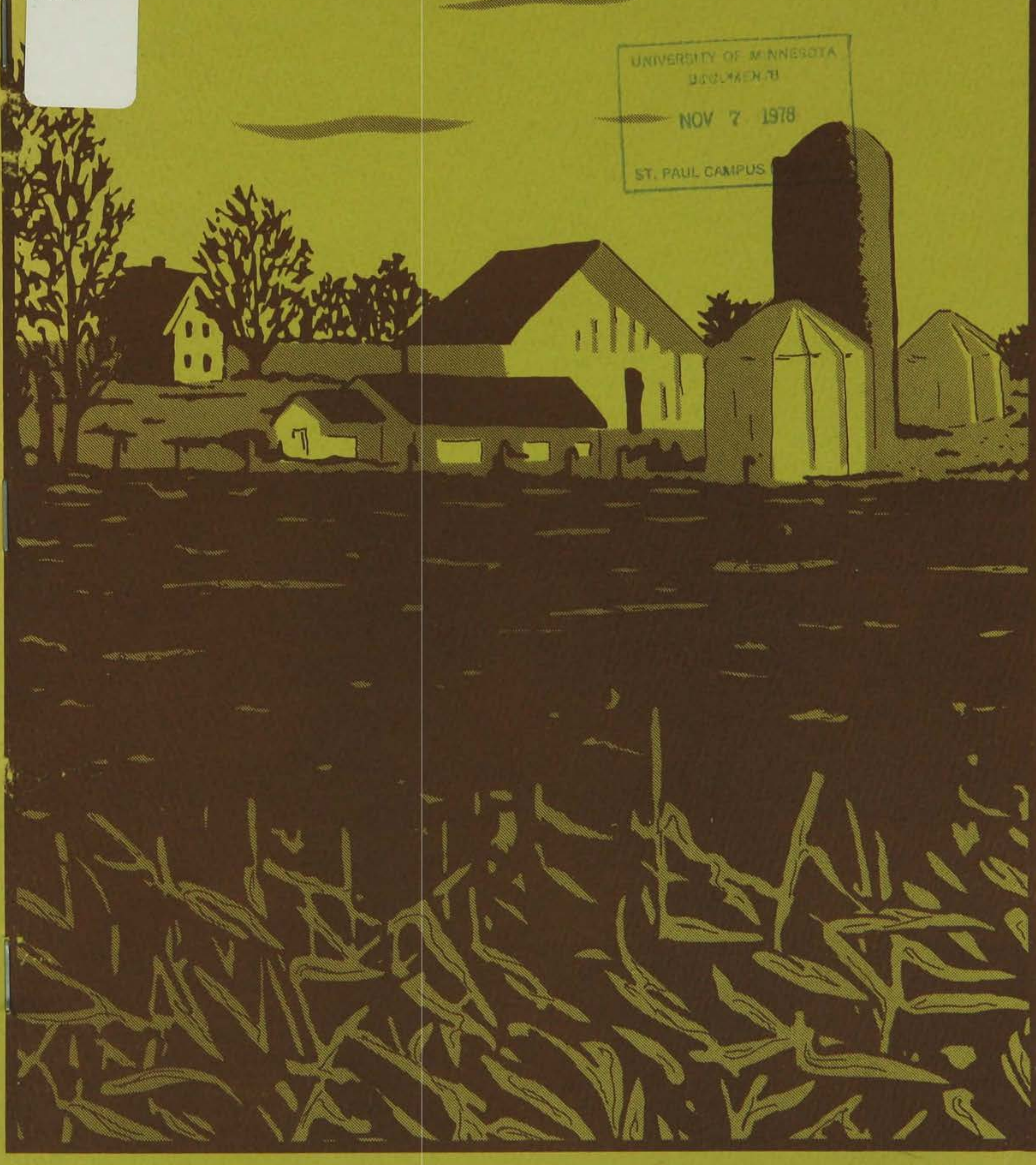
Soils, Fertilizer and Agricultural Pesticides Short Course

Minneapolis Auditorium

December 13, 14, 15, 1976



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

COMBINED SOILS, FERTILIZER AND AGRICULTURAL PESTICIDES SHORT COURSE

PROCEEDINGS

December 13,14,15, 1976
Minneapolis Auditorium

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

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

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APPLICATION OF LIQUID FERTILIZERS AND PESTICIDES

A COMMITTEE REPORT 1/ by H. L. MEREDITH 2/

INTRODUCTION

Liquid fertilizers and liquid pesticides are readily available - the question to be resolved - should liquid fertilizers and liquid pesticides indiscriminately be mixed and applied through corn planters.

LIMITS OF DISCUSSION

This paper will be limited in scope to application of liquid fertilizer - pesticide mixtures through corn planters. No recommendation of fertilizer and/or pesticides is implied or intended.

NOW, A LOOK AT THE SITUATION

Corn planting is an extremely precise operation. Corn seed is expensive, it must be placed at a uniform desired depth, it must be protected against disease, insects and weed competition. High fertility is one of the most important factors in profitable corn production. Fertilizers and pesticides must be considered separately, evaluated and applied according to: (1) need, (2) label clearance, (3) safety and (4) effectiveness.

Perhaps some of the more important considerations of fertilizer - pesticide combinations should include but not be limited to:

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2/ Area Director TVA and Research Associate Soil Science Department, University of Minnesota, St. Paul, MN 55101.

1. compatibility, 2. effectiveness, 3. toxicity, 4. legality and 5. need.

Compatibility: Numerous compatibility tests are available which permit ready evaluation of fertilizer - pesticide mixtures. These tests are good guides in isolating mixtures which are not compatible. Addition of adjuvants and/or emulsifiers is recommended by manufacturers of certain pesticides depending on the nature of the material. Both the physical and chemical characteristics of fertilizer - pesticide mixes need be considered.

a. physical - Density and flowability are two important considerations of compatible mixtures. Mixtures varying in density likely will require continuous agitation and/or recirculation. A solution must be free - flowing at a predetermined rate to prevent an excessive or inadequate application, hence, mixtures must be selected which to not increase viscosity to an inordinate level. Temperature flucuations, time following mixing and agitation are factors which affect viscosity.

b. chemical - Fertilizer solutions are at or near the saturation level of dissolved chemical salts. Addition of other chemicals as pesticides could exceed the solubility level of the solution. When this occurs, "salt-out" results. Salt-out is formation of crystals, the degree of severity will be variable depending upon sundry factors. Chemical compounds of fertilizer-pesticide mixtures will be foreign to fertilizer or pesticide mixtures individually. The effectiveness of the pesticide may be altered in complex chemical systems. This possibility, although most often overlooked, merits consideration. Gel formation in fertilizer-pesticide mixtures is not an unnatural phenomenon. Gels vary depending upon the quality of the base fertilizer solution, contamination of the tank mix, temperature and time following mixing. Base fertilizer solutions containing phosphorus likely result in the greatest variance due to the impurities in wet-process phosphoric acid. Some of the impurities contributing to gel formation include: carbon, iron, aluminum and magnesium.

Effectiveness: Placement of fertilizers, insecticides and herbicides is a factor of vital importance when evaluating effectiveness.

placement - Corn is sensitive to fertilizer salts. Fertilizer placed to the side and below the seed has long been recognized as a safe method of fertilizer application. Placement of fertilizer with the seed is somewhat hazardous and rates of application are highly restrictive. Insecticides applied at planting are designed to protect the seed and/or the root system. Placement is of paramount importance. Herbicides need to be applied at the soil surface or incorporated into the surface soil. Placement again is critical.

equipment - Variability of application equipment provides many options of placement of fertilizers and pesticides. Dealers and farmers are skilled design engineers and essentially no alterations of equipment are beyond their capability. There is too little communication between equipment manufacturers and fertilizer-pesticide users. The farmer with large planter equipment has optioned to transfer fertilizer and pesticide holding tanks from the planter to the tractor. Perhaps out of convenience more emphasis is being placed on simplicity of application at the expense of desired effectiveness.

As placement is of vital concern, it would appear tank mixtures of fertilizer-pesticides would have limited value at best.

Toxicity: Fertilizers and pesticides may individually be phytotoxic depending upon placement and rate of application. Mixtures of fertilizer-pesticides contribute to increased potential phytotoxicity, particularly if improperly applied.

Legality: Adherence to label clearance must receive strict attention. Violation of label may invite more problems than we wish to consider at this time. But - label clearance does not in itself insure a system free of problems.

Need: Although it would appear need is so obvious it does not warrant discussion, one should not fail to consider the need for a particular practice. As an example, corn root worms are the most serious insect pest of corn growers. The need for a protective insecticide on continuous corn is imperative. However, much corn is grown following wheat, soybeans or other non-corn crops. Root worms would not be a serious problem on first year corn, hence, little or no need for control. Likewise, a herbicide application at planting may be vastly inferior to a preemerge or early post emergence broadcast treatment.

TIT FOR TAT

The common sense of it all dictates that expenditures for fertilizers and pesticides produce positive results. If the pesticide or the fertilizer is improperly placed and yields are less than optimum, who wins? If near crop failure results, who pays? If a tank mixture forms a gel how will the grower get it out of his tank and where will he dispose of it? Because two or more liquids are miscible (as water-alcohol) it has nothing to do with the intended application. It only indicates the capability of two or more liquids existing in harmony together. Some of the truly great failures of fertilizer-pesticide mixtures occur because of separation due to inadequate agitation. Continuous agitation of fertilizer-pesticide mixtures is imperative to prevent separation of two-phase systems.

SUMMARY

1. When placement of fertilizer or pesticides is essential to desired effectiveness, placement should merit consideration over all other factors.
2. Do not bunch the entire fertilizer-pesticide program into a single operation.
3. Do not be misled about saving a trip across the field and end up sacrificing part of production profits because of improper application.

SINCE SOIL, GRASS AND CANCER

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The above title is parallel to a similar book about pesticides and was selected in order not to plagiarize a book, Soil, Grass, and Cancer published in 1959 by the French Agronomist Andre Voisin.

PLANTS AND DISEASE

"You are what you eat." This cry from dieticians, nutritionists, and particularly food-faddists has been heard so often that it has become a cliche. It is, nevertheless, true. Our foodstuffs present us with essential energy, proteins, amino acids, hormones, vitamins, and minerals. Plant or soil scientists recognize that our foodstuffs reflect the fertility and/or peculiarities of the soil where it grew.

Crosby (1967) said that, "Food is a mixture of chemicals not all of which are necessarily good for us." He closed by saying, "Our mothers wisely told us to be careful of everything we put in our mouth, and there can be no dispute that our daily food represents by far the greatest variety and quantity of exotic chemical compounds we are ever likely to have administered by the oral route." He was talking about naturally occurring toxins, not food contaminated by the activities of modern man.

The nutritional aspects of disease are of increasing concern to medical scientists. Much of this concern deals with mineral imbalance; i.e., a deficiency or excess of one or more elements in conjunction with an excess or deficiency of another. Specific trace element deficiencies or excesses have been associated with many diseases. For example, imbalances in zinc/copper have been linked with skin diseases, urinary diseases, infertility, tumors, liver diseases, heart diseases, pancreatic disorders, anemia, and stomach cancer (Fell et al., 1971 and Stocks and Davies, 1964).

Furthermore, virtually all edible plants produce exotic organic chemicals which are either depressants, stimulants, poisonous, hallucinatory, mutagenic, teratogenic, carcinogenic or some combination of these. In fact Crosby (1967) feels that part of our good cheer around Christmas time is due to the fact that nutmeg contains a hallucinatory compound in physiologically significant quantities. This is a compound called myristicin and is also found in dill, celery, parsley, parsnips, and mint. Myristicin has insecticidal properties (Lichtenstein & Casida, 1963) and with other compounds found in carrots and parsnips may be mistaken for aldrin and dieldrin in pesticidal analysis if certain precautions are not taken (Adams, 1969). Crosby (1967) also reported that carrots contain acetylene compounds similar to the toxic component in water hemlock and reminiscent in biological activity to the chlorinated hydrocarbon insecticides.

At least 250 plant genera have been reported to be cyanogenic (Conn, 1969); i.e., containing cyanogenic glyocosides which on digestion release cyanide. In desert regions many plants produce alkaloids, which, if consumed at a specific time produce monster offspring (teratogenic) in animals in pregnancy (Binns et al., 1970).

The cabbage family and many root crops such as carrots, parnsips, turnips, and rutabagas contain goitrogens similar in chemistry and biological effect to amino-triazole (Durham, 1963). According to Durham rutabagas contain naturally 200 ppm of L-5-vinyl-2-thiooxazolidine, a very potent goitrogen. Astwood (1960) claimed that one serving of turnips contains 100 times as much goitrogen activity as a serving of cranberries badly contaminated with amino-triazole. Parsnips contain enough of these compounds to be considered mutagenic.

SOIL AND CANCER

Polyphenols are among the organic compounds regarded as carcinogenic. These compounds are found naturally in many plants and make up 50% of the dry weight of tea leaves (Kaiser, 1967). Polyphenols are the chemical building blocks of soil humus (Flaig, 1975). This leads, therefore, to the main topic of this paper, soil and cancer.

In a literature review, Armstrong (1964) observed that the first paper on soil and cancer was read to the Medical Society of London in 1868. Early in this century work in France, the Netherlands, and England associated stomach cancer with certain soil types (Armstrong, 1962 and Voisin, 1959). These studies found a higher incidence of stomach cancer in areas with soils that were poorly drained clay, alluvial, and peat soils high in organic matter and acidity. Stomach cancer incidence was lowest in areas with well drained, calcareous mineral soils. In these studies a greater incidence of stomach cancer occurred among people drinking water from rivers or shallow wells.

Later work (Stocks and Davies, 1960, 1964) expanded upon the English study. This work implicated trace element imbalances, i.e., zinc/copper ratios, with the higher incidence of cancer. Scientists in this study regarded zinc as a cancer promoter and copper as a cancer inhibitor. Cancer was greatest where the ratios were highest. Other essential trace minerals have also been linked with cancer (Dixon et al., 1969). Stocks and Davies either did not consult soil biochemists or ignored two important aspects of their work. They found that garden soils contained more organic matter than adjacent lawns in high cancer areas; only possible if residents were gardening organically. Furthermore, they did not recognize that organic matter mobilizes zinc making it more available to plants and more subject to leaching, nor did they recognize that copper is bound by humus almost irreversibly making it unavailable.

As previously indicated polyphenols can be carcinogens. Singleton and Kratzer (1969) found most plant phenols were toxic. Boutel and Bosch (1959) found 14 of 50 polyphenols tested produced carcinoma in mice. Benzoquinone, the oxidized form of a common soil phenol produces cancer in mice (Shimkin et al., 1971). Benzyrene, one of the most potent carcinogens known is a common constituent of soil humus (Shabad, 1968; Blumer, 1961), particularly in forest soils (Blumer, 1976). This compound is an industrial contaminant from smokestacks and probably occurs in soils as a result of prairie and forest fires. Little is known whether plants can take up these carcinogens from soils, but some workers (Shabad, 1968) indicated plant content increases with increases in soil content, suggesting uptake is possible.

WHAT IS THE SIGNIFICANCE OF THESE CARCINOGENS?

The spectre of cancer stimulates great public concern. Some form of cancer now accounts for 20 percent of all U.S. deaths (Cairns, 1975). Cancer deaths have been increasing. Cancers of the lung and colon account for most of the increase (Cairns, 1975). The former was considered due largely to cigarette smoking. A smoker faces a 50-fold increase in risks of lung cancer. A change in dietary habits, resulting in lower intact in fiber and greater intake in meat receives the blame for increased cancer of the colon. Chief concern for dietary intake of natural or synthetic carcinogens would be expected to affect esophogeal and stomach cancer. The incidence of both have declined over the past 50 years; stomach cancer experiencing an eightfold decrease.

Mason et al. (1975) found that most cancers were associated with industry or urban life. Stomach cancer was among the few that were not. There is a definite geographic distribution of stomach cancer unrelated to either industry or agriculture. The highest incidence of stomach cancer in decreasing order in the U.S. occurs in northern Minnesota and Michigan, an area in northern North Dakota, and an area in northern New Mexico. Northern Minnesota and Michigan is a region of bogs, many of them acid. The area in North Dakota is just adjacent to the only acid bog in that state. The area in northern New Mexico is where some of the so-called "organic soil amendments" are mined indicating fossil remains of an environment similar to that in present day Minnesota. The countries of Norway, Sweden, Japan and Chile lead the world in incidence of stomach cancer. Scandinavia is bog country. The amorphous clay soils of Japan and Chile have a similar chemistry to soil humus.

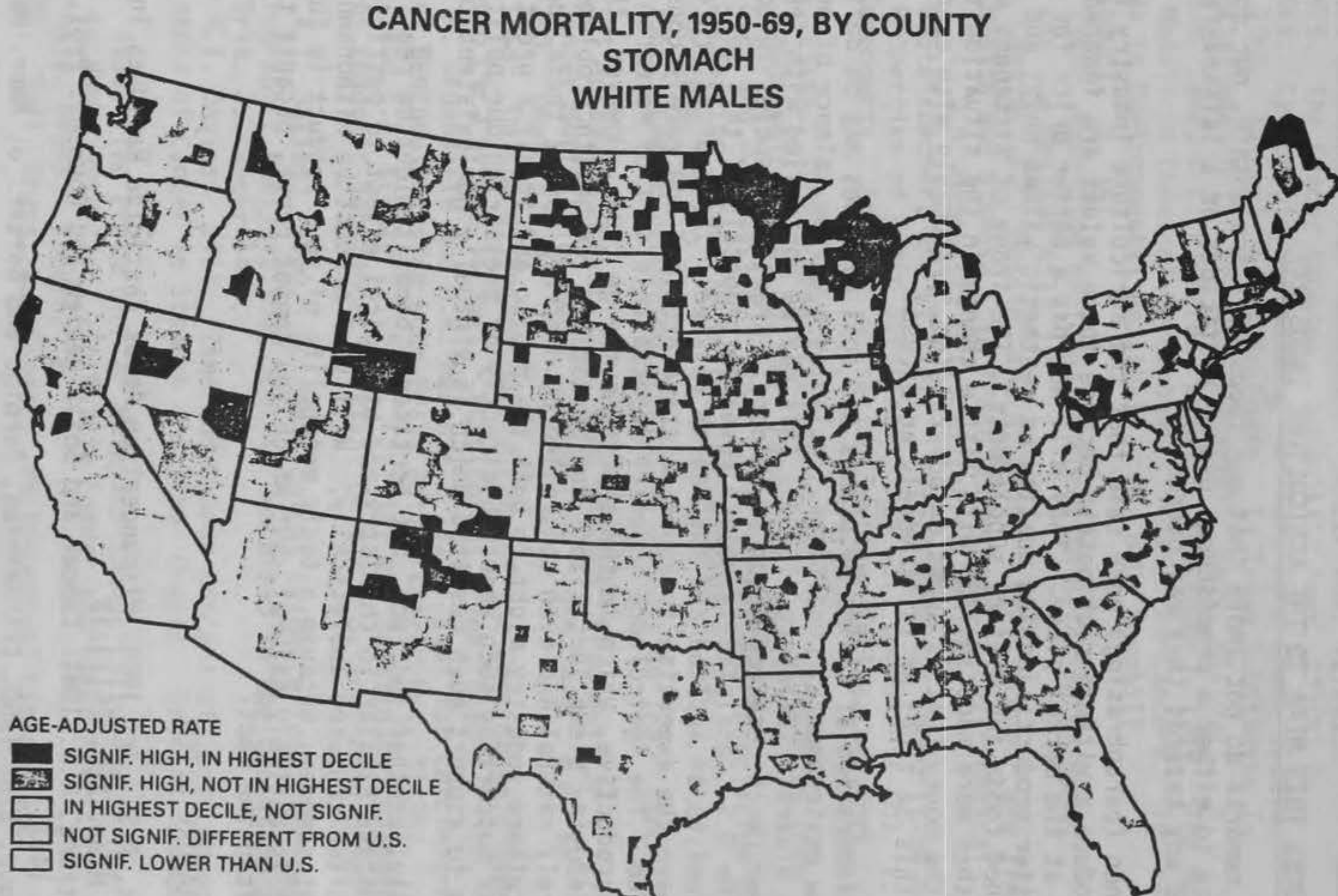
The lack of correlation between the incidence of stomach cancer and major agriculture areas does not prove that the cause is not dietary. These regions are remote from large urban shopping centers. Residents are more likely to grow much of their own food and drink water from their own wells, frequently shallow. As with the earlier studies in Europe there is a strong correlation in Minnesota between community water coming from shallow wells and surface water and the incidence of stomach cancer. This suggests that some factor in the water contributes to cancer. Available data do not reveal a cause. Zinc and copper data are not available.

According to Stocks and Davies (1964) several things were necessary to bring about stomach cancer correlated with soil properties:

1. The soil had to be acid or low in pH.
2. The soil had to be high in soil humus or organic matter.
3. The soil had to be poorly drained and frequently water saturated.
4. The victim had to drink water from his own well and grow most of the food for himself and his animals.
5. The victim had to reside at one location and live this life style for at least 10 years.

Such rigid requirements suggest that the correlation between cancer and soil is not coincidental. However, this may present little threat to the average American's health. Excesses and deficiencies are averaged away by the broad production and distribution area involved and the great variety in source and kind of foodstuffs eaten (Hopkins and Eisen, 1959). Conditions like

FIGURE *Stomach cancer mortalities in white males, by county from 1960 through 1969 in the United States (from Mason et al. 1975).*



these are likely to be met only by people living in communities distant from major marketing areas, drinking their own water and growing much of their own food; by people on fad diets; and by people zealously pursuing the "back to the land" movement and subsistence farming.

WHAT DOES THIS MEAN TO THE AGRICULTURE INDUSTRY?

These remarks do not imply that our foodstuffs are unsafe, nor do they give license to either a promiscuous use of pesticides or a laissez-faire attitude toward any hazards they may present.

Virtanen (paraphrasing) once said that the agriculture industry is powerless to produce a vitamin rich potato because these values are ignored by the consumer at the market place. They will not pay a better price for a nutritionally better product; judging quality on aesthetic values only; and preferring enriched foods and dietary supplements. The irony of Virtanens words are that they were made in 1938 with little change in the situation today. However, with the money that is spent on advertising, presumably with economic return, need this be true, or is it merely an excuse?

The elaboration of toxins by plants and soil microbes may be defined by fairly narrow environmental conditions, including a narrow balance of one or more trace minerals (Weinberg, 1970). This may be controlled with fertilizer. However, much research needs to be done. Granting agencies in both Canada and the U.S. consistently reject research proposals of this sort coming from agronomists as applied and not health related. The medical profession does not have the expertise to approach these problems and rarely consults those that do. The Agriculture industry rejects this sort of research as economically unproductive, which in the short run may be true. However, those outside the industry blame fertilizers and pesticides for health problems that may be entirely natural and even controlled by discreet use of these chemicals. Agriculture industry might do both the public and itself a great service by either supporting such research directly or pressuring our political institutions to support such research which is virtually non-existent today.

Finally, another indirect, but pertinent, benefit might be realized. Natural toxins are similar in chemistry and biological effect to pesticides. They are often confused analytically. Will your product be withdrawn from the market someday, because a toxic metabolite of your product is found in soils, which is entirely natural, but which you cannot prove, because the research is after the fact?

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FUNGICIDE APPLICATION TECHNIQUES

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INTRODUCTION

Spraying crops with fungicides and bactericides is primarily a protective measure to reduce the possibility of invasion by disease-causing organisms. The chemicals serve as barriers between the attacking pathogens and the plant. Therefore, to be of maximum benefit, they should be applied before organisms are present. Success in protecting against infectious diseases is as much a matter of proper application techniques as it is selecting suitable chemicals. Good protection is no accident, but a result of applying the right chemical with the right equipment in the right manner at the right time.

METHODS OF APPLICATION

Ground Spraying

Ground spraying has been and still is the predominant method used in applying chemicals for disease control. Boom type sprayers have been in use since the turn of the century and for many kinds of row crops they provide the best means of obtaining good protective coverage. When used with drop nozzles, the boom sprayer is considered by many to be the only type of equipment that will give adequate spray coverage in dense foliage on crops such as potatoes, tomatoes, celery, cucurbits, etc.

The air displacement sprayer (airblast), originally developed to spray fruit trees, was later adapted for use on row crops. This type of equipment has certain advantages over the conventional boom sprayer in that it can travel faster, is more maneuverable, and is better adapted to rough terrain. The main disadvantage of the airblast sprayer is the long distance that the spray must travel to reach the crop. This becomes critical with unfavorable wind conditions, since large amounts of spray in fine droplets may be diverted and end up as drift.

The airblast sprayer is a sophisticated piece of equipment as compared with a boom sprayer -- a fact which is frequently overlooked by the user. Unsatisfactory performances with this type of sprayer can often be traced to one or all of the following conditions: improper adjustment, malfunctioning due to poor maintenance, lack of understanding as to the capabilities of the equipment, and failure to operate it properly. Airblast sprayers are well suited for spraying open planted crops. They are not considered the best choice of ground equipment for row crops with dense foliage.

Another method of ground application being given consideration is the use of overhead irrigation equipment. The fungicide Du-ter is now approved for application through solid set and center pivot irrigation systems for control of early and late blight on potatoes. Recent studies in Michigan have demonstrated control of late blight on potatoes with Bravo, Difolatan, Dyrene, and Cit Cop 4E applied through solid set irrigation (6). The same technique was demonstrated using Du-ter, Benlate, and Topsin for the control of Cercospora leaf spot on sugarbeets (5).

On potatoes and sugarbeets, the irrigation method appears to be as effective as the boom and airblast sprayers for applying fungicides. It is less expensive to use, is faster and requires less fuel than other methods of ground application.

AERIAL APPLICATION

Acceptance of aircraft application of fungicides and bacteriacides has been slow due to insufficient convincing data as to its effectiveness. There has been a determined effort in the past decade to prove that the aerial method is a satisfactory substitute for ground spraying. To accomplish this, it has been necessary to establish that diseases may be effectively controlled by fungicides applied as concentrate sprays. Because of inherent weight limitations of aircraft, aerial application of fungicides and bacteriacides is dependent upon reliable disease control using low volumes of water (5-10 gals/A). Since, under these circumstances, the volume of water is insufficient to wet completely the plant surface, initial coverage is incomplete and the protective chemical dries on the surface in discrete concentrated deposits. For many years, it was generally accepted that fungicide sprays to be effective should completely cover the plant surface. With new formulations now available, discrete drops of fungicide or bacteriacide on the plant surfaces are effective in preventing infection, even though chemical-free areas appear to exist between deposits. By a mechanism, often referred to as redistribution, the chemical exerts a protective action at some distance from its point of deposition (1)(2).

As a result of new information on efficacy of aerial application for disease control, there has been a significant increase in the use of this method during the past 5 years. Interest has been stimulated because of the many advantages of using air over ground application. Two very obvious advantages are: 1. Increased rapidity of application (with air, 10-20 times greater acreage is covered per unit of time than with the most efficient ground sprayer); 2. Application can be made over soil too wet for wheeled vehicles. Wet ground is likely to promote disease. Therefore, to be able to apply protective chemicals when ground spraying would be impossible could mean the difference between success and failure of a crop.

Another advantage of the aerial method that should be mentioned is the elimination of soil compaction and mechanical damage to the crop. Information from Canada (3) and Maine (3) indicate substantial reductions in potato yields as a result of ground spraying. A four-year study in Michigan has shown that marketable yields of potatoes from rows adjacent to sprayer wheel tracks were reduced by as much as 38%, and that losses for entire fields ranged between 3% and 11%. It seems likely that comparable yield losses occur with other crops as a result of compaction and mechanical damage caused by ground spraying.

In attempting to control halo blight on colored beans with coppers, the use of ground sprayers will very often contribute to the spread of the disease. For that reason, Michigan is now recommending only the aerial application for protection against halo blight.

SPRAY ATOMIZERS

When spraying chemical protectants in suspension or solution, they are atomized through some type of nozzle or rotary dispensing device.

Nozzles

Nozzles for crop spraying fall into 3 general categories based on the pattern produced as the spray leaves the orifice, i.e., solid cone (includes jet), hollow cone, and flat fan. The solid cone will produce the largest droplets and the hollow cone the smallest. The two cone type nozzles have round orifices, but they differ internally. The solid cone is unobstructed within, whereas the hollow cone uses either a core or configurations in the chamber wall to produce a swirling motion which results in a hollow cone spray pattern.

The flat fan nozzle has an eliptically shaped orifice which produces a fairly coarse spray in a flat-fan pattern. The orifice is recessed with flow channels by either side to help prevent pattern distortion. Depending on variations in the shape, the spray may be evenly distributed across the width of the spray band or it may be tapered at the edges.

Cone and flat fan nozzles are designed for both ground and aerial spraying. When used on aircraft, the body of the nozzle includes a diaphram shutoff mechanism which prevents dripping when the spray system is not in operation.

The hollow cone nozzles, because they are believed to give better spray distribution, are usually selected for applying fungicides and bactericides. Fungicide tests comparing the performance of hollow cone and flat fan nozzles on potatoes and other vegetables, indicate little if any significant differences between the two (4). Some growers, when spraying with a boom, prefer to use hollow cone nozzles overhead and flat fan nozzles on their drops. They claim to get the best spray coverage when the fan is oriented in the verticle position or tilted forward at a 45^{o} angle.

When spraying fungicides with drop nozzles to control crown and stem rots, i.e., crown rot of sugarbeets, pink rot of celery, drop of lettuce, etc., there may be some advantage to using flat fan nozzles. For success, it is important to spray not only the base of the plant, but the ground on either side as well. Coverage might be better accomplished under these circumstances with the flat fan pattern than with the cone pattern.

ROTARY ATOMIZERS

The rotary atomizer is essentially a cylinder of wire mesh or perforated metal rotating around a hollow fixed spindle. The chemical spray is introduced into the stationary spindle under pressure, and from there is metered into the outer cylinder. The centrifugal force exerted on the spray causes it to pass through the openings in the cylinder and, in so doing, to be broken up into smaller droplets.

Some rotary atomizers like the Beecomist and the Span Sprayer are self-powered. The Beecomist is electrically driven and can be used for both aerial and ground applications. The Span Spray atomizer is driven by hydraulic power and is designed for ground application only.

The rotary atomizer most frequently used in this country is the Micronair. It is wind driven and therefore can be used only on aircraft. It is equipped with adjustable fan blades. The speed at which the unit turns is regulated by changing the pitch of the blades and/or modifying air speed. Droplet size is regulated by speed of rotation, so the faster the unit turns the finer the droplets.

Rotary units mounted on aircraft are usually evenly spaced on either side of the fuselage with the distance between outboard units no greater than 3/4 the wing span or rotor blade. When used on a helicopter, the wind driven type of atomizer should be equipped with long fan blades (15") to compensate for the slower operating speeds of this type of craft (55-60 mph).

Extensive testing has demonstrated that the Micronair atomizer produces a more uniform and a narrower range of droplet size than conventional boom and nozzle systems. This may account for improved penetration of dense foliage and increased spray coverage on the undersurface of leaves with this type of equipment, as opposed to a conventional aircraft boom system. Furthermore, Micronair atomizers are extremely flexible, and they can be quickly adjusted to spray a few ounces to many gallons per acre.

It is important to note that when using Micronair atomizers the aircraft should be flown between 9 and 12 feet above the crop. At lower flight heights there is insufficient blending of the spray from the atomizer, which may produce an uneven spray pattern.

SPRAY ADDITIVES

Effective disease control frequently depends on additives to improve the performance of pesticides. These are primarily surface-active agents which increase the degree of contact (wetting ability) or adhesiveness (sticking ability), thereby providing better distribution and retention of insecticides, fungicides, and bacteriacides on plant foliage. Manufacturers normally include an unspecified amount of these agents when formulating their products. However, because of the wide variation in surface types of plant leaves, growing characteristics, and foliage density, additional amounts may be needed in the finished spray. Common household detergents may improve surface wetting, but they are inferior and do not have the desirable sticking characteristics found in adjuvants formulated specifically for spray tank use, i.e., Biofilm Triton B-1956, Triton C S7, Nu Film P, duPont Spreader-Sticker, Plyac Spreader-Sticker, Ortho Spreader-Sticker, Spread-Rite, and Superior Spreader, etc.

There are also additives with special properties for adjusting pH such as Buffer X and others. The buffering capacity protects alkaline-sensitive chemicals such as organic phosphates or carbamates from degradation in the spray tank and after they are on the plant. Some adjuvants are specifically designed to aid in the uptake of systemic chemicals (Regulaid). Other additives such as Nu Film 17 are considered to be extenders with the capability of prolonging the active life of certain organic compounds on the plant surface. Emulsifiable spray oils often improve spreading, tenacity of sprays, and also serve as anti-evaporants for the spray in flight. Thickener-elasticisers, such as Nalcotrol and L O Drift, as well as invert emulsions are now being used with fungicides and insecticides to reduce drift. There is also substantial evidence indicating that the addition of foam will reduce spray drift without impairing the effectiveness of fungicide sprays.

DRIFT

The problem of drift should be foremost in the minds of those applying pesticides. Damage from misplaced toxic chemicals occur too frequently and are costly to all concerned. A better understanding of factors that cause and control drift will help to reduce the severity of the problem.

There are 4 factors which are primary in relation to drift. The first, and perhaps the most important, is droplet size. Droplets below 100 microns (1 micron = 1/25,000 inch) size often fail to reach their intended target and get lost in the atmosphere or contribute to a drift problem. A second factor is the distance between the spray atomizer and the target. The greater the distance, the greater the chance that an increasingly larger portion of smaller droplets in the spray stream will lose their projected velocity and respond to gravity or air turbulance, and thereby contribute to the drift potential. The third factor affecting drift is wind velocity. Unless other drift protection measures are taken, winds above 6-8 miles per hour make spraying hazardous both on the ground and from the air. The fourth factor is humidity. This can have a rapid effect upon water-based sprays. When the humidity is low, rapid evaporation is likely to occur, transforming droplets into floating dust. Under such circumstances spray coverage will be poor and the danger from drift great.

With these factors in mind the following are some practical ways in which application can reduce the amount of drift.

1. Avoid spraying in winds over 8 mph. and when conditions are gusty.

2. Increase droplet size by lowering pump pressure, using larger nozzles, using nozzles of a type that produces a coarser spray, i.e., conventional flat fan, solid core, raindrop, foam type, adjust the orientation of nozzles so they are directed away from the direction of air movement (aircraft only), use skirts or deflectors to reduce air movement (ground boom sprayers). Use chemical drift retardants, Nalco-trol, L O Drift, Foam, etc.

3. Use chemicals to reduce water evaporation (anti-evaporants).

4. Maintain equipment in proper adjustment and insure proper functioning while applying pesticides.

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LONG TERM EFFECTS OF HERBICIDES ON WEEDS AND CROPS

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In 1965 we initiated a study on crop and herbicide rotations. The purpose was to study the long term effect on yields, weed species, weed seed content of the soil, and soil life. Although the study was terminated in 1976, additional measurements are being made on the soil flora and fauna. Five cropping systems were used: continuous corn, continuous soybeans, continuous wheat, corn-corn-soybean rotation, and corn-soybean-wheat rotation. Three weed control treatments were imposed on each crop. One involved using the same herbicide treatment each year, one involved rotating the herbicide treatment, and the third involved no herbicide treatment. In the case of corn and soybeans, one cultivation was used on those plots receiving chemical treatment and three cultivations were used where no herbicides were applied. In the winter wheat plots the wheat stubble was mowed several weeks after harvest on all plots. All herbicide treatments were broadcast. The herbicide treatment chosen to be used continually for corn was atrazine, for soybeans was amiben, and for wheat was dicamba. All work in this study was completed with regular field equipment and no hand labor was used.

Only in 2 years of the study cultivation without herbicides produced yields comparable to the herbicide treatments. In all other years, it was impossible to complete timely cultivation and, hence, yields were reduced substantially. For the 10 year period of 1966-1975, continuous corn yields were increased 23% over the no herbicide plots with the use of atrazine continuously during that period and 27% where the herbicide treatment was rotated. Soybean yields were increased by 22% with either the continuous or rotated herbicide treatment over the cultivated check plots. Using 1975 prices for corn and 1975 prices for the cost of production, the continuous herbicide treatment yielded a net profit of 54 dollars per acre more than the cultivated check. The rotated herbicide provided a net increase of 61 dollars. For each dollar invested in terms of herbicides then the return was 4.81 dollars and 4.97 dollars. The net profit for soybeans was similar to corn and for each dollar invested in herbicides, 4.50 dollars net profit was returned. Since wheat yields were not increased by herbicide treatment, the net returns for wheat were generally higher where no herbicide treatment was used. At the start of this study in 1965, the weed seed level in the soil was determined. Both the total amount of seeds were recorded and the amount of seeds of each species present. The seed level was determined again in 1970 and 1975. Some 30 different kinds of weed seeds were found in the original sampling in 1965. In 1970 about half of the species found in 1965 were not present and in 1975 the seed of less than 10 weed species were present. In addition to the disappearance of about two thirds of the species, the amount of seeds of the remaining species has dropped to very low levels in the herbicide treated plots. This study indicates that if weeds are controlled and are not allowed to produce seed, the weed seed level in the top 8 inches of soil will drop rather rapidly. Herbicide residues in the soil have not been in sufficient amounts to be recorded by bioassay techniques. Studies on the levels of bacteria, fungi, small animals, and earthworms have indicated that they have not been effected by the cropping systems or herbicide treatments.

RAINFALL EFFECTS ON HERBICIDE PERFORMANCE

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Rainfall may result in increased or decreased weed control with herbicides. Without rainfall before weeds emerge the activity of most soil-applied herbicides is poor. From 0.5 to 1.0 inch of rainfall is necessary to carry soil-applied herbicides into the soil so that germinating weeds are contacted and controlled. In 1976 many areas in Minnesota did not get enough rainfall after preemergence herbicides were applied and poor weed control was the result. If rainfall is lacking and weeds emerge cultivation or postemergence herbicide applications are required to bring the weeds under control. Occasionally a very heavy rainfall of many inches may cause excessive downward movement of herbicide in the soil. Chemical near the soil surface then becomes inadequate to control weeds and chemical moved deeper in the soil near the crop seed may result in injury if crop tolerance to the herbicide is limited. Fortunately in most years rainfall is not so extreme that poor weed control or crop injury occurs.

It is well known that rainfall shortly after foliar applications washes herbicide from the leaves before it is absorbed and, thereby, reduces weed control. However, we have not been certain of the amount of rain required to wash the herbicide from plant leaves or of the minimum length of time between herbicide application and rainfall that is necessary to give good weed control. University of Minnesota studies have provided information on rainfall amounts and rainfall timing on the effectiveness of foliar herbicide applications. The quantity of rainfall required to remove herbicides from plant leaves varies with the herbicide, the rate of herbicide application and the kind of plant. As little as 0.04 inches of rain immediately after herbicide application greatly reduces the effectiveness of many herbicides including 2,4-D, glyphosate, and bentazon. One-half inch of precipitation washes nearly all of an applied herbicide from leaf surfaces. Substantial rainfall, 0.4 inch or more, occurring a few minutes after herbicide application eliminates weed control with most herbicides. However, a few that have activity through the soil (eg. dicamba and atrazine) give at least partial weed control when washed from the leaves because of root uptake of the chemical washed into the soil by the rain. Studies on the time interval between foliar herbicide application and rainfall indicate that rainfall within two hours of treatment substantially reduces weed control with most herbicides. A time interval of four to eight hours from treatment to rainfall results in poor to good control depending on the herbicide and plant species. In a few instances a time interval of 24 hours or more between herbicide application and rainfall was required to reach maximum weed control. Factors of importance in determining rainfall effects on herbicide effectiveness in foliar treatments were the herbicide, herbicide formulation, plant species, quantity of rainfall and rainfall timing.

WILD OAT DISTRIBUTION AND CONTROL

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INTRODUCTION

Wild oat, Avena fatua L. is a serious weed problem in northwestern and west central Minnesota small grain fields. In northwest Minnesota, wild oat also causes problems in other field crops such as sugarbeets, sunflowers, flax, dry edible beans, soybeans and corn. In recent years wild oat appears to be spreading to other areas of the state as well, being reported from northeast, southwest and southeast Minnesota as well.

Wild oat is an annual member of the grass family, reproducing only by seed. It is well adapted to and is found in most of the small grain growing regions of the world. Wild oat plants produce mature seeds earlier in the season than most small grains, flax or other crops. These seeds shatter and fall to the ground before harvest of the crop to insure a new seed supply for succeeding years. Wild oat seed is dormant at maturity which prevents germination until the following spring. Germination begins when soil temperatures reach 40^{o}F. and continues until soil temperatures exceed 70^{o}F. This characteristic helps wild oat to survive as a species during summer fallow or summer tillage operations.

According to recent surveys, wild oat infests 70 million acres in Canada and 28 million acres in the United States. However, more than half (15 million acres) of the United States total acreage is in the state of North Dakota alone. Wild oat is most competitive with field crops in regions of low to moderate rainfall (below 25 inches average annual precipitation). An estimated one million acres of cropland is infested with wild oat in Minnesota. However, less than half of this acreage (400,000 acres) is rated as being an "economic infestation". The estimated dollar loss in crop yields in Minnesota to wild oat is 3-1/2 million dollars per year compared to 271 million dollars for the United States as a whole.

MINNESOTA WEED SURVEY RESULTS

To help determine the distribution and density of wild oat in Minnesota, a survey was conducted among Minnesota County Extension Directors and County Agricultural Inspectors during the summer of 1976. Four crop categories were included in the survey. These were small grain, pasture, corn and soybeans. Respondents were asked to estimate the percentage of the county acreage of each of these crop categories that were (1) severely infested with wild oat, (2) moderately infested with wild oat, (3) lightly infested with wild oat, and (4) free of wild oat. County acreages of each of these crop categories were tabulated from Minnesota Crop and Livestock Reporting Service statistics for 1975 and the number of wild oat infested acres in each county were estimated. (Table)

Table. Estimate of acres of small grain in Minnesota moderately to severely infested with wild oat by county. Minnesota Weed Survey - 1976

County	Acres of Small Grain (1975) (1000's)	Percent Acres Infested	Estimated Acres Infested (1000's)
Northwest District[1/]			
Becker	137.2	60	82
Clay	308.9	35	108
Clearwater	33.9	80	27
Kittson	307.2	90	276
Mahnomen	98.7	90	89
Marshall	496.9	55	273
Norman	314.5	82	258
Pennington	159.6	60	96
Polk	635.3	34	216
Red Lake	118.9	41	49
Roseau	138.1	70	97
North Central District[1/]			
Beltrami	17.0	10	2
Hubbard	11.2	12	1
Koochiching	6.6	50	3
Lake of the Woods	20.3	50	10
Northeast District[1/]			
St. Louis	8.5	46	4
West Central District[1/]			
Big Stone	96.4	67	65
Douglas	110.9	6	7
Grant	174.5	68	119
Lac Qui Parle	121.8	2	2
Otter Tail	266.8	40	107
Pope	111.0	40	44
Stevens	147.3	75	110
Swift	122.1	15	18
Traverse	186.7	70	131
Wilkin	299.7	55	165
Southwest District[1/]			
Lincoln	66.7	17	11
Lyon	56.4	10	6
Pipestone	39.1	25	10
Central District[1/]			
Carver	23.9	4	1
Scott	18.3	1	1
Stearns	129.4	18	24
East Central District[1/]			
Hennepin	11.2	5	1
Pine	13.7	50	7
Southeast District[1/]			
Olmsted	36.1	10	4
Wabasha	30.0	10	3
Winona	29.3	3	1
TOTAL	4904.1		2328

[1/] Crop Reporting Districts in State of Minnesota

Survey results showed that wild oat was considered a problem primarily in the small grain acreage of the county. Thirty seven counties reported moderate or severe infestations of wild oat in small grains. (Map)

Thirty one of these counties reported severe wild oat infestations. Only 30 of the 87 counties reported no wild oat problems in small grain. Counties with severe infestations of wild oat in small grain are located primarily in northwestern Minnesota in the Red River Valley section of the state. Northern and west central Minnesota counties also reported severe infestations in small grain.

WILD OAT CONTROL

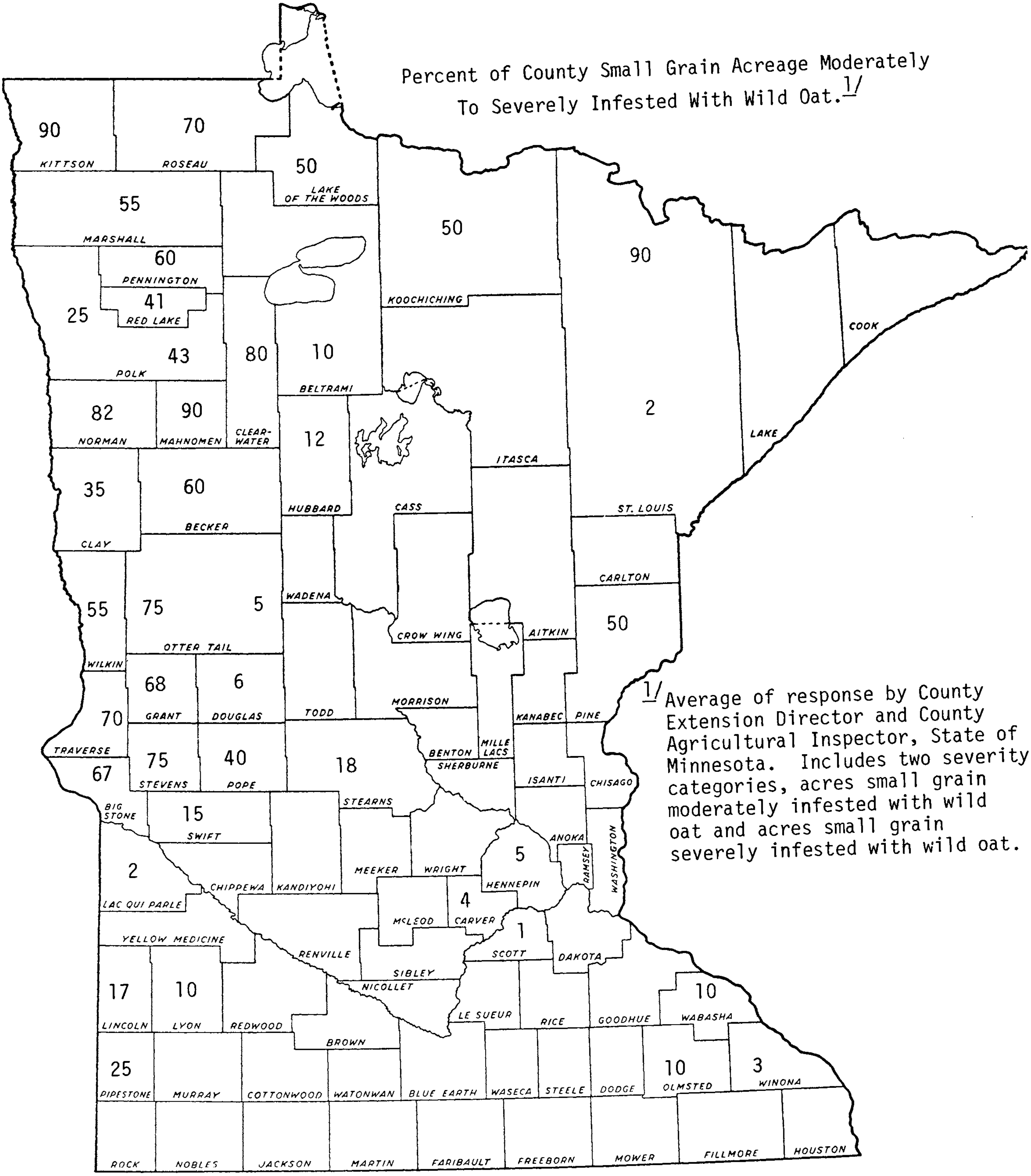
Wild oat may be effectively controlled by both cultural and chemical methods. The most effective method of cultural control is delayed seeding of small grain or other crops. Early spring tillage to stimulate wild oat germination with subsequent tillage to kill emerged wild oat seedlings gives effective wild oat control but reduces small grain yields because the crop cannot be seeded early enough for best growth and development. Summer fallow with repeated tillage to kill emerging wild oat seedlings followed by fall sown rye is effective in reducing wild oat populations. However, economic returns from this practice have not been good.

Several herbicides are available for wild oat control and chemical control of wild oat is gradually becoming more popular with farmers. However, it is estimated that in the spring wheat region of the United States, only 20 percent of the fields with moderate wild oat infestations have been treated. Triallate (Far-go) may be applied preplant or preemergence on barley or preemergence on wheat with immediate soil incorporation to control wild oat seedlings as they emerge. Barban (Carbyne) can be used as an early post-emergence treatment on wheat, barley, flax soybeans, sugarbeets or sunflowers after the crop and wild oat have emerged and does not require soil incorporation. However, to be effective, barban must be applied when the majority of the wild oat seedlings are in the 2-leaf stage from 4 to 10 days after emergence of the wild oat. With varying soil moisture conditions in the spring, wild oat often germinates over a long period of time and proper timing of barban application may be difficult. To reduce crop injury potential, barban should not be applied after wheat or barley are in the 4-leaf stage or more than 14 days after crop emergence. Similarly, barbon should not be applied after the 12-leaf stage of flax nor later than 14 days after soybean or sunflower emergence nor later than one month after sugarbeets emerge. Diallate (Avadex) may be used for wild oat control in flax or corn as a preplant or preemergence treatment with immediate soil incorporation or in sugarbeets, fall or spring as a preplant, soil incorporated treatment. A new herbicide, difenzoquat (Avenge), may be used for wild oat control as an early postemergence application on Era spring wheat, barley or winter wheat. Difenzoquat alone or as a tank-mix combination with certain broadleaf herbicides may be applied when the majority of the wild oat plants are in the 3 to 5-leaf stage of growth.

Usually, a combination of cultural and chemical practices will give best wild oat control. Even though wild oat seeds have remained viable for seven years or more in the soil, it is estimated that wild oat populations could

MINNESOTA WEED SURVEY - 1976

Percent of County Small Grain Acreage Moderately To Severely Infested With Wild Oat.[1/]



[1/] Average of response by County Extension Director and County Agricultural Inspector, State of Minnesota. Includes two severity categories, acres small grain moderately infested with wild oat and acres small grain severely infested with wild oat.

be drastically reduced by four years of complete control of emerged wild oat plants using presently available cultural and chemical control practices. However, complete control is necessary because one wild oat plant can produce as many as 250 seeds to reinfest the soil. Promising new experimental herbicides for wild oat control are also being developed and new research on a crop rotation "systems approach" to wild oat control may provide additional answers to the wild oat problem.

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NEW CONTROLS FOR QUACKGRASS AND OTHER PERENNIAL WEEDS

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Introduction

The proliferation and spread of perennial weeds in recent years is due partly to improved control of many of the annual weed species. By controlling annual weeds competition on perennial species has decreased. This factor, plus a trend toward earlier planting and reduced tillage (both before and after planting), have resulted in an environment that allows perennial weeds to flourish. Perennial weeds are very difficult to control, they spread both by seeds and vegetatively. The vegetative underground parts of the plants store large energy reserves and are able to produce new plants even when detached from the parent plant. Chemical and nonchemical methods of weed control should be combined in attacking perennial weeds. Today we will consider some of the recent developments in the control of several perennial weeds.

Quackgrass

Glyphosate, a recently released herbicide, gives consistent quackgrass control when applied as a postemergence treatment. Corn, soybeans and wheat are not tolerant to over-the-top applications. This restricts the use of glyphosate to preplow treatments. In all three crops fall applications are the most practical, because quackgrass does not reach treatable height until mid-May, while these crops should be planted at or before this time. The limiting factor for spring applications is the 3 to 4 leaf-stage requirement before treatment. However, the field may be plowed and planted three days after treatment; once the herbicide has translocated into the rhizomes. Glyphosate is not active through the soil and leaves no residue in the soil. Single glyphosate applications have controlled quackgrass for more than one growing season, the residual control being the greatest when a crop is grown in the treated area.

Yellow nutsedge

One of the most effective systems for control of yellow nutsedge in field crops involves growing soybeans. Preplanting tillage to reduce tuber food reserves is the first step. A soil-incorporated application of either alachlor or vernolate is then applied during the last tillage operation before planting. Soybeans are then planted at a fairly high population in rows that are narrow, but allow for cultivation. After soybeans emerge, cultivation is helpful and postemergence bentazon is available if needed.

Canada thistle

Bentazon, a postemergence treatment in soybeans, has shown good Canada thistle control. Double applications of bentazon have been more effective than single applications. The first application should be made when the thistles are 3 to 6 inches tall. The repeat treatment should be made 10 to 14 days later. If a single application is used, apply when the tallest thistles are 6 to 8 inches tall.

American germander

Postemergence applications of 2,4-D and dicamba have not controlled germander in corn. Preplant incorporated treatments of EPTC have shown excellent control. Atrazine applied as a preemergence treatment has not been effective on this weed. However, when atrazine is applied preplant incorporated or postemergence, fair to good control has been observed.

MANAGING HERBICIDES IN MINNESOTA CROPPING SYSTEMS

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Minnesota farmers are changing a number of cropping practices which have implications for herbicide use and weed control. These changing practices along with low rainfall are significantly affecting the weed problem and the performance of chemicals.

Some of the major trends in crop production include:

1. There is more land being row-cropped continuously. In 1976, over 10 million acres of Minnesota's 28 million acres of cropland were planted to corn and soybeans. Corn and soybeans often follow each other in successive years. Fallowing and forage legume-grass crops are not as extensively used in rotations as in the past.
2. Small grains increased to 7-1/2 million acres in 1976, with wheat showing the major increase of about 1/3 more acreage to 4 million acres. Much of this increased planting was in fields where corn and soybeans were grown the previous year.
3. Limited rainfall over most of the state in 1975 and 1976 and drought conditions for the last three years in parts of the state have influenced selection of crops, tillage practices, the kinds of weeds that are predominant, and herbicide performance.
4. Reduced tillage systems are increasing in popularity. We have recently seen a trend toward less moldboard plowing and increasing use of chisel plows or field cultivators. Reduced tillage often increases weed populations since the weed seeds are left on the surface where they can germinate. Tillage practices also limit the choice of herbicides and may change the kinds of weeds in the field.
5. Farmers are relying more on herbicides for weed control. Herbicides are now used on about 90% of Minnesota's corn and soybean acreage, on about 80% of the small grain acreage, and on all the sugarbeets. Multiple treatments and mixtures of chemicals are used on much of this acreage.

Dry weather, reduced tillage, and the crop sequences now in use have increased the potential for herbicide carry-over problems in 1977. Herbicide residues gradually disappear from the soil over time. The chemicals are broken down primarily by chemical reactions and digestion by microorganisms. These activities take place more slowly under dry or cool conditions than under warm, moist conditions. The persistence of an herbicide is dependent also on the characteristics of the chemical, the rate of application, and soil characteristics.

Atrazine, simazine (Princep), and cyprazine (Outfox, Fox-4) are some of the more persistent herbicides used in crops. These chemicals may carry over enough to damage susceptible crops such as small grains, flax, forage legumes and grasses, soybeans, sunflower, sugarbeets, and vegetable crops. Corn, sorghum, and millet are tolerant to these herbicides. Metribuzin (Sencor, Lexone) is similar in chemistry to the triazine compounds listed above. It has not resulted in residue problems from the rates used on soybeans, but at the higher rates used on potatoes, it may persist enough to affect susceptible crops grown the next year.

Carry-over problems from atrazine, simazine, or cyprazine are more likely to occur in areas of low rainfall, on soils that are low in organic matter or high in pH, where high rates of application are used, where applications were made late in the season, and where the fields are not moldboard plowed. If soybeans are planted in fields that have some residues of atrazine, simazine, or cyprazine, the use of metribuzin, linuron (Lorox), or chlorbromuron (Maloran) on the soybeans may enhance the potential for crop injury since these compounds and the triazines have similar effects on plants.

Chemicals used on soybeans do not normally persist enough to affect crops the following year. But, following dry conditions and with reduced tillage, trifluralin (Treflan) may carry over enough to affect corn, grain sorghum, small grains, and sugarbeets the following year. Wheat is more tolerant than the other small grains. Soybeans, dry beans, sunflowers and alfalfa are tolerant to trifluralin.

There are several newer herbicides chemically similar to trifluralin - fluchloralin (Basalin), profluralin (Tolban), butralin (Amex), oryzalin (Surflan), and penoxalin (Prowl) - which may have carryover characteristics similar to trifluralin, but experience with these materials is too limited to draw definite conclusions. Dinitramine (Cobex) is a similar material which has not persisted enough to cause any carry-over problems.

Moldboard plowing has reduced the problem of crop injury from trifluralin carry-over. Plowing buries the chemical below the seedling development zone so that the seedling shoot is not exposed to as much chemical and the seedling is well established before the roots come in contact with the chemical. Plowing also dilutes the chemical and may bring the chemical into contact with moist soil where it will continue to decompose.

If corn is planted after soybeans that have been treated with trifluralin, using penoxalin (Prowl) on th corn may increase the corn injury potential, since both chemicals are in the same chemical family and have similar effects on plants.

Picloram (Tordon) has been used at low rates of 1/4 to 3/8 ounce per acre to control wild buckwheat in wheat and barley. Under dry conditions or if the rate of application has been exceeded, there may be enough carry-over to affect sensitive crops such as field beans, soybeans, sunflowers, peas, potatoes, sugarbeets, alfalfa, or vegetables the next year.

Herbicide residue problems can be reduced by several management practices. These include:

1. Grow a tolerant crop where there is a potential problem.
2. Use an herbicide which will not carry over the year prior to rotating crops.
3. Plow with a moldboard plow where it is necessary to grow a susceptible crop in rotation following a herbicide that may carry over.
4. On the crop which may be injured, use a herbicide that is not in the same chemical family as the carry-over-herbicide from the previous year.
5. Use mixtures of herbicides which allow some redcution in rates of persistent herbicides.

New herbicides

There are some recent clearances of new herbicides that may be used in 1977.

Difenzoquat (Avenge) was recently labelled for wild oat control in barley, winter wheat, and Era spring wheat. Some spring wheat varieties are susceptible to injury by difenzoquat, but other varieties will probably be added in the near future. Difenzoquat is applied as a postemergence treatment when the wild oat plants have three to five leaves. The suggested rate ranges from 5/8 to 1 pound per acre, with the proper rate depending on the density of wild oat plants. Higher rates are required for denser stands. Difenzoquat may be used with MCPA and bromoxynil. It should not be applied when plants are wet or if rain is expected with 6 hours.

Metolachlor (Dual) is now cleared for preemergence use on corn grown for grain. It is not cleared for silage corn, popcorn, or sweet corn. It also may be used in a mixture with atrazine. Metolachlor, chemically similar to alachlor and propachlor, controls annual grasses and pigweed. It also looks promising for nutsedge control when incorporated preplanting, but this method of application is not labelled yet.

EPTC (Eradicane) and butylate (Sutan^{+}) were recently labelled for use of higher rates, up to 6 pounds per acre, on corn. These rates should prove helpful for improving control of nutsedge with either chemical or control of quackgrass with EPTC.

Penoxalin (Prowl) was cleared in 1976 for use as a preemergence application for corn. It may be used alone or in mixtures with atrazine, cyanazine (Bladex), or dicamba (Banvel). Penoxalin was recently labelled for preplanting incorporated applications on soybeans. Suggested rates are 1-1/2 to 2 pounds per acre for corn and 1/2 to 1-1/2 pounds per acre for soybeans. In Minnesota trials on corn, penoxalin has been somewhat less effective on grasses, but more effective on some broadleafs than alachlor. Limited trials on soybeans indicate that preplanting applications may be more effective than preemergence applications, but these trials were under dry conditions and we do not have sufficient information to be conclusive. Corn will not tolerate incorporated applications and corn may be injured by preemergence treatments on sandy soils or soils that are low in organic matter.

Fluchloralin (Basalin), chemically similar to Trifluralin (Treflan), is now cleared for soybeans. It is applied preplanting incorporated and controls annual grasses, pigweed, and common lambsquarters. Fluchloralin is used at slightly higher rates than trifluralin to obtain comparable weed control. Soybean tolerance to fluchloralin is comparable or slightly greater than to trifluralin.

Other recent clearances include chloramben (Amiben) plus alachlor (Lasso) tank mixture for soybeans, terbacil (Sinbar) for established alfalfa, and dinitramine (Cobex) for sunflowers.

Suggestions for herbicides to use in crops are listed in Tables 1 to 7. Tables 2 and 4 show the expected crop tolerance and control of common weeds for several herbicides used on corn and soybeans. More information on weed control in crops is given in "Cultural and Chemical Weed Control in Field Crops--1977", Extension Bulletin 400, Agricultural Extension Service, University of Minnesota, St. Paul, MN 55108. Labels should be read carefully for specific use instructions.

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

Chemical	Pounds per acre of active ingredient or acid equivalent broadcast	Remarks[2/]
Preplanting incorporated		
Alachlor (Lasso)	4	For nutsedge control
(Lasso II)	3.9	For nutsedge control
Atrazine	2 to 3	May injure some crops following year.
Butylate (Sutan+)	3 to 6	Controls annual grasses only.
EPTC + protectant (Eradicane)	3 to 6	For nutsedge, quackgrass and annual grass control.
Atrazine + butylate	1 to 1-1/2 + 3 to 4	For annual grasses and broadleafs.
Cyanazine (Bladex) + butylate	1 to 2 + 3 to 4	For annual grasses and broadleafs.
Preemergence		
Alachlor (Lasso)	2 to 3-1/2	Control annual grasses primarily.
(Lasso II)	2.4 to 3.9	
Atrazine	1 to 3	May injure some crops following year.
Cyanazine (Bladex)	2 to 4	Do not use on sandy soils.
Metolachlor (Dual)	2 to 3	Do not graze or use corn for silage.
Propachlor (Ramrod, Bexton)	4 to 6	Controls annual grasses only.
Atrazine + alachlor	1 to 2 + 1-1/2 to 2-1/2	
Atrazine + metolachlor	1 to 2 + 1-1/4 to 2	Do not graze or use corn for silage.
Atrazine + propachlor	1 to 1-1/2 + 2 to 3-3/4	
Cyanazine + alachlor	1 to 2.2 + 2 to 2-1/2	Do not use on sandy soils.
Dicamba (Banvel) + alachlor	1/2 + 2 to 2-1/2	Do not use on sandy soils.
Linuron (Lorox) + alachlor	1/2 to 1-1/2 + 1 to 3	Do not use on sandy soils.
Linuron + propachlor	1 to 1-1/2 + 2 to 3	Do not use on sandy soils.
Postemergence		
Atrazine + oil	1.2 to 2	Apply when weeds less than 1-1/2 inches tall.
Cyanazine (Bladex)	2	Apply when weeds less than 1-1/2 inches tall and before corn has more than 4 leaves.
Dicamba (Banvel)	1/8 to 1/4	Controls broadleafs only. Apply before corn is 2 feet tall and not within 15 days of tasseling. Follow drift control precautions on the label.
Dicamba + 2,4-D amine	1/8 to 1/4	
2,4-D amine	1/4 to 1/2	Corn 4 inches to 3 feet tall. Use drop nozzles after corn is 8 inches tall. 2,4-D controls broadleafs only.
2,4-D ester	1/6 to 1/3	

Table 1. (Continued)

Chemical	Pounds per acre of active ingredient or acid equivalent broadcast	Remarks[2/]
2,4-D amine 2,4-D ester	1/2 to 1 1/3 to 2/3	After corn is 3 feet tall. Use drop nozzles so only base of stalk is sprayed. Do not apply between tasseling and dough stage.

1/ From Cultural and Chemical Weed Control in Field Crops - 1977. Extension Bulletin 400. Agricultural Extension Service. University of Minnesota. St. Paul, Minnesota, 55108.

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

Table 2. Effectiveness of Herbicides on Major Weeds in Corn

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

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

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

Chemical	Pounds per acre of active ingredient or acid equivalent	Remarks[2/]
Preplanting incorporated		
Alachlor (Lasso)	4	For nutsedge control.
(Lasso II)	3.9	For nutsedge control.
Dinitramine (Cobex)	1/3 to 2/3	Primarily annual grass control.
Fluchloralin (Basalin)	1/2 to 1-1/2	
Profluralin (Tolban)	1/2 to 1	
Trifluralin (Treflan)	1/2 to 1	
Vernolate (Vernam)	3	Controls annual grasses and some broadleafs. Incorporate immediately.
Preemergence		
Alachlor (Lasso)	2 to 3-1/2	Controls annual grasses primarily.
(Lasso II)	2.4 to 3.9	
Chloramben (Amiben)	3	Controls annual grasses and broadleafs. Apply same day soybeans are planted.
Chloramben + alachlor	2 + 2	
Chlorbromuron (Maloran) + alachlor	3/4 to 2-1/4 + 1-1/2 to 2-1/2	For medium textured soils with less than 4% organic matter. Do not use on sandy soils.
Chlorpropham (Furloe Chloro-IPC)	2 to 3	For annual smartweeds only.
Linuron (Lorox) + alachlor	1/2 to 1-1/2 + 1 to 3	For medium textured soils with less than 4% organic matter. Do not use on sandy soils.
Metribuzin (Lexone, Sencor) + alachlor	1/4 to 1/2 + 2 to 2-1/2	Do not use on soils low in organic matter or on sandy soils. Soybean injury may be more severe on alkaline soils or on soils with atrazine residues.
Postemergence		
Bentazon (Basagran)	3/4 to 1-1/2	Apply when soybeans are in first trifoliolate leaf stage. Controls most annual broad-leaved weeds, Canada thistle, and nutsedge. Apply second treatment to Canada thistle and nutsedge 10 days after first application.
Chloroxuron (Tenoran)	1 to 1-1/2	Apply when soybeans are in first trifoliolate leaf stage and weeds are less than 2 inches tall. Controls certain broad-leaves only.

Table 3. (Continued)

Chemical	Pounds per acre of active ingredient or acid equivalent	Remarks[2/]
2,4-DB amine	1/5	Controls only cocklebur. Apply 10 days before bloom up to midbloom or as directed spray when soybeans are 8 to 12 inches tall.

[1/] From Cultural and Chemical Weed Control in Field Crops-1977. Extension Bulletin 400. Agricultural Extension Service. University of Minnesota, St. Paul, Minnesota, 55108

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

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

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

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

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

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

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

Crop	Chemical	Rate - pounds per acre of active ingredient or acid equivalent broadcast	Remarks
Dry beans	<u>Preplanting incorporated</u>		
	Alachlor (Lasso)	2 1/2 - 3	Controls annual grasses, nutsedge, pigweed black nightshade.
	EPTC (Eptam)	3	Controls annual grasses, some broadleafs.
	Dinitramine (Cobex)	1/3 - 2/3	Controls annual grasses, pigweed, common lambsquarters.
	Profluralin (Tolban)	1/2 - 1	
	Trifluralin (Treflan)	1/2 - 1	
	<u>Preemergence</u>		
	Alachlor (Lasso)	2 1/2 - 3	Controls annual grasses, pigweed, black nightshade.
	Chloramben (Amiben)	3	Controls annual grasses and most annual broadleafs.
Sugarbeets	<u>Preplanting incorporated</u>		
	Diallate (Avadex)	1 1/2 - 2	Controls wild oat.
	EPTC (Eptam)	2 - 3	Controls annual grasses and some broadleafs.
	<u>Preemergence</u>		
	TCA	5 - 7	Controls annual grasses except wild oat.
	<u>Early postemergence</u>		
	Dalapon (Dowpon, Radapon)	2-3	Apply when sugarbeets are up to 6-leaf stage for controlling annual grasses except wild oat.
	Dalapon	2 1/2 - 3 1/2	Apply as directed spray when sugarbeets are 7-leaf stage to 14 inches.

Table 6. (Continued)

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

1/ From <u>Cultural and Chemical Weed Control in Field Crops-1977</u>. Extension Bulletin 400. Agricultural Extension Service, University of Minnesota, St. Paul, Minnesota 55108. Check label for detailed use instructions and restrictions on crop use.

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

Chemical	Pounds per acre of active ingredient or acid equivalent broadcast	Time of application	Crop
Barban (Carbyne)	1/4 - 3/8	wild oat in 2-leaf stage	Wheat, barley flax, soybeans, sunflowers.
Barban (Carbyne)	3/4 - 1	Wild oat in 2-leaf stage	Sugarbeets
Diallate (Avadex liquid)	1 1/2 - 2	Preplanting or pre-emergence, fall or spring	Flax, sugarbeets
Diallate (Avadex granules)	1 1/2 - 2	Preplanting, fall or spring	Sugarbeets
Triallate (Far- go)	1 - 1 1/4 1 1/4 - 1 1/2	Preplanting or preemergence, fall or spring	Wheat Barley
Difenzoquat (Avenge)	5/8 - 1	Wild oat in 3- to 5-leaf stage	Era spring wheat, barley, winter wheat

1/ From Cultural and Chemical Weed Control in Field Crops-1976. Extension Bulletin 400, Agricultural Extension Service, University of Minnesota, St. Paul, Minnesota 55108. Check label for detailed use instructions and restrictions on crop use.

NEW APPROACHES TO CORN ROOTWORM CONTROL

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Corn rootworms are considered to be among the most damaging agricultural pests in the North Central States. Economic losses in 1973 were estimated to exceed 100 million dollars.[1/] Rootworm populations and subsequent damage have increased in most of the North Central States since 1973 with severe damage occurring in many areas the last three years.

Both the adult (beetle) and larval stages of the corn rootworm damage corn with larval damage being the most serious. Larvae of the corn rootworm damage corn by feeding on the roots which may result in: (1) death, (2) stunting, (3) lodging, (4) reduced ear size and (5) harvest problems due to lodged and tangled stalks. Corn rootworm adults damage corn to a lesser extent than larvae by: (1) feeding on corn leaves (western sp.) and (2) clipping silks which may interfere with pollination. In some years, late planted corn may be seriously damaged by the feeding of corn rootworm beetles.

Corn Rootworm Control

Crop rotation has always been considered the most reliable means of reducing corn rootworm damage. Corn rootworms occasionally damage first year corn, especially when corn follows weedy soybeans or small grains stubble. Where crop rotation is not practiced and/or practical, soil insecticides are the most common means of reducing rootworm damage.

Prior to 1960, corn rootworm control on continuous corn land was accomplished primarily by broadcast applications of organochlorine insecticides such as aldrin, BHC and heptachlor. With the development of corn rootworm populations which were resistant to the organochlorine insecticides in the late 1950's and early 1960's, most areas changed to band applications of organophosphate (carbamates were introduced shortly there after) insecticides at planting time. This is still the most common method of reducing rootworm damage to continuous corn. In the last few years another potential control technique, adult suppression, has received a great deal of attention as an alternative to the use of soil insecticides at planting time.

Adult Corn Rootworm Control to Reduce Larval Damage

Adult suppression to reduce larval populations is not a new concept. It

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1/ The North Central Branch insect loss estimates-1973, prepared by North Central Branch ESA survey entomologists in 1975.

was first proposed in 1948 by Hill et al. in studies conducted in Nebraska. Adult suppression involves killing rootworm beetles before they have laid enough eggs in the soil to produce damaging larval populations the following year when the eggs hatch. In the early 1960's when resistance to the organochlorine insecticides first developed, farmers in portions of south-central Nebraska began using adult suppression on a wide-area basis as their only means of reducing rootworm damage. The practice is still popular in certain areas of the state. Studies conducted by Pruess et al. (1974) in central Nebraska from 1968-1970 indicated that adult suppression on a wide-area basis was an effective method of reducing rootworm injury. As indicated, most previous studies have been conducted on a wide-area basis rather than on individual fields. The possibility of extended beetle emergence and beetle immigration from surrounding unsprayed fields makes it essential that adult suppression be evaluated on an individual field basis.

Advantages.-The use of adult suppression (if the technique is perfected) on an individual field basis rather than soil insecticides would have the following advantages:

(1) Controlling an insect which is present at the time the controls are applied.-Soil insecticides are usually applied at planting time which is usually one to one and a half months prior to rootworm hatch. This may result in the insecticide breaking down to ineffective levels before the rootworm eggs hatch. Also, since the fields are treated in anticipation of damaging rootworm populations developing later, many fields receive unnecessary insecticide applications each year. In Nebraska, it is estimated that appx. 80% of the land in continuous corn production in the eastern half of the state receives "corn rootworm" soil insecticide treatments each year. However, beetle counts and damage estimates in many areas indicate that less than 50% of the treated fields really have a rootworm problem. Adult control, if properly used, could reduce the no. of fields treated each year. *In actual practice, the implementation of field scouting programs could also reduce the no. of insecticide treated fields regardless of the type of control selected.*

(2) Increased farmer safety.-Soil insecticides require a considerable amount of handling and close contact by a farmer and he is often exposed to the chemical for several days during planting time. Aerial application of insecticides, especially if low toxicity chemicals such as carbaryl are used, could increase farmer safety.

(3) Could reduce the chance for improper insecticide application.- Modern corn planters are complex pieces of equipment, usually accomplishing several operations in a single pass over the field. Each operation must be properly calibrated and checked frequently to insure proper performance. Failure to calibrate and frequently check insecticide applicators is a common problem related to many reported cases of poor insecticide performance. Results of a 1975 survey in Nebraska indicated that approximately 53% of the corn acreage treated with a rootworm insecticide at planting time received less than the recommended

amount of insecticide/acre. Much of this was due to improper calibration. Some of the new corn planters as well as the "Minimum Tillage" planters are not designed to apply rootworm insecticides in a manner which will provide the best degree of control possible. Adult suppression, especially with respect to the latter points, could be useful in reducing damage which results from soil insecticide application problems.

Disadvantages.-Although adult suppression would be a useful control technique from several standpoints, there are some potentially serious disadvantages:

(1) Greater potential to harm non-target species.-Insecticides usually are not selective and affect other animals in the area sprayed. Parasitic and predatory insects and mites which may be controlling other pests (i.e., spider mites, earworms, armyworms, etc.) may be killed which could result in increased damage. In addition, other beneficial insects such as bees may be killed if the corn is pollinating at the time the fields are sprayed or if the spray drifts onto adjacent areas.

(2) Timing of spray application is critical.-Corn rootworm beetles emerge from the soil over an extended period of time. In order to be effective, adult sprays must be applied after most of the beetles have emerged from the soil and before many eggs are laid. Also, since beetles often move from field to field, the spray should have some residual killing power (2 or more weeks preferably) in order to kill immigrating beetles. The rate of development of rootworms is dependent on environmental factors, therefore the best time to spray may be different for each year. The use of long residual insecticides will, to some extent, allow for the year to year variation in the proper time to apply sprays to control beetles. However, the use of long residual insecticides will increase the chance of killing beneficial insects.

Although there are serious disadvantages (as well as advantages) in using aerial suppression of corn rootworm adults as an alternative to using soil insecticides, there certainly is a need for developing and selectively using alternative methods of rootworm control such as adult suppression.

Results of adult suppression studies in Nebraska (1972-76).-Studies to evaluate adult suppression on an individual field basis were conducted in a total of 29 fields in Nebraska from 1972 to 1976. All studies were conducted by spraying one-half of each field in August and evaluating larval damage in the sprayed and unsprayed areas the next year. Corn rootworm larval damage was evaluated by digging plants from the sprayed and unsprayed areas of each field and rating the roots for feeding damage. Each root system was scored according to a 1-6 root damage rating scale (1=minor feeding damage --- 6= three or more nodes of roots destroyed). Although many things influence root damage, the sprayed areas should have root damage ratings below 2.8 in order for the adult suppression program to be considered as effective as the use of one of the better soil insecticides.

Of the 29 fields studied, only four failed to develop (in the unsprayed areas) damaging rootworm larval populations (root damage ratings of 2.8 or above) the year after spraying. Rootworm damage was reduced in 17 of the remaining 25 fields. However, only 9 of the fields had root damage ratings reduced below 2.8 which would indicate comparable control to a soil insecticide. A rough interpretation of these data indicate that, at best, adult suppression was as effective as one of the better rootworm soil insecticides in only 36% of the fields studied. The avg. results for all fields combined/year is presented in Table 1.

Table 1. Results of Nebraska adult corn rootworm suppression studies to reduce larval damage the following year.

Year Adult Control was Applied	Avg. No. of Corn Rootworm Beetles/Plant Prior to Spraying	Rootworm Damage the Next Year Root Damage Rating: Sprayed area	Rootworm Damage the Next Year Root Damage Rating: Unsprayed area	% Reduction in Rootworm Injury
1973	2.7	3.4	4.9	38.5%
1974	10.7	2.9	3.3 (5.0)[1/]	17.4% (52.5%)[1/]
1975	8.6	3.6	4.1	16.1%

1/ Damage ratings corrected for spray drift into the "unsprayed"area (appx.).

Adult suppression in 1973 resulted in a 38% reduction in rootworm feeding injury the following year. Rootworm egg samples collected at the time the fields were sprayed (Aug. 10) compared to final egg collections in October indicated that approximately 30% of the eggs were already laid in the fields by the time the fields were sprayed. Based on these data the 1974 and 1975 spray dates were moved up to the first of August.

Insecticide drift into the "unsprayed" areas in 1974 resulted in significant reductions in the beetle populations in the unsprayed areas. Consequently, root damage comparisons between the sprayed and unsprayed areas the following year indicated only a 17% reduction in rootworm injury in the adult suppression area. If spray drift had not occurred in 1974 and based on the rootworm adult population that was present (10.7 beetles/plant) prior to spraying, it is estimated that adult suppression actually resulted in approximately a 52% reduction in rootworm injury the following year. The 1975 beetle sprays resulted in only a 17% reduction in rootworm injury the following year.

One thing that is apparent when evaluating the results from the 1974-5 and 1975-6 tests, is that beetle populations were extremely high prior to spraying. If only a small portion of the beetles were laying eggs prior to insecticide application, that might be enough to cause serious damage. In other words, in order for adult suppression to be an effective means of reducing rootworm injury, beetle populations may have to be below certain levels (i.e., 3-4/plant ?) prior to spraying. Above this level adult suppression may not be a reliable means of control. The idea is partially supported by observations and root damage ratings taken from 21 additional fields in which the farmers used adult suppression as their only means of control. All fields had populations of over one but less than six beetles/plant prior to spraying. None of the fields had "economic" rootworm damage the year following spraying. However, there were no unsprayed areas in the fields for direct comparison. The program appeared to be successful since several of the fields probably would have been economically damaged if sprays had not been used.

Insecticides.-Since the optimum time to apply adult corn rootworm controls varies from year to year depending on environmental conditions, the use of a long residual insecticide provides some degree of flexibility in timing of applications. Long residual insecticides can be applied at the earliest date that a significant no. of beetles may begin to lay eggs. In Nebraska, based on available data, the best time to spray appears to be around the first of August. If applied too early, the insecticide residue will not last long enough to control late emerging beetles and/or immigrating beetles. If applied too late the beetles may have already laid too many eggs in the field.

There are several insecticides which are effective controls for corn rootworm beetles but most of them have very short residual activity (1-7 days). A new carbaryl formulation, Sevin 4-Oil, with extended (2 or more wks. in most tests) residual activity has proven to be an effective insecticide for adult suppression purposes. Studies were conducted in 1975 and 1976 to determine how long Sevin 4-Oil remains effective in the field after it is applied. This was done by collecting leaf samples from the sprayed fields and putting them in containers with corn rootworm beetles and counting the no. of beetles that were killed. The 1976 studies were conducted in both dryland and sprinkler irrigated fields while the 1975 tests were conducted in sprinkler irrigated fields only. The results are summarized in Fig. 1.

The irrigated fields received approximately one and a half inches of water/acre/week. The 1976 dryland fields received less than one and a half inches of rainfall during the entire post-spray period. The Sevin 4-Oil treatments provided excellent initial control and the residual control was still very effective 15 days later. However, residual control in the irrigated fields dropped rapidly after 15 days. The dryland treatments were still providing above 95% residual control after 25 days. The dryland fields were harvested for silage shortly after the last samples were collected. These data indicate that conditions of frequent rainfall or sprinkler irrigation following Sevin 4-Oil applications may result in a rapid decrease in residual control after two weeks. However, based on preliminary results of 1976 studies, two weeks residual control is higher than most other insecticides will provide under the same moisture conditions. Sevin 80S, Furadan 4F and Malathion 50%EC all provided excellent initial control but essentially no control one week later (0.75 inches of rainfall occurred four days post-spray). There is some evidence that other long residual insecticides may prove to be useful alternatives to Sevin 4-Oil but data are inconclusive at the present time.

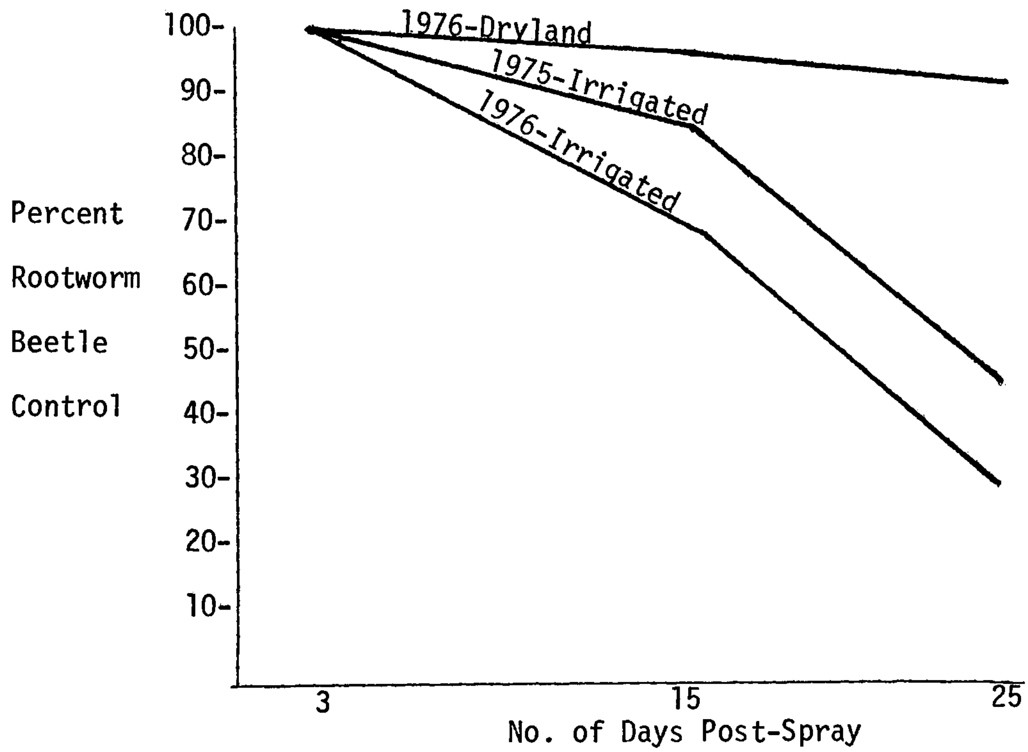

Fig. 1. Residual corn rootworm beetle control provided by Sevin 4-Oil on corn grown under dryland and sprinkler irrigated conditions.

Summary.-Adult corn rootworm control as an alternative to using soil insecticides has provided inconsistent control results in Nebraska studies and cannot be recommended based on available data. It does appear to be an effective management technique under some conditions but needs further study to determine its overall effectiveness.

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WEEVILS IN THE SUNFLOWERS
David Noetzel

With the increase in sunflower acres and the continuous growing of the crop in some areas, new insect problems seem to occur every year. In 1974 through 1976 a number of weevils appeared to create some problems.

It is perhaps easiest to classify these weevils into root feeders, stem borers, head feeders and a seed feeders. In all but one case it is the feeding stage of the larva which causes the damage.

The single root feeding weevil is Baris strenua. It feeds as an adult on sunflower foliage early in the morning or late in the evening. During the daytime the adults congregate near the base of the plant where mating takes place. Eggs are laid under callous tissue at the base of the stem. Pupation takes place in the ground.

Two species oviposit in the stem. The most commonly observed weevil, Apion occidentale and the apparently most severely damaging weevil, Cylindrocopturus adspersus. Apion is black and has a long snout. The adult is active up and down the plant and all day long. Oviposition scars from Apion are present in almost every field and occur from 2/3 plant height to ground level. The larva burrows in the pith but usually does not destroy the pith zone.

In contrast C. adspersus adults are found in the upper portions of the plant. They descend to the lower 1/4 of the plant where oviposition occurs. Their larval stage burrows in the pith and, in small plants or where drouth is severe, cause, along with black rot, the total destruction of the pith. We have observed economic damage from this species of weevil only, and then only in dense plant populations or where severe drouth exists.

There is no control other than reducing plant populations or increasing rainfall.

The largest weevil on sunflower is Haplorynchites aeneus (or sunflower weevil). The adult weevil drills a neat row of holes just back of the head. It then lays its eggs in the head. The row of holes plus larval feeding weakens the stalk so that the head breaks loose and falls to the ground. Larval development is completed in the downed head. The larval stage winters. Damage from this insect is almost always along field edges and is rarely economically important.

Two weevils have larval stages which infest seed, Smicronyx fulvous and S. sordidus. S. fulvous is a reddish-brown color while S. sordidus is bluish-black. Adult activity occurs in August. The adult oviposits just under the seed coat and the larva then feeds on the developing seed. At one time these two insects actually limited sunflower production in Illinois and Indiana. They have only been a problem in northcentral South Dakota and southcentral North Dakota. However, they are also present in westcentral Minnesota.

None of these weevils is limiting to sunflower production in our area. We have no data to show these insects can be controlled with insecticides. At the same time we also have no data to show they singly or collectively reduce yields.

Summary of Insecticide Suggestions
for Crop Insect Control
1977

Crop	Insect	Insecticide	Dosage	Limitations - Remarks Days before harvest
Alfalfa	Alfalfa weevil	azinphosmethyl (Guthion)	1/2-3/4 lb.	21 days, one application per cutting
		carbofuran (Furadan)	1/4-1/2 lb.	7 days 1/4 lb; 14 days 1/2 lb
		methyl parathion	1/4 lb.	15 days
		Imidan	1 lb.	7 days one application per cutting
		diazinon plus methoxychlor	1/2 + 1 lb.	7 days
		malathion plus methoxychlor	3/4 + 3/4 lb.	7 days
		methidathion (Supracide)	1/2 lb.	10 days
	Aphids and leafhoppers	diazinon	1/2 lb.	7 days
		dimethoate (Cygon, DeFend, Rebelate, Dimex)	1/4-1/2 lb.	10 days
		malathion	1 lb.	No time limitations
		parathion	1/4 lb.	15 days. Qualified aerial applicators only.
	Armyworm cutworms	carbaryl (Sevin)	1 1/2 lb.	No time limitations, spray or bait
		malathion	1 lb.	No time limitations.
		trichlorfon	1 lb.	7 days - spray 14 days - bait
	Leafhoppers (see also under Aphids)	azinphosmethyl	1/4-1/2 lb.	14 days
		carbaryl	1 lb.	No time limitations
		diazinon	1/2 lb.	7 days
		methoxychlor	1 lb.	7 days
		malathion	1 lb.	No time limitations
	Grasshoppers	azinphosmethyl	1/2-3/4 lb.	21 days (over 1/2 lb.)

Presented by John Lofgren at the Soils, Fertilizer and Agricultural Pesticides Short Course, Dec. 14, 1976

Crop	Insect	Insecticide	Dosage	Limitations - Remarks Days before harvest
(Alfalfa cont.)	Grasshopper	carbaryl	1-1 1/2 lb.	No time limitations
		carbofuran	2-4 oz.	7 days, one application
		diazinon	1/2 lb.	7 days
		malathion	1 1/2 lb. or 1/2 lb. tech. as ULV by air	No time limitations
	Spittlebug	methoxychlor	1 lb.	7 days
	Plant bugs	diazinon plus methoxychlor (Alfatox) malathion plus methoxychlor	See under alfalfa weevil	
		trichlorfon	1 lb.	7 days
Corn, field	Armyworm	carbaryl	1 1/2-2 lb.	No time limitations
		malathion	1-1 1/2 lb.	5 days
		toxaphene	2 lb.	Harvest for grain only. Do not feed or ensile leaves, stalks or husks.
		trichlorfon	1 lb.	No time limitations
	Corn rootworms	carbofuran chlorpyrifos (Lorsban) ethoprop (Mocap) fensulfothion (Dasanit) (if available) fonofos (Dyfonate) phorate (Thimet) terbufos (Counter)	Use equivalent of one pound active ingredient per acre on 40 inch row basis as a row treatment at planting time. Apply granules in 7 inch band lightly incorporated. Do not place in furrow with seed unless directions on the label permit. If liquid formulations are used, avoid placement close to seed. If used with fertilizer be sure products mix properly and provide adequate agitation to keep mixed. Some products may be registered for basal, post emergence treatment but are less effective, especially in dry conditions. Reduced control may be observed after several years of continued use of one chemical. If this is noticed, switch to another compound or adopt a rotation of insecticides on 2 or 3 year schedule on continuous corn.	

Crops	Insect	Insecticide	Dosage	Limitations - Remarks Days before harvest
(Corn, field Cont.)	Corn rootworm beetles	carbaryl	1 lb.	No time limitations
		diazinon	1 lb.	No time limitations
		malathion	1 lb.	5 days
		malathion ULV	4-8 oz. tech.	
		EPN	1/4-1/2 lb.	14 days
	Cutworms	carbaryl	1-2 lb. spray or bait	
		trichlorfon	1 lb.	See under Armyworm
		toxaphene	2 lb.	
	European corn borer	carbaryl	1 1/2 lb.	No time limitations
		carbofuran	1 lb.	Granules. No more than two applications
		diazinon	1 lb.	No time limitations.
		fonofos	1 lb.	30 days
		EPN	1/2 lb.	14 days
		phorate	1 lb.	Do not graze or cut for forage within 30 days. No more than one application.
		toxaphene	2 lb.	Harvest for grain only.
	Grasshoppers	carbaryl	1 1/2 lb.	No time limitations
		diazinon	1/2 lb.	No time limitations
		malathion	1 lb. or 1/2 Tech. as ULV	5 days
		toxaphene	1 1/2 lb.	Harvest for grain only.
	Seed beetle maggot, beetle, wireworms	heptachlor, lindane	1 oz. per bu.	Seed treatment or planter box treatment.
	Seed corn beetles, maggots	fensulfothion	1 lb.	Band over row at planting time as for corn rootworm.
		fonofos	1 lb.	
	Wireworms	ethoprop	1 lb.	As for rootworm
		phorate	1 lb.	
		terbufos	1 lb.	
		diazinon	4 lb.	Broadcast incorporated soil treatment preplant
		fonofos	4 lb.	

Crops	Insect	Insecticide	Dosage	Limitations - Remarks Days before harvest
Small grains	Aphids	dimethoate	1/4-1/3 lb.	Wheat only. 60 days
		disulfoton (DiSyston)	1/4-3/4 lb.	Wheat only. 30 days Do not graze. By qualified aerial applicators only.
		malathion	1 lb.	No time limitations
		methyl parathion	4 oz.	No time limitation. Qualified aerial applitors.
		parathion	4 oz.	15 days. Qualified aerial applicators only.
	Armyworm	malathion	1 1/2 lb.	7 days
		toxaphene	2 lb.	Harvest for grain only. Do not graze or feed treated straw.
	Grasshoppers	malathion	1 lb. or 1/2 lb. Tech. as ULV	7 days
		toxaphene	1 1/2 lb.	See under Armyworm
	Wireworms	heptachlor or lindane	1 oz. per bu.	Seed treatment
	Barley thrips	methyl parathion	6 oz.	15 days
		parathion	6 oz.	15 days Qualified aerial applicators only.
Flax	Cutworms, Crickets	trichlorfon	1 lb.	21 days
Soybeans	Bean leaf beetles, flea beetles, blister beetles	carbaryl	1 lb.	No time limitations
	Cutworms, armyworm	carbaryl toxaphene	1 1/2 lb. 1 1/2 lb.	No time limitations 21 days. Harvest for beans only.
	Grasshoppers	carbaryl	1 1/2 lb.	No time limitations
		malathion	1 lb. or 1/2 lb. ULV	7 days
		toxaphene	1 1/2 lb.	21 days. Harvest for beans only.

Crop	Insect	Insecticide	Dosage	Limitations - Remarks Days before harvest
(Soybeans Cont.)	Green cloverworm	azinphosmethyl	6-8 oz.	45 days
		Bacillus thuringiensis (Biotrol, Dipel, Thuricide)		As labeled
		carbaryl	1 lb.	No time limitations
		malathion	1 lb.	7 days
Sugarbeets	Webworm	carbaryl	1 1/2 lb.	14 days, tops
		endosulfan (Thiodan)	1 lb.	Do not feed tops
		parathion	4-8 oz.	15 days. Qualified aerial applicators only.
		trichlorfon	1 lb.	14 days
	Root maggots	aldicarb (Temik)	1 1/2 lb.	Row treatment of granules at planting time. Place in 5 to 7 inch band above seed or in furrow above seed. Some products may be side dressed at time of fly emergence.
		carbofuran	2 lb.	
		fensulfothion	1-2 lb.	
		diazinon	2 lb.	
		fonofos	1-1 1/2 lb.	
		phorate	1 lb.	
	Wireworms	lindane	1 oz. per bu.	as seed treatment
	Cutworms	carbaryl	2 lb. bait or spray	14 days, tops
		trichlorfon	1 lb.	14 days
Sunflower	Sunflower moth larvae	endosulfan	1 lb.	No more than 3 applications. Do not feed plants.
		methidathion (Supracide)	1/2 lb.	50 days. Will require at least 2 applications
		methyl parathion	1 lb.	No more than 3 applications. 30 days. Avoid spraying with all three compounds when honey bees are foraging.

Crop	Insect	Insecticide	Dosage	Limitations - Remarks Days before harvest
(Sunflowers Cont.)	Cutworms, sunflower beetles, grasshoppers, thistle caterpillar	toxaphene	1 1/2-2 lb.	Do not apply after the ray petals have formed. Do not graze or feed treated plants to livestock. No more than two applications per season. Use higher rates for cutworms and grasshoppers.
Wild Rice	Wild rice worm	malathion	1-1 1/2 lb.	7 days
Blue Grass, Timothy for seed	Plant bugs	diazinon	1/2 lb.	No time limitations
		malathion	3/4 lb.	No time limitations
	Armyworm	carbaryl	1 1/2 lb.	No time limitations
		malathion	1 lb.	No time limitations
Sweet corn	Aphids	malathion	1 lb.	5 days
		methyl parathion	4 oz.	3 days
		parathion	4 oz.	12 days
	Corn earworm	carbaryl	1 1/2 lb.	No time limitations
		diazinon	1 1/2 lb.	2 days
		endosulfan	1 1/2 lb.	Not for corn for processing. Not more than 5 applications. Do not feed treated forage.
		methomyl (Lannate, Nudrin)	1/4-1/2	3 days for forage
		methyl parathion (Penncap M)	1/2 lb.	3 days
	Corn rootworms	fensulfothion		see under field corn
		fonofos		see under field corn
		ethoprop		see under field corn
		phorate		see under field corn
	Corn rootworm adults	carbaryl	1 lb.	No time limitations
		diazinon	1/2-1 lb.	2 days
		malathion	1 lb. or ULV	5 days
		EPN	1/4 lb.	14 days
		methyl parathion	1/2 lb.	3 days

Crop	Insect	Insecticide	Dosage	Limitations - Remarks Days before harvest
Sweet corn Cont.	Cutworms, armyworm	carbaryl spray or bait	1 1/2-2 lb.	No time limitations
		toxaphene	2 lb.	Do not ensile or feed leaves, stalks or husks.
		trichlorfon	1 lb.	No time limitations
	European corn borer	carbaryl	1-2 lb.	No time limitations
		diazinon	1-2 lb.	No time limitations for spray. 10 days for forage with granules.
		EPN	1/4 lb.	14 days
		methyl parathion	1/4 lb.	3 days
	Wireworms	heptachlor, lindane	1 oz. per bu.	As seed treatment
		diazinon	1-2 lb.	Band on row at planting time, incorporated
		fonofos	1 lb.	
		phorate	1 lb.	
Peas for processing	Pea aphids	demeton (Systox)	1/4 lb.	21 days
		diazinon	1/2 lb.	No time limitations for peas, 4 days for hay.
		dimethoate	3 oz.	No time limitations for peas, 21 days for forage.
		malathion	1 lb.	No time limitations for peas, 7 days for forage.
		mevinphos (Phosdrin)	0.2 lb.	1 day
		naled (Dibrom)	1-2 lb.	4 days
		parathion	1/4 lb.	10 days
	Loopers	carbaryl	1 1/2-2 lb.	No time limitations
		methomyl	1/2-1 lb.	1 day
		parathion	1/2 lb.	15 days
		mevinphos	4 oz.	1 day
Beans (Dry edible)	Aphids	diazinon	1/2 lb.	7 days, Lima and pole and snap beans.
		dimethoate	1/2 lb.	No time limitations
		endosulfan	3/4 lb.	No more than 3 applications. Do not treat Lima beans. Do not feed forage.

Crop	Insect	Insecticide	Dosage	Limiations - Remarks Days before harvest
Beans (Dry edible) cont.	Aphids	malathion	1 lb.	1 day
	Bean leaf beetle	carbaryl	1 lb.	No time limitation
		methoxychlor	1 lb.	1 day
	Green clover-worm	carbaryl	1 lb.	No time limitations
		malathion	1 lb.	1 day
	Leafhoppers	carbaryl	1 lb.	No time limitations
		diazinon	1 lb.	7 days. For Lima, pole and snap beans.
		dimethoate	1/4 lb.	No time limitations
		malathion	1 lb.	1 day
		methoxychlor	1 lb.	1 day
	Seed corn maggot	chlorpyrifos (Lorsban SL) diazinon	1 oz. per bu.	Seed Treatment

Corn Rootworm Insecticide Evaluation

1. Date of Planting X Treatments in area of 5 years continual use of carbofuran.

   Southern Experiment Station, Waseca, Minnesota

   Early - planted April 28, 1976
   Late - planted May 18

   All rates are 1 lb. AI/A, 40 inch row basis.

Treatment	Av. Root Rating (1-6)	% Lodged	Yield bu/A
terbufos (Counter) Early	2.2	0	41
terbufos Late	2.3	13.3	54
phorate (Thimet) Early	2.3	12.0	54
phorate Late	3.0	42.8	53
carbofuran (Furadan) Early	3.5	80.0	37
carbofuran Late	3.2	98.8	37
check Early	4.3	72.0	33
check Late	4.8	94.8	38

2. Planter Treatments, Waseca, 1976

   Planted May 4, 7 inch band, 1 lb. AI/A.

Treatment	Root Damage Rating (1-6)	% Lodged	Yield
Counter	2.2	4	83
Furadan	2.3	0	92
Dyfonate	2.4	5	70
Dasanit	2.4	14	77
Thimet	2.5	9	69
Lorsban	2.5	25	65
Mocap	2.9	32	55
Check	2.8	26	64

3. Planter Treatments, Lamberton, 1976

Planted May 5, 7 inch band, 1 lb. AI/A.

Treatment	Root Damage Rating (1-6)
Dyfonate	2.0
Dasanit	2.0
Furadan	2.1
Thimet	2.1
Counter	2.2
Lorsban	2.2
Mocap	2.3
Check	2.9

(Lodging and yield data not recorded because of inadequate stand)

4. Several years' averages, Lamberton and Waseca.

Treatment	Average Root Damage 1-6 (74, 75, 76 Lamberton and Waseca)	Average % Lodged (74-Lamberton 74, 76 Waseca)	Yield, Bu/A. (Lamberton 74, 75 Waseca 74, 75, 76)
Furadan	2.2	0.0	89.6
Counter	2.3	4.3	84.2
Dyfonate	2.4	5.0	84.2
Mocap	2.5	14.0	83.4
Dasanit	2.6	6.7	83.4
Lorsban	2.7	10.7	84.6
Thimet	2.7	9.0	87.4
Checks	3.9	45.3	71.0

SOIL MOISTURE AND TILLAGE METHODS IN WESTERN MINNESOTA

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To be dry in southwestern Minnesota is part of living and farming in Southwest Minnesota. It appears to be as much of agriculture as the rising and setting of the sun. It means that this area is on the western edge of the corn belt because of the moisture, however, it is also on the northern edge of the corn belt because of temperature. In the center of a continent normal moisture and weather is only the average of the extremes, so to have a normal year in temperature and moisture would be very abnormal.

SOIL MOISTURE

Soil moisture in the top five feet is normally considered the area that plants such as corn, soybeans, forages and wheat are able to utilize. It is therefore very important that we look at the amount of soil moisture available in these areas and when the recharge occurs and how much and when it is used by these plants. At the Southwest Experiment Station we have been looking at the soil moisture under continuous corn since 1960. We have found that the low point of stored soil moisture occurs on approximately September 1. This is at the end of the growing season. A silty clay loam soil such as is found in the southern area of the state most commonly will hold in the neighborhood of approximately 10 inches. The average moisture left on September 1 has been approximately 3 inches available and by the end of October or early November the soil moisture recharge has been approximately to 6 inches. After the thaw in the spring, the soil moisture again tends to move up until June 1, when the crop starts using more moisture than it is receiving. This water use is from both evaporation and transpiration. During the months of July and August the normal use by the corn and soybeans is approximately twice that of normal precipitation is so it is very important that we have a subsoil moisture reserve for the corn, soybeans and other plants during July and August.

The subsoil moisture the last three falls has been depleted on September 1 to less than 1 inch of soil moisture available in the top 5 feet. In the spring of 1975 we had an exceedingly large recharge from rainfall in April thus we were back up to normal soil moisture reserves at planting time and a relatively good crop was harvested even though we ran into a droughty period in July and August. In 1976 however there was very little recharge of our stored soil moisture. This resulted in the lowest stored soil moisture that we have recorded in the last 15 years amounting to only slightly over 4 inches and the rainfall was short during the season resulting in a very disasterous corn yield. This fall we have had no recharge to freeze up and so are in approximately the same situation that we were in the fall of 1975, and so much will depend upon the spring of 1977 for soil water reserves. In 1976 the area in Minnesota that is at a very low soil moisture reserve has greatly expanded however and encompasses perhaps the majority of the corn growing area in Minnesota.

TILLAGE

The subject of tillage comes up not only as a matter of water conservation but also it has a number of other purposes. The use of tillage to manipulate climatic variables under a mid-continental slimate, where the rainfall and temperatures can change rather drammatically in sudden swings should not be forgotten. Tillage is a manipulation to effect the establishment of crops that we want to plant and can be and should be divided into various areas so that the effect of the tillage decision can be appraised.

1. Seed Bed. The use of tillage is to prepare a convenient place for the seed to be placed to maximize its early germination and growth.

2. Weeds. Primary tillage is used to help control perennial weeds, uproot annuals, and destroy seeds along with putting the weed seeds in a poor seed bed. The value of tillage for weed control, even with effective herbicides cannot be overlooked with wide variability in rainfall.

3. Water Relations. In a dry year the maximum retention of water is most important. In thinking about the water relations, I would like to divide the soil into 2 parts, the surface or top 10 to 12 inches which can also be considered the tillage area and the area below 12 inches to approximately 60 inches, which for our purposes will be called the subsoil.

   The surface soil moisture is a transient type soil moisture in that it is readily lost by evaporation, it is lost by transpiration through plants during the growing season or it may move into the subsoil. The water in this surface 10 to 12 inches is usually in a very non-stable condition, and may be rapidly lost.

   The sub-soil moisture, however, between wilting point and field capacity, is very stable and is lost only through transpiration of the plants during the growing season after their roots have extended into this area. Thus it is usually lost only during the hot, dry periods of the season, normally late June, July and August. I believe we could, therefore think of the surfact soil moisture as something like a checking account where there has to be a continuous flow in because normally there is quite a draw out of it, at least this tends to be true in my case. The sub-soil water, however, can be thought of as a savings account where the water is put in and is only used during a period of stress and when the crops are actively needing it.

   The use of tillage for water storage should be such that during fall and early spring, it has the primary purpose of mosing water into the sub-soil or the savings account, so that it can be used during the maximum growth period of the crops in June, July and August. For timely planting tillage must also be such that the surface will dry out rather rapidly in the spring so that it will warm up and be workable without compaction.

4. Air. Root growth without air is impossible. The uptake and availability of various nutrients are also dependent on favorable aeration. Without tillage there may be zones of compaction developed which prevents the free inter-change of air and water and thus restricts root growth and nutrient availability.

5. Temperature. Being on the northern edge of the corn belt due to the short growing season and cool temperatures in the spring and fall, every day is critical. Earlier data has shown that rough fall tillage tillage compared to leaving a smooth surface results in a warmer soil temperature to a depth of 5 feet during early spring. In addition tillage will remove mulch which also prevents the warming of the soil.

6. Fertilizer Placement. Movement of phosphorus and potassium in particular is very slow without mechanical mixing and this is necessary at intervals to provide a larger area for optimum root growth and nutrient uptake.

7. Insect and Disease Control. The debris of many past crops harbors insects and diseases that are somewhat controlled by burying and decomposition.

8. Timeliness. Many studies on timeliness in the northern and western part of the corn belt indicate that this is perhaps one of the most critical aspects of bringing together all of the parts of the system for maximum corn production. In looking at the number of days available to get crops in on time, we have approximately 10 days on the average to plant all of our corn and beans. Therefore we need to have primary tillage that will allow for early and rapid planting of our corn and beans at the optimum time. This means that the surface soil must be drained rapidly. There should not be a great deal of mulch on the surface to prevent this early drying and yet it should form an adequate seed bed without a great deal of additional tillage.

In conclusion we need to look at long term normal weather which is only the average of a number of extremes and not have "historesis" to remember only what happened last spring. It would appear from all of the work and studies that the ideal tillage following a dry season would be rough, with perhaps a greater than normal amount of debris left to catch snow and to prevent wind erosion. This rough tillage would also allow maximum water movement into the subsoil and relatively rapid drying in case there should be above normal moisture in the spring at planting time. In addition to this rough tillage even with a relatively small amount of debris left is relatively stable and not subject to wind erosion.

SOIL MOISTURE AND TILLAGE METHODS IN SOUTHERN MINNESOTA

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Crop production in Minnesota has become increasingly difficult and less prosperous as the drought conditions have become more severe. Therefore, many questions arise as to how can we conserve and utilize to a greater extent what soil moisture we have. To cover these aspects in greater detail I would like to address myself more specifically to crop rotations and tillage. How do rotations and tillage affect crop production?

CROP ROTATIONS

Crop rotations have been studied for many generations. Early rotations leaned heavily toward legumes and grass for either grazing or hay production. But with fewer livestock farms and more large crop farms, simple crop sequences such as corn-soybeans and even monocultures like continuous corn have become more popular.

University of Wisconsin research conducted for eight years at Lancaster showed corn yields following soybeans and receiving no N fertilizer equal to or greater than continuous corn receiving up to 300 lb N/A. Corn yields following soybeans averaged 133.6 bu/A while corn following corn averaged 113.2 bu/A when both were fertilized with 150 lb N/A -- a 20.4 bushel decrease or a 163 bushel/acre decrease over 8 years.

Various reports across southern Minnesota indicate anywhere from 10 to 40 bushel/A advantages for corn following soybeans or wheat to continuous corn in 1976. Results from a rotation-N study conducted at the Southern Experiment Station in 1975 and 1976 show significant yield depressions for continuous corn (Table 1). Continuous corn yields averaged approximately 30 and 50 bushels/A lower compared to corn following soybeans, wheat or wheat + alfalfa in 1975 and 1976, respectively.

Table 1. Influence of preceding crop and N rate on corn yields at Waseca in 1975 and 1976.

Crop Sequence		Year			
		1975		1976	
	N rate(lb/A):	0	200	0	200
		----- bu/A			------
Cont. Corn		56	83	35	50
Corn following Corn		84	111	87	105
" " Wheat		83	106	86	101
" " " + Alfalfa[1/]		96	108	88	102

1/ Alfalfa was interseeded with wheat. Wheat plus alfalfa growth was plowed down in October.

WHY do we find these marked yield reductions? We don't exactly know, but we can offer some speculation as follows:

1) soil moisture
2) fallow affect
3) microbial activity
4) nutrient availability
5) tilth
6) compaction
7) rhizosphere affect
   -(organic acids, toxins, etc.)
8) rootworms
9) nematodes

Soil moisture differences remaining between last year's corn and wheat or soybeans may have played a major role; especially in Minnesota where both years were dry. Late season use of soil moisture is greater with corn; consequently, perhaps less water is left for the following crop. Microbial activity and nutrient availability are both affected by soil moisture. Soil tilth is generally better and compaction less after soybeans or small grains. Perhaps some phytotoxic effects linger from the decomposition of corn roots; especially in a dry year. Rootworm larvae not controlled by insecticides along with sporadic cases of nematodes may also enter into the picture.

Based on results from the past few years, recommendations for future crop production would include more crop sequences (corn-soybean, corn-wheat, etc.) and less monoculture systems (continuous corn).

TILLAGE METHODS

Conservation tillage methods generally involve very little tillage and result in conserved time, labor, fuel as well as soil moisture in the soil surface. They have drawn much attention lately but have not reached wide-scale acceptance yet. However, if crop yields obtained with these tillage systems are comparable to those obtained with conventional systems, the conservation systems should catch on because of the above mentioned factors.

An experiment is presently being conducted at Waseca to evaluate some of these conservation methods on corn production. The soil type is a poorly drained Webster clay loam and corn is grown continuously. Results obtained in both 1975 and 1976 indicate that yields with till-planting were equal to or slightly above those found with conventional moldboard tillage (Table 2). Continuous fall chiseling and no tillage resulted in lowest yields.

Table 2. Effect of conservation tillage practices on continuous corn production at Waseca in 1975 and 1976.

Tillage Treatments	Population 1975	Population 1976	Yield 1975	Yield 1976	Yield Avg.
	ppa x 1000		------	bu/A	------
No tillage (flute coult.)	22.1	21.7	73.0	76.3	74.6
Fall plow, f. cult.	25.6	23.3	97.9	93.3	95.6
Fall chisel, "	22.4	23.3	69.4	82.0	75.7
Till plant, ridge	25.5	17.5	104.8	92.6	98.7
Till plant, no ridge	24.8	18.2	110.9	92.0	101.4
Significance:	*	**	**	*	
BLSD(.05):	1.8	1.9	23.3	14.7	

In both years, which were very dry following planting, plant population was affected significantly. The seed germination zone apparently dried out with the no tillage and fall chisel systems in 1975. The resulting stand was reduced and emergence date was not uniform. Some plants emerged 3 weeks after the first ones. The same situation occurred in the till-planted plots in 1976 when the soil dried down from the top to the seed which was planted about 1½" deep. However, even with these low populations, yields were not reduced below the conventional tillage systems under the dry conditions.

Preparation of a ridge of soil along the corn row at the last cultivation is thought to be necessary for till-plant systems on poorly drained, cold Webster soils. However, little difference in yield was found in 1975 and 1976 between planting on these ridges and random planting with no ridges.

An experiment was conducted in 1976 to determine if ridging about the soybean row in early July in preparation for till-planting of corn in 1977 would affect soybean production. Results shown in Table 3 show a significant soybean yield reduction with ridging; primarily because of lowered pod height and increased harvest losses.

Table 3. Effect of ridging on soybean production at Waseca in 1976.

Treatment	Pod Height	Plant Height	Yield	Harvest Loss
	---- inches	----	----- bu/A	-----
No ridge	4.0	28.7	36.7	1.8
Ridge	2.5	26.1	33.7	3.9
Significance:	*	+	+	NS

Another experiment was initiated in 1973 to evaluate 12 tillage systems in a corn-soybean sequence on a Webster clay loam at Waseca. Six of the systems were continuous and did not vary with the crop; whereas, the other six did vary with the crop each year (Table 4). Secondary tillage included either field cultivation and/or disking.

Table 4. Effect of tillage systems in a corn-soybean sequence on corn and soybean yields at Waseca.

Tillage System[1/]	Yield: Corn 1974-76 Avg.	Yield: Soybean 1973-76 Avg.
	bu/A	bu/A
NONE	104	36
FP[2/], FP[3/]	127	43
FC , FP	130	44
SC , FP	118	42
Z , FP	128	43
SP , SP	113	43
FC , FC	122	41
Z , FC	120	42
SC , SC	119	41
SD , SD	130	43
FFC, FC	130	43
FP , FD	127	43
Significance:	**	**
BLSD(.05):	13	3

1/ Z=zero, FP=fall plow, SP=spr. plow, FC=fall chisel, SC=spr. chisel, FD=fall disk, SD=spr. disk, FFC=fall field cult.
2/ Tillage treatment for corn following soybeans.
3/ " " " soybeans " corn.

Corn yields were highest with the fall chisel, fall field cultivate and spring disk primary tillage treatments on the soybean ground (Table 4). Lowest yields followed no tillage (planted with fluted coulter) with intermediate to low yields following spring moldboard or chisel plowing. In essence, highest corn yields can be obtained with very little tillage following soybeans.

Four-year average soybean yields were identical for all treatments except no tillage. Both perennial and annual weeds became a problem the second year following no tillage and have persisted. It appears, therefore, that soybeans don't need the finely-tilled seedbed often thought necessary for top yields. As an example, spring plowing has left a very rough, cloddy seedbed, yet combine-harvested yields have consistently been high. Perhaps soybeans could follow cornstalks which are left untouched throughout the winter and then disked only once or twice prior to planting.

This system would have the advantage of trapping extra winter precipitation along with reducing evaporation due to both fall and spring tillage.

Spring soil moistures were taken to a depth of four feet in this study to reflect the moisture conditions associated with four tillage treatments (Table 5). Results showed consistently higher soil moisture following soybeans than corn. In addition, soil moisture was highest in the no tillage and spring disk treatments (before disking). Differences between moldboard and chisel plowing were insignificant.

Table 5. Influence of tillage method on spring soil moisture in a corn-soybean sequence at Waseca in 1976.

Tillage method	Preceding crop: Corn	Preceding crop: Soybeans
	----- $\%H_2O$[1/] ------	
No tillage	27.5	31.3
Fall plow	25.3	29.3
Fall chisel	26.7	28.0
Spring disk	27.3	30.4
Significance:	+	*
BLSD(.10):	1.5	1.8

1/ Average moisture (weight basis) in a 0-4' profile on April 15.

CONCLUSION

How can we best conserve and utilize our soil moisture for crop production? Perhaps some of the following suggestions will help as farmers determine their future cropping plans.

1) Use primary tillage operations that leave the soil surface rough along with some residue on the surface.

2) Eliminate primary tillage and substitute till-planting where management is good and crop permits.

3) Minimize secondary tillage operations and stay shallow. With the newer planters we don't need table-top-smooth field conditions. The planter will provide that in the seed: soil contact zone.

4) Use crop rotations. Change from continuous corn to various corn, soybean, wheat or other crop combinations. Economics of each crop has to be considered.

5) Reduce compaction. Avoid, if possible, tilling of fields when conditions are not fit. Minnesota results don't show any advantage for planting corn April 15 over April 25.

6) Use PROPER planting date.

7) Use PROPER planting depth.

8) Use good weed control. Weeds compete for soil moisture.

9) Sufficient fertilizer is needed to adequately supply the plants' needs.

RESEARCH TODAY FOR TOMORROW - LIME AND FERTILIZERS

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UNIVERSITY OF MINNESOTA

In spite of the temporary setback because of drought in Minnesota, crop production from our 18 million harvested acres of good soils is in for "better times" because of the rapidly increasing demand for food on a world-wide basis. The population explosion and concern for energy supplies are key elements in turning our nation's attention back towards agriculture and it is appropriate that this be a major focus of national interest in this our bicentennial year! Agriculture for too long has been taken for granted. We are the world's most prosperous nation because of agriculture. Our agricultural exports are increasing and must reach "boom" levels very quickly if the world population, which will double in less than 25 years, is to be fed. How will we feed each day over 7 billion people? How can we be certain that there will be enough food to go around? Research and education must be given major attention with an infusion of the needed dollars from legislative, commodity and industry groups if we are to succeed. Current staffing in our agricultural production departments is inadequate, laboratory and classroom facilities must be expanded, technical equipment and supply budgets increased, and support for expensive field researches greatly expanded!

That research and education in the past have been effective is evident from a fifty percent increase in field crop production in the U.S.A. since the late 40's and that the acreage harvested per consumer has been nearly cut in half - to about 5 acres per person. Note that these 5 acres consist of almost 3 acres of pasture, 1/2 acre in woodland, 1/4 acre in farmsteads, etc., and 1-3/4 acres in crops for <u>market</u>, of which a half acre is for crops for <u>export</u>. The University of <u>Illinois</u> quotes an estimate (from the National <u>Research</u> Council) that attributes roughly 80% of the increase in production to research and technology from the Land-Grant Universities and the USDA. But increases now badly needed are leveling off and production breakthroughs must come from future researches that must be strongly supported. We are concerned about drought and what lies ahead for weather in the future, and also for an expansion in irrigation acreages, about adequate energy supplies to run our tractors and other mechanical equipment, and also to produce the fertilizers and chemicals needed for sustained and profitable production. I should note here that total U.S. energy demand is projected to increase by 42 percent between 1976 and 1990. We are also concerned about the retention of prime agricultural lands for food and fiber production, and about tillage and other management procedures that will decrease erosion and moderate the potential for "non-point" sources of pollution in our streams and reservoirs. And of course we must be concerned about improvements in crop varieties which are designed to reduce the production hazards of climate and disease, that can be efficiently produced, that are safe, of high nutritional quality and inexpensive in the market place.

RESEARCH PRIORITIES

So what must our research "imperatives" be? A substantial amount of time is now being expended by agricultural researchers, farmers, consumers, and our political leaders in an assessment of our research priorities for future years. An interim committee report on agricultural research and development has just been released by the ninety-fourth congress (June 1976). It summarizes the concensus from eleven hearings on the subject held throughout the country, which together with eight background papers has surfaced the research priorities that it is believed we must give the most attention to in the immediate future.

To remove recognized research gaps, six areas of agricultural research were identified. Most of these are in the areas of specialization represented by those participating in this conference, namely the plant and soil sciences.

1. Research on basic biological processes: photosynthesis, nitrogen fixation (such as with soybeans), and genetic improvement. Very complex studies are needed. This is "basic" or "fundamental" research.

2. Research on energy-conserving and environmentally sound agricultural practices. The inter-relationships among food, energy and the environment are inseparable and must be given careful attention.

3. Research on human nutrition.

4. Research on intensive, high-yielding systems of agriculture and other types of research which will benefit small scale farm operations.

5. Research on climate and weather prediction and modification and information systems. More reliable research information on cloud seedings, both the potential for benefits and hazards comes in here.

6. A complete inventory of soil and water resources. This is required to provide a data base for other research and policymaking. The use of satellites with remote sensors for speeding up land use information collections can be helpful.

The above research priorities were also supported in the "Farm and Food Policy, 1977, report of the Senate Committee on Agriculture and Forestry", (September 15, 1976). It was noted that the U.S. agricultural research system as a joint Federal-State effort with national and international components has been remarkably successful, but that scientific breakthroughs to increase food production have become increasingly difficult. And resource allocations have unfortunately been declining with budgets for fiscal 1977 less than 90 percent of those in 1972, five years ago.

To categorize further and also illustrate how our Minnesota program is relating to the above research priorities, may I reference a remarkable document entitled: "Crop Productivity-Research Imperatives" which resulted from a conference of working scientists meeting in 1975 at Horbon Springs, Michigan. The researchers not only carefully considered those factors they believed to be limiting crop productivity but also identified those research imperatives deemed essential to provide production breakthroughs in the years ahead.

To quote: "Enhancement of crop productivity is inseparable from the resource base. The goal of agriculture should be to increase and maintain at high levels the yield of highly nutritious food per (acre) of land, per increment of water, per calorie of energy input, per unit of time, while maintaining a high quality environment."

"Good farm land, water for irrigation, and fossil fuel energy are in limited supply and we must not only protect these resources but develop research programs that improve the efficiency of utilization of these resources."

You have a competent and hardworking research and extension staff at your University of Minnesota and all are working vigorously to move forward the frontiers of knowledge in the several categories which follow. This will be of particular benefit to the good people of Minnesota but also to the many peoples world-wide who must have food to live!

SOIL RESOURCE INVENTORY SURVEYS:

Soil resource inventory surveys in Minnesota must be accelerated to guide land use decision-making and also research on conservation practices. The legislature is supporting an accelerated soils survey program which is jointly supported by State-Federal and County funds and a legislative interim committee has recommended that all of the counties in the State be completely inventoried largely within the next ten years or so. This will include wet and peat-lands surveys since some of the peats may be used directly to supply some of our energy needs. These will include interpretive information (how they may best be used) to aid those making management decisions. It is important that our prime agricultural soils be reserved for needed crop production. In this connection, may I specifically mention our Soil Atlas project which is nearing completion and is illustrated in the Institute's booth on the exhibit floor. Generalized and interpretive groupings of soils are shown on maps scaled to Geological Survey sheets so that topographic and other features of the Minnesota landscape may be superimposed to aid the user.

SOIL AND CROP MANAGEMENT:

Integrated and predictive farm management schemes on a whole-farm basis using sophisticated statistical "modelling" schemes are under study. These include climatic probabilities, crop varieties, rotations, cultivation (minimum tillage), fertilizers and pesticides, harvesting practices and others. Multidisciplinary research teams are combining their talents on these studies, designed to optimize farm enterprise combinations.

MINIMUM TILLAGE:

Minimum tillage, no-till and reduced tillage researches for specific crops both to conserve energy, decrease compaction, increase infiltration of rainwater and snow-melt, and reduce erosion are continuing. Cognizance must be taken of the potential towards pest problems (weeds and insects) from a "mulch-tillage" program and the trade-offs that often require higher pesticidal chemical usages as we strive to maintain a safe and clean environment.

SOIL EROSION:

Soil erosion control via conservation practices is not only for the purpose of protecting our vital land resources but also to moderate "non-point" pollution coming largely from erosion debris as sediment in our water supplies. Losses of topsoil in the U.S. are estimated at 3.6 billion metric tons annually, and this after some 40 years of educational programs by the Soil Conservation and Agricultural Extension Services of the USDA and Land-Grant University system.

BIOMASS (CROP RESIDUE) HARVEST?

Biomass studies are concerned with the amount of crop residue that can be safely harvested and utilized for energy conversion without harm to the physical structure and water relationships in soils.

IRRIGATION:

Irrigation studies largely confined to the outwash sands of central Minnesota, are designed to not only eliminate the uncertainties of drought, but towards increasing the efficiency of water usage by crops which currently is only 30 to 40 percent, a far too low figure. Controlled and timed irrigations based on measured water stress in the soil profile, so-called trickle irrigation, and other water conserving procedures are under study.

CLIMATE-MICROCLIMATE:

Weather (precipitation, temperature, solar radiation, wind) is perhaps our most important variable influencing crop productivity. Studies on the climate of Minnesota are receiving major attention. Precipitation and other weather patterns for Minnesota farmlands are being elaborated based on long-term records and predictive probabilities calculated as a guide to management decision-making. For example, what are the probabilities that the three-year drought in Minnesota will be broken next year? Our climatologists are somewhat more optimistic than was true a year ago but they point out that the soil mantle is dry and that it will take an unusual amount of precipitation in the Spring to restore soil moisture to levels which are adequate for long-season crops.

In microclimate researches at Morris, Minnesota it was found that intercropping corn with soybeans (2 rows of corn + 20 rows of beans) changed the microclimate (temperature and moisture) in the root zone and increased yield by 25 percent, which is indicative of the importance of these kinds of studies. We must understand more of what is happening in the vital root zone of crop plants if we are to meet needed production goals!

FERTILIZER USE EFFICIENCY AND NITROGEN FIXATION:

Improved efficiency in the utilization of nutrients is another area of vital importance in today's agriculture if we are to conserve both energy and resources. Nitrogen will be in most demand and its use is projected to increase by four times (to 160 x 10^6 metric tons) by the year 2000. Less than 50 percent of the fertilizer nitrogen applied is taken up by non-legume crops and even less of the phosphorus and potassium fertilizers.

Eighty-seven percent of the energy required to produce fertilizers is used in the production of fertilizer nitrogen and this is roughly 2 percent of the domestic natural gas consumption. A 50 percent increase in the efficiency of use would save billions of dollars annually.

This area also is receiving major attention in the crops and soils researches at the University. It involves the selection and improvement of alfalfa, soybeans and other leguminous plants, not only for improved utilization of soil nutrients but also for improved nitrogen fixation relationships by the root-nodule rhizobia (bacteria).

Mycorrhizal fungi have also been found to improve the utilization of nutrients in the root zone. Some evidence is surfacing that it may be possible to develop nitrogen fixing microorganisms that will live in the vicinity of the roots of non-legume plants and supply nitrogen for their use. Losses of nitrogen from the soil-plant system may be moderated by nitrification inhibitors (like N-Serve) which may decrease leaching or denitrification losses. Extensive and complex studies are underway to develop better methods for the recycling of organic and other wastes (like sewage wastes) on agricultural lands with the enhanced utilization of plant nutrients. Foliar applications of nutrients, particularly on soybeans and small grain, are being tested for yield improvements but also to determine if a higher percentage of the nutrients applied can be taken up by the plant.

THE IMPORTANCE OF AGRICULTURAL LIME:

In conclusion, may I illustrate how our many researches on aglime, which should be applied to acid soils, can increase the efficiency of utilization of other fertilizer nutrients.

Lime is undoubtedly one of our more important soil amendments; it supplies our most neglected plant nutrient, (calcium and magnesium) and it is also relatively inexpensive. Research conducted nation-wide and also in Minnesota has proved that lime, where it is needed, is essential if we are to optimize yields on a sustained basis and increase the availability of many essential soil nutrients including those from applied fertilizers. It can help moderate the build-up of some nutrients to toxic levels. We routinely provide a lime requirement recommendation when we test your soils and our bulletins and fact sheets document the research results that support our recommendations. And yet in Minnesota where we have substantial acreages of acid soils and our estimates call for the use of over three million tons, we are using less than a half million tons, approximately 14 percent of that needed. The lime industry of Minnesota is providing by and large a high quality product. It is readily available when you need it and it should be used.

Dr. Leo Walsh from Wisconsin in a short-course presentation last year pointed out that soil acidity is becoming a more serious problem throughout the north central region because of a reduced emphasis on alfalfa and other forages that require adequately limed soils for establishment of stands and the increasing use of ammonia. Ammonium-type nitrogen fertilizers are acid forming in the soil (by microbial oxidations) and it takes about five pounds of aglime to neutralize the residual acidity per pound of nitrogen applied. For alfalfa, the pH of the topsoil should be 6.5 or above for acceptable yields. Other crops vary in their response to lime but optimum yields cannot be obtained unless aglime is applied at recommended rates to acid soils. Relative responsiveness to lime is alfalfa first, then in order, corn, oats and red clover. This is shown in the following slides taken from Dr. Walsh's presentation last year. For reference, refer to the Proceedings of the Combined Soils, Fertilizer and Agricultural Pesticides Short Course, Minneapolis Auditorium, December 8-10, 1975, pp. 25-34.

That adequate and needed amounts are not being used is likely because it takes time for the added aglime to neutralize soil acidity and the visual effects are not evident. Minnesota's dolomitic limestones supply both calcium and magnesium, two essential plant nutrients. These nutrients, however, are not the first limiting growth factors in acid soils and consequently must be combined with adequate fertilizer applications for growth effects to become noticeable.

Some have suggested that the ratio of calcium to magnesium in soils is important and that it is necessary to balance the magnesium with calcitic limestone or gypsum. We have no evidence to indicate that magnesium is harmful in any soil treated with dolomitic limestone and calcium is adequately available in all soils with a pH of 6.0 or above. Magnesium is known to be deficient in some of our acid sandy soils in the Anoka sandplain area which have grown potatoes for many years under irrigation and have been heavily fertilized with potassium and ammonium fertilizers.

Dr. Walsh also presented data showing that various calcium:magnesium ratios in the soil did not influence the yield of alfalfa. The dolomitic limestone available in Minnesota should be entirely adequate for use in correcting soil acidity and our only problem is that not nearly enough of it is being used to assure optimum production of crops and adequate supplies of food.

SUMMARY

And a final quotation from "Research Imperatives" : "Weather is the most determinant factor in food crop productivity. Production stability at high levels can be achieved only as environmental stresses are minimized. Decreased vulnerability of crops to weather uncertainties from season to season and to potential hazards of changing climatic patterns must be sought through genetic improvement, soil, water and fertilizer management, chemical regulators and cropping systems that efficiently combine space and time."

HOW ABOUT IRRIGATING WESTERN MINNESOTA?

by Edwin H. Ross
Senior Hydrologist
Minnesota Department of Health

Introduction

Consideration of irrigation for Minnesota, expecially during drought years, must take into account the total water resource picture of Minnesota. The potential for irrigation of agricultural crops in Minnesota is related not only to hydrology and geology of Minnesota, but also consideration must be given to economic, political, legal and environmental realities.

Minnesota-Water Rich or Water Poor?

We should not necessarily believe that we are water rich in Minnesota because of our numerous lakes. The majority of these lakes lose more to evaporation than they gain from precipitation in a year's time (Figure 1). Minnesota is a headwater state (Figure 2). We have no major streams beginning in other states that flow through Minnesota. With the exception of our boundary streams, rivers and lakes, Minnesota does not receive water in appreciable amounts from beyond her boundaries. Twelve states in the continental United States receive less annual precipitation than Minnesota. Six of these twelve, like Minnesota, receive only minor amounts of stream flow from beyond their state boundaries. In only one of these six, Nevada, do major streams receive less runoff than in Minnesota. With the exception of the northeastern part of the State and the Rainy River, most surplus water of Minnesota is in the Mississippi River below the Twin Cities (Figure 3).

In future years there is some doubt that the great reservoir system in the headwaters of the Mississippi River will provide sufficient water for the Twin City area. The Minnesota Legislature of 1961 authorized the Department of Natural Resources to propose a plan for the operation of the Upper Mississippi Reservoirs which would, in effect, supplement low stream flows at St. Paul. Preliminary calculations submitted for this study were based on stream flow and gage height records of the Mississippi River and the Upper Mississippi River Reservoir. The Winnibigoshish Reservoir was found to be the most desirable reservoir for storage of water for supplementing stream flow from all points of view. It was found that 1800 cfs was the maximum amount that would maintain stream flow for any period of time. 20 to 25 days are required for water to travel from Winnibigoshish Reservoir to St. Paul. Low flows at St. Paul can be anticipated but not accurately predicted.

Using a previous 10-day average flow at St. Paul as a basis for regulating the discharge of Winnibigoshish Reservoir to maintain a flow of 1800 cfs at St. Paul, it was found that on August 10-20 of 1936 the flow at St. Paul would have diminished to 832 cfs, at which time the discharge from Winnibigoshish would have been increased from 200 cfs (flowing at the time) to about 1080 cfs (maximum permissible discharge) which would arrive at St. Paul September 10, 1936, to increase the flow to 2380 cfs from September 10-20, 1936. In other words, reservoir regulation can be based only upon weather predictions or stream flow predictions, both of which are not reliable for periods of more than a few days in advance. Stream flow at St. Paul, as shown by the above hypothetical regulation using the 1930 drought figure, would have resulted in a stream flow deficiency of about 950 cfs in one series of days and wasting water to the extent of 700 cfs on a succeeding series of days.

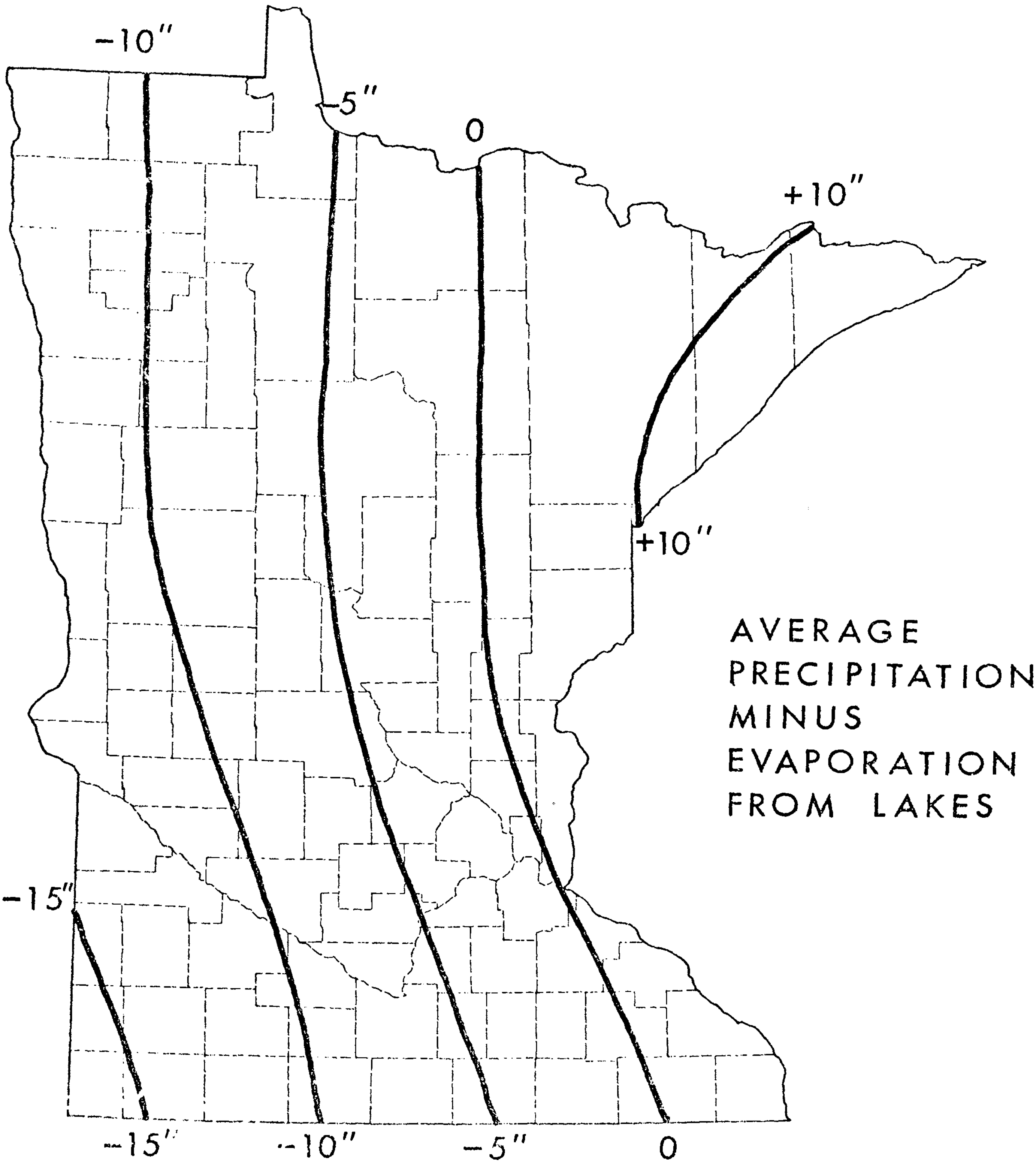
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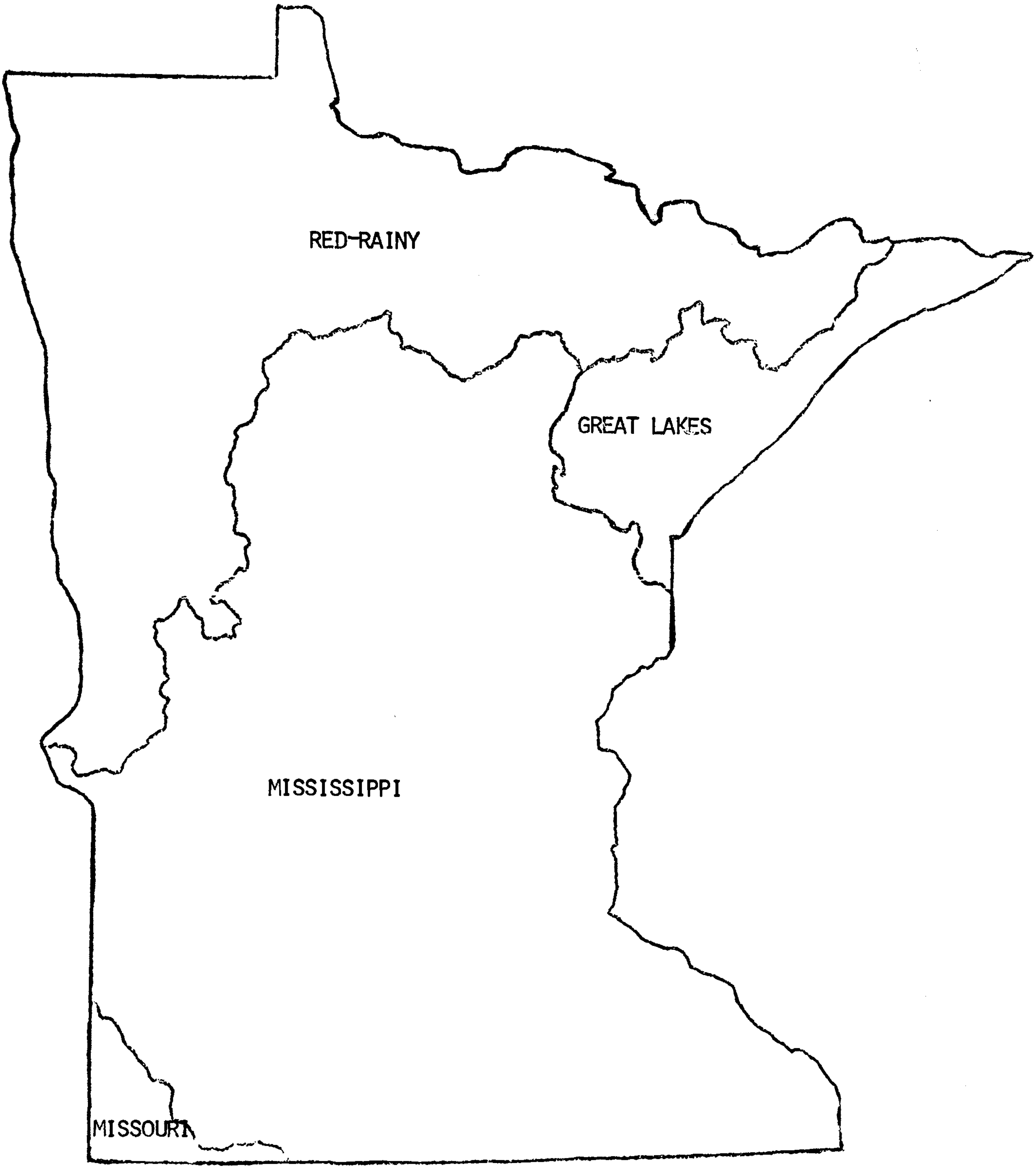
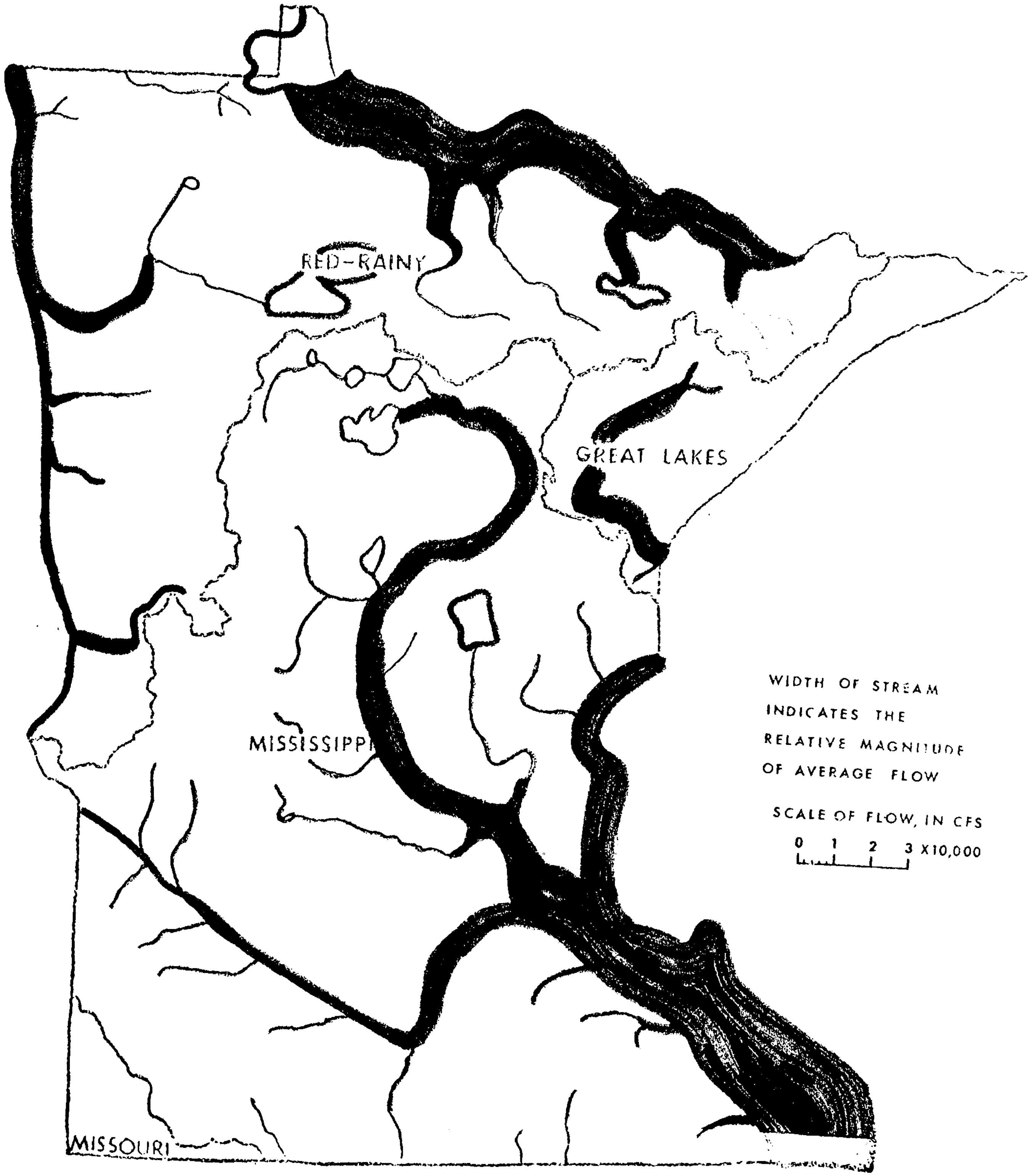
Figure 1



MINNESOTA - MAJOR RIVER BASINS

Figure 2



FLOW OF MINNESOTA STREAMS

Figure 3

More recent projections of water requirements for electrical energy production indicate a very large amount will be evaporated for cooling purposes. The present capacity for power production of NSP is 5500 megawatts. At a doubling rate of eight years, this means they will need 7000 megawatts in 1980. Representatives of NSP believe that demand for electricity may decline to an annual increase of 6% by 1985. This is equivalent to a doubling in energy demand every twelve years. The following table would indicate NSP's demand in future years:

Year	Megawatts	Water Consumed	Water Demand
1972	3500	105	158
1980	7000	210	316
1990	14000	420	632
2002	28000	840	1264
2014	56000	1680	2528
2026	112000	3360	5056
2038	224000	6780	10112

The water consumed is based on a figure of 30 cfs for evaporation and 15 cfs for blowdown per 1000 megawatts produced by nuclear power.

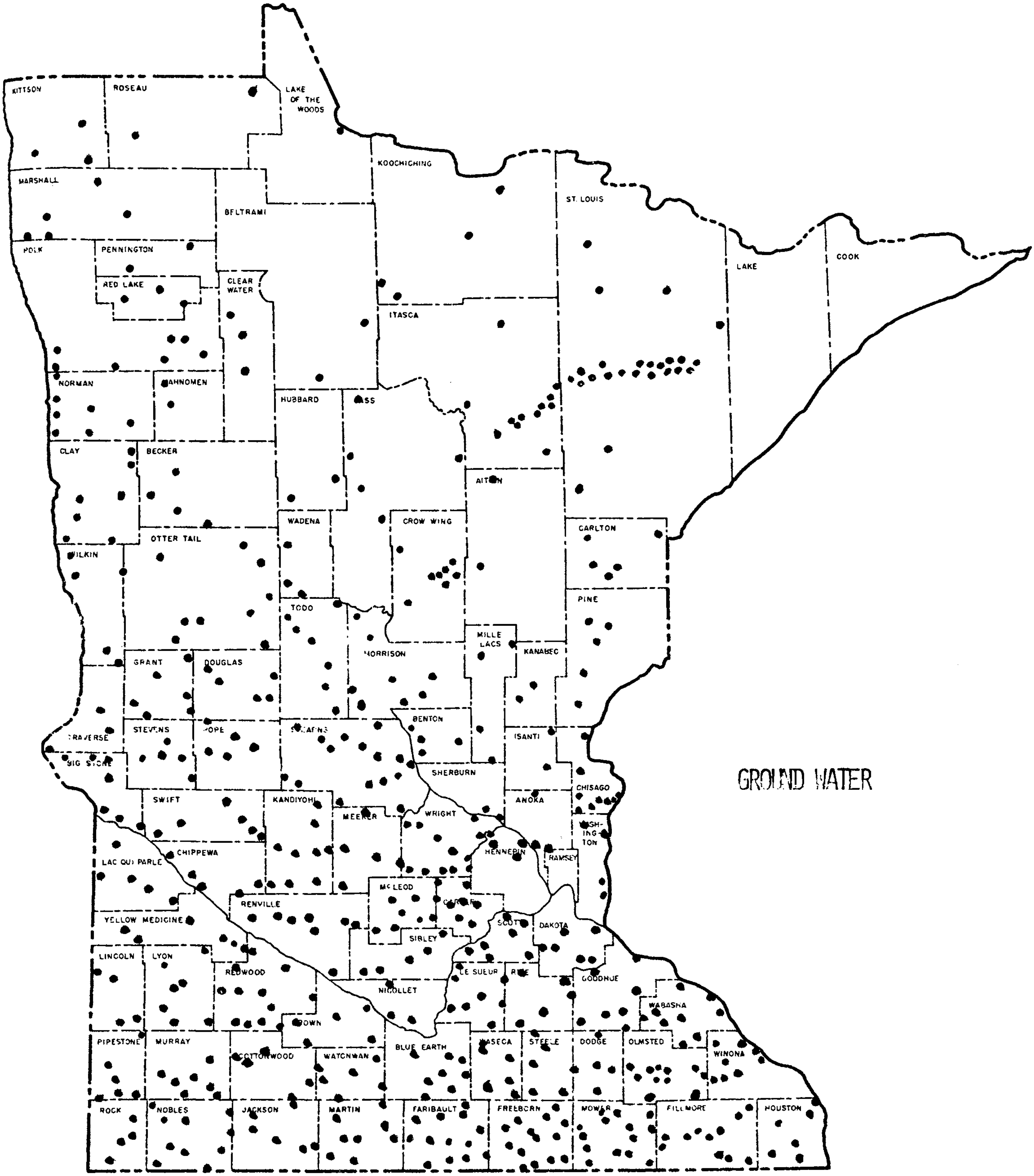
It may be interesting to compare the consumptive use of water for power production in future years with the minimum and average flow of the Mississippi River at St. Paul. The minimum flow recorded is 632 cfs. The average flow is 9853 cfs. This is an indication that the present surface water supplies in the Metropolitan Area will not be adequate and more reliance must be placed on the ground water reservoir. Ground water may not furnish all our needs in Minnesota, but it will continue to be the source of water for most of our citizens, both in municipalities and on the farm.

The base flow of the Mississippi River during drought conditions is maintained from ground water entering from the many glacial outwash sand plains of the watershed. These are the areas being developed with well water for agricultural irrigation projects. An accurate assessment of the impact on the Twin City water supply has not been determined. A mathematical model should be developed to show what effects irrigation use of sand plain water will have on the flows of the Mississippi River during drought conditions.

Presently the U. S. Corps of Engineers is releasing water from the headwater reservoirs to maintain navigation flows in the Mississippi River. To demonstrate the contribution that ground water provides to the river, one may compare the difference in river flow prior to the vegetation killing frost this fall. Before the frost kill, the Mississippi River flow was about 900 cfs. After the frost the flow increased to 1800 cfs, reflecting the decreased demands of vegetation for water. Should full development of outwash plains take place coincidentally with a drought condition and increased use of water for power plant cooling, it is likely that all water in the Mississippi could be fully consumed.

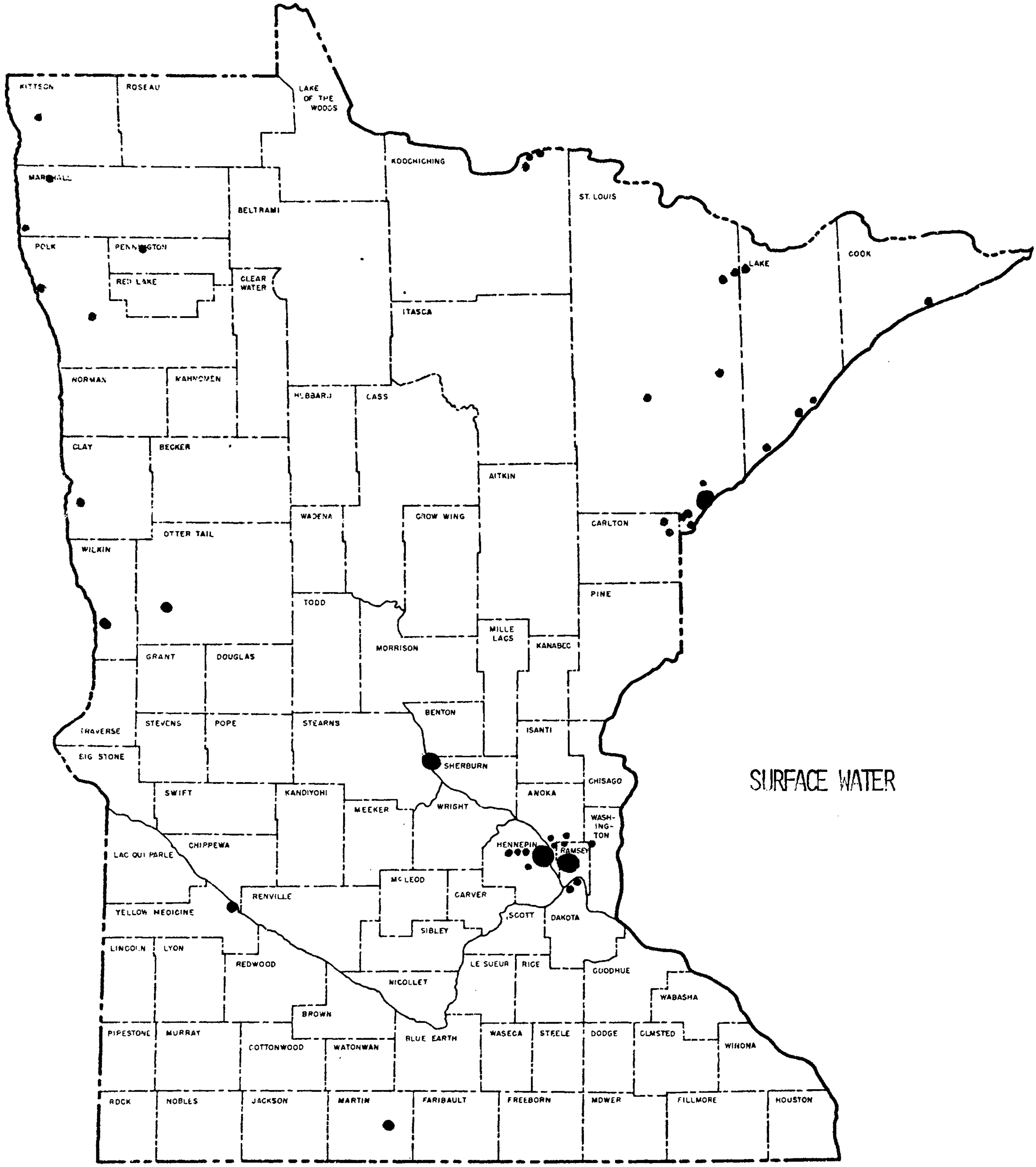
Public Water Supplies in Minnesota

In excess of 90% of the communities in Minnesota are dependent upon ground water for municipal use (compare Figure 4 with Figure 5). Ground water provides a high-quality water requiring little or no treatment for millions of people in the State, both in cities and on farms. Under most circumstances, the ground water system



PUBLIC WATER SUPPLIES

Figure 4



PUBLIC WATER SUPPLIES

Figure 5

provides its own filtering and purification system as well as a vast reservoir system. It also provides much of the base flow to many of Minnesota's streams during drought periods. Over 2,500,000, or 66% of the State's population, are served by ground water. The following table will give a comparison of water sources for the population of the State (Table 1).

Geology

The geology of Minnesota, in consideration of the ground water possibilities, has generally been classified into four regions. In the northeastern portion of the State, the water-bearing formations consist primarily of pre-Cambrian granitic rocks, greenstone, slate, basalt, and the iron formation, all which outcrop at the surface or are covered with a very thin mantle of glacial drift material. As a result, the availability of ground water in this region is very negligible. In the central portion of the State, a relatively thick mantle of sandy and clay glacial drift material covers pre-Cambrian granitic rocks, slate and iron formation and, in some parts, Cretaceous shales, sandstones and limestones. In northwestern Minnesota the bedrock is not well mapped because it is covered by a relatively thick mantle of glacial drift. The amount of water available in this material is not considered to be in great abundance; however, the amount of drilling that has been done in these areas is not of great significance when trying to determine the total amount of available water. The U. S. Geological Survey has done some drilling for their watershed studies in recent years. In the southwestern region of the State there is a relatively thick mantle of glacial drift materials consisting primarily of clays and some lenses of sand overlying both Cretaceous and pre-Cambrian igneous type rocks. Most of the ground water in Minnesota is contained in the Paleozoic formations of the southeastern part of the State.

Based on certain assumptions made about these geological formations, it has been calculated that there is approximately 300 cubic miles of ground water in the State of Minnesota. Most of this is probably in the southeastern part of the State. By comparison, this amount of water is greater than the total amount of water flowing at any one time in all lakes and streams of the world, excluding the Great Lakes of North America.

Hydrology

The hydrology of Minnesota is extremely variable with respect to both the states to the west and the states to the east of Minnesota. In eastern Minnesota, precipitation exceeds evapotranspiration; however, in western Minnesota there is a deficiency of precipitation compared to evapotranspiration. In the southeastern part of the State we have approximately 32 inches of precipitation per year and in the northwestern areas, approximately 20 inches of precipitation. In southwestern Minnesota there is an average deficiency of precipitation compared to the evapotranspiration of approximately 10 to 15 inches per year. In the northeastern part of the State, precipitation exceeds the evapotranspiration by approximately 10 inches per year. This hydrological difference between northeastern and that of southwestern Minnesota is quite likely the principal factor for the great difference in the geochemistry of the waters of both surface and ground water in the two areas. The total dissolved solids and most dissolved chemicals in the water of northeastern Minnesota are much less than those in the southwestern part of the State. There are exceptions to this, of course. In the northeastern part of the State the ground water in the basalt type formations is extremely high in sodium chlorides; however, in the most shallow aquifers and also in the lakes in

Table 1

SOURCE OF WATER

1970 Census - Minnesota

		% of Total State Population	% of Municipal Water Supply Population
TOTAL STATE POPULATION.	3,805,069	100	
POPULATION SERVED BY MUNICIPAL SYSTEM	2,829,585	74	100
POPULATION NOT SERVED BY MUNICIPAL SYSTEM	975,484	26	
MUNICIPAL SYSTEM POPULATION - SURFACE WATER SOURCE. .	1,293,775	34	46
MUNICIPAL SYSTEM POPULATION - GROUND WATER SOURCE . .	1,535,810	40	54
TOTAL PERSONS SERVED BY SURFACE WATER	1,293,775	34	
TOTAL PERSONS SERVED BY GROUND WATER.	2,511,294	66	

		% of Total
1971 TOTAL NUMBER OF MUNICIPAL WATER SUPPLIES	665	100
MUNICIPAL WATER SUPPLIES - SURFACE WATER SOURCE	47	7
MUNICIPAL WATER SUPPLIES - GROUND WATER SOURCE.	618	93

northeastern Minnesota the dissolved chemicals in the water is extremely low, reflecting the greater amount of flushing action from both surface water and the ground water by the action of surplus waters of the area.

Minnesota is confronted with two problems in the western part of the State. In the Red River Valley, ordinarily the area is confronted with surplus water in the spring or at times of heavy precipitation. Because of the flat terrain in the ancient Glacial Lake Agassiz Basin, flooding is a common problem in the Red River Valley. Much of southwestern Minnesota is covered by relatively recently deposited glacial drift material and was poorly drained prior to the construction of artificial drainage systems. Now these natural reservoirs for water in that area no longer exist.

Within the northeastern and southeastern part of the State there is a sufficient amount of water for almost any need. In northeastern Minnesota there is an ample supply of surface water from the many lakes in that area and from Lake Superior. In southeastern Minnesota there is a great abundance of high quality ground water if wells are constructed in a manner that will not cause contamination to enter the ground water system. There is some concern and some studies are being made of the contamination entering some of the aquifers in southeastern Minnesota. There is cause for concern for a similar problem to develop in areas as far west as Martin County, should these aquifers be fully exploited and contaminants drawn down into the deeper formations.

Water for Irrigation

Minnesota does have a problem in developing an adequate irrigation water supply source for agricultural irrigation in western Minnesota. There is potential for on-site development and there is a potential for importation of water from other sources. It is useful to review irrigation projects in the western United States.

Water Development Projects for Irrigation in Other Parts of the Country

In California water storage and conveyance are among the activities of some 4,000 separate organizations. The California Water Plan is the largest single project ever to be constructed by a single state in the nation. After World War II, California state government leaders decided that the state would have to enter the water development field to help satisfy the growing demands of California's agriculture, industry and population.

The California Feather River Project, 1951

The California Legislature authorized the Feather River Project, also named the California State Water Project, to conserve winter and spring runoff from the upper Feather River area in a large reservoir behind the dam near the town of Oroville, California. In 1957, $25 million in state tideland, oil and gas revenues were allocated to begin relocating highways and railroads around the site of Lake Oroville. South Bay and California aqeducts were started in 1959. In 1960, the largest single source of funds were approved by a general election in California which authorized the state to issue $1.7 billion in general obligation bonds backed by the state's credit.

The California Water Project is expected to be in full operation by about the year 1990, where approximately 4 million acre feet of water will be delivered to users in rural and urban areas from northern California to southern California. In 1970, Californians were using water at the rate of about 25 million acre feet each year. About 32% of the project water (1,355,000 acre feet annual maximum) will be supplied to the San Joaquin Valley, one of the major agricultural regions of the nation. This is enough water to irrigate the equivalent of 600 square miles of land in the valley. In 1970, it was expected that the total capital expenditures for the California Water Project from 1952 to 1985 would be approximately $3.8 billion.

U. S. Bureau of Reclamation Projects

Other large irrigation projects in the nation have been financed primarily by the Federal government through the Bureau of Reclamation of the U. S. Department of Interior. There has been a trend away from irrigation projects being financed by the Federal government since 1970 by the U. S. Senate. In 1970, Senator Ellendar of Louisiana, Chairman of the Finance Committee, indicated that $1,200 an acre to develop irrigation land was not a wise investment of public funds and that practice has been largely discouraged. Although large-scale Federally financed irrigation projects are declining, Congress is observing an earlier commitment to complete the Garrison diversion in North and South Dakota as a part of the Pick-Sloan Plan for flood control of the Missouri River Basin and to develope irrigable lands in the Dakota's.

Garrison Diversion

The Garrison Diversion was first proposed as a diversion of the Missouri River in North Dakota in 1889. The modern version of this plan, called the Garrison Diversion, will provide water to irrigate one million acres and other needs and will require 60 years to complete. The first phase of the Garrison Diversion will be to irrigate 250,000 acres in North Dakota.

Every western state has benefited greatly by the expenditure of public funds for irrigation and water resource development projects in these states. Not only have the funds for these projects been provided by the nation as a whole but it can probably be argued that the irrigation of these lands has worked to some extent to the disadvantage of midwestern farmers in developing and marketing their agricultural products.

Texas Water Plan

Another enormous project that has been proposed would be to irrigate the high plains of Texas with water pumped from the Mississippi River in order to make up water deficiencies resulting from the over-exploitation of the ground water resources of the high plains of Texas and New Mexico. This project in 1970 was expected to cost approximately $15 billion. Some Texans were hopeful that the Congress would provide at least $12 billion for this project.

Water Sources to Irrigate Western Minnesota

Water to irrigate western Minnesota could be obtained from three primary sources: (1) importation of surface water, (2) importation of ground water, and (3) on-site water resource development projects. The on-site availability of large amounts of either surface water or ground water does not seem to be a solution for irrigating western Minnesota. It seems likely that if either surface water or ground water is to be provided for irrigation that these sources will have to be developed in some other part of the State where they are in much greater abundance than in western Minnesota. This water could be imported by an aqueduct system consisting of either pipelines or canals.

Southeastern Minnesota Paleozoic Ground Water Basin
One possibility would be to develope the ground water aquifers in the southeastern part of the State. This would require the construction of large capacity wells and the pumping of this water to areas of western Minnesota. This would involve policy questions with respect to private lands. Although all water resources of Minnesota are considered public under the common laws doctrine of reasonable use, appropriation of ground water for use on distant land could require authorization of owners to develope a well on private property. The cost to develope ground water resources in southeastern Minnesota would unquestionably be more than diverting surface water sources from northeastern Minnesota. Ground water in the deeper aquifers of Minnesota has generally been of high quality and meets the public health standards for potable water; however, some areas are showing signs of deteriorating quality. Studies are being developed to assess that trend and to address the problem. If demands for ground water should greatly increase in the southeastern Minnesota Paleozoic area, there would be concern about the deterious affects on the quality of the water.

Lake Superior
Lake Superior, the greatest inland fresh water sea in the world, forms one boundary of Minnesota. Pipelines could be constructed from Lake Superior near the mouth of the St. Louis River to western Minnesota. Economic and engineering studies would be necessary to determine the cost and benefits for such a project. There are also political and legal problems associated with appropriation of St. Lawrence River Basin water.

Rainy River and Lake of the Woods
A more feasible possibility for irrigating western Minnesota lands, at least those in the Red River Valley and lands at elevations below 1,000 feet in southwestern Minnesota, could be provided by constructing an aqueduct from the Rainy River Watershed. This would consist of a canal (Figure 6) from Lake of the Woods constructed near the 1,000 foot elevation contour from Lake of the Woods to Brown's Valley into Big Stone Lake. The maximum runoff from the Rainy River Watershed has been as high as 17 million acre feet. Even in the driest year of record, over 3 million acre feet has been discharged from the Rainy River Watershed. At Lake of the Woods the average annual runoff or discharge is estimated to be 10,250,000 acre feet. Approximately 4,250,000 acre feet is from the United States part of the Rainy River Watershed. The average annual flow at Manitou Rapids is approximately 12,000 cubic feet per second and the minimum flow recorded was 2,200 cubic feet per second. To develope this resource would likely require both the consent of the U. S. Congress and the parliament of Canada. North and South Dakota would likely have a keen desire to obtain a share of the water diverted from the Rainy River. The Twin City metropolitan area of Minnesota, as well as many western Minnesota cities, might see a need for Rainy River water if such a project were deemed feasible. These are only concepts that have not been given consideration from any legal, economic, political, engineering, or environmental considerations, therefore, the potential or possibility would require a much more detailed and further analysis. In other words, from a hydrological, geological and topographical point of view, a diversion of this type would appear to be a feasible physical possibility. The City of Winnipeg would have serious questions about the diversion of water from the Rainy River

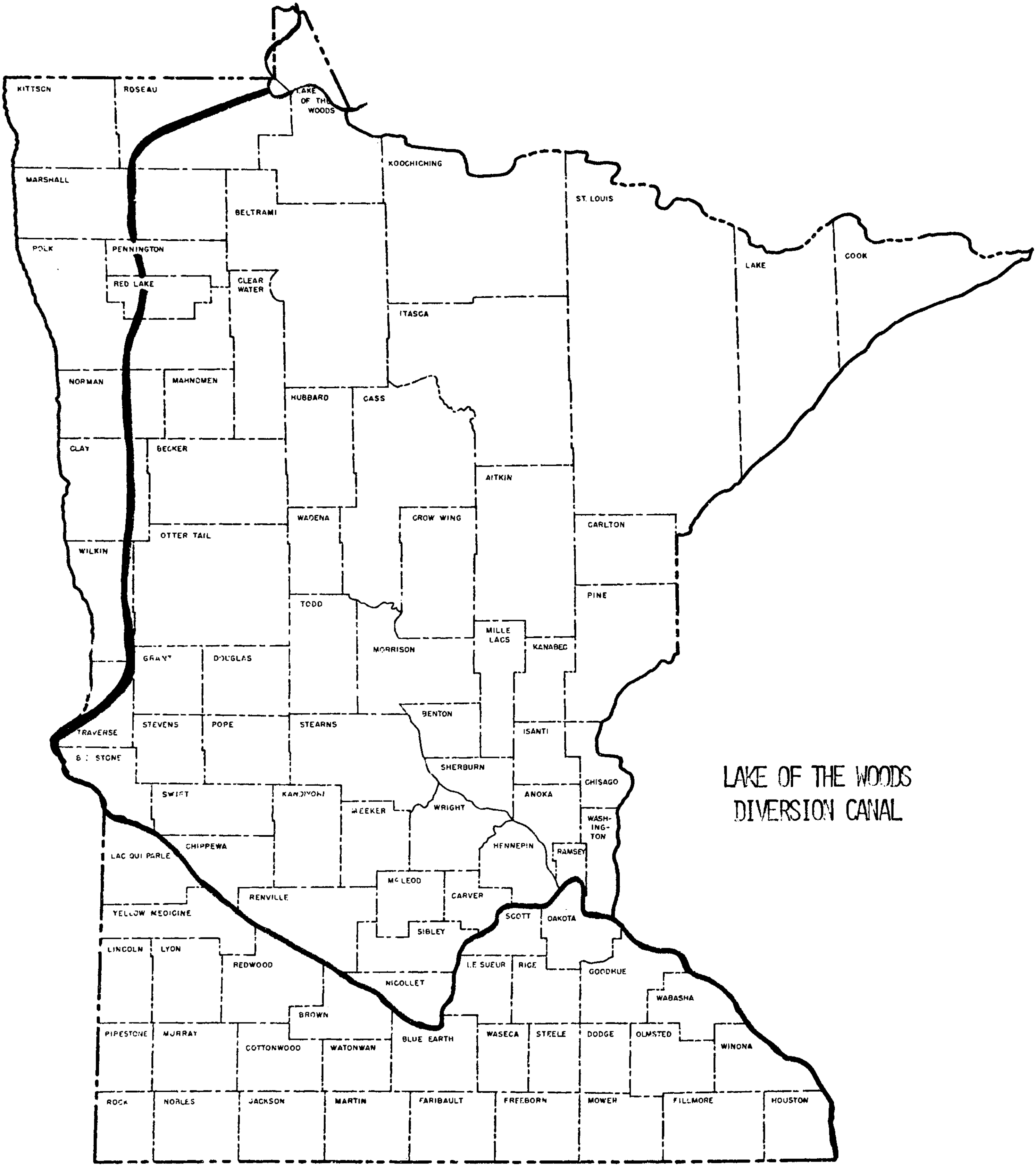

LAKE OF THE WOODS
DIVERSION CANAL
KITTSON
ROSEAU
LAKE OF THE WOODS
KOOCHICHING
MARSHALL
BELTRAMI
ST. LOUIS
POLK
PENNINGTON
RED LAKE
CLEAR WATER
LAKE
COOK
ITASCA
NORMAN
MAHNOMEN
HUBBARD
CASS
CLAY
BECKER
AITKIN
WADENA
CROW WING
CARLTON
OTTER TAIL
WILKIN
TODD
PINE
MILLE LACS
KANABEC
MORRISON
GRANT
DOUGLAS
BENTON
STEVENS
POPE
STEARNS
ISANTI
TRAVERSE
SHERBURNE
CHISAGO
SWIFT
KANDIYOHI
ANOKA
MEEKER
WRIGHT
WASHINGTON
CHIPPEWA
HENNEPIN
RAMSEY
LAC QUI PARLE
McLEOD
CARVER
RENVILLE
YELLOW MEDICINE
SCOTT
DAKOTA
SIBLEY
LINCOLN
LYON
REDWOOD
LE SUEUR
RICE
GOODHUE
NICOLLET
WABASHA
BROWN
PIPESTONE
MURRAY
BLUE EARTH
WASECA
STEELE
DODGE
OLMSTED
COTTONWOOD
WATONWAN
WINONA
ROCK
NOBLES
JACKSON
MARTIN
FARIBAULT
FREEBORN
MOWER
FILLMORE
HOUSTON

Figure 6

Basin, as their municipal water supply is derived through a pipeline from Lake of the Woods. Further exploitation of the Rainy River Watershed may require development of additional storage of water in the headwaters area of the basin. The high topographic relief provides potential for rather enormous reservoir capacity in the area. Fortunately, most of this area is under the control of the State of Minnesota and the U. S. Government. There is relatively little private development in the headwaters of the Rainy River Watershed. Mining activities in northeastern Minnesota may, in the future, require the appropriation of water from the Rainy River Watershed. It would seem that over a long-term basis many years of runoff could be stored in this part of Minnesota by constructing a few relatively high head dams.

Water diverted from the Rainy River Watershed upstream from Lake of the Woods at an elevation over 1,300 feet would provide an open channel gravity flow to a much greater area of Minnesota (Figure 7). This diversion, following near the 1,300 foot elevation contour along the north side of the Mesabi Iron Range, could provide water to Winnibigoshish Reservoir through Bowstring Lake. This aqueduct could be constructed to provide supplemental irrigation water to other western Minnesota areas in the Red River Valley and discharge into other natural waterways such as the Pomme de Terre River, the Long Prairie River through Lake Osakis, the Sauk and Crow Rivers and to Lake Minnetonka in Hennepin County. In other words, it would be a canal connecting Vermillion Lake with Minnetonka Lake. Water for southwestern Minnesota would require pumping water stored in Big Stone Lake. Water in Big Stone Lake would be maintained by Rainy River water discharged from the canal into the Pomme de Terre River. Another canal could be constructed parallel to the Coteau des Prairie from Lyon County to discharge into the Blue Earth River in Faribault County. Other options to this concept could be considered in feasibility studies. Much less water would be available from the Rainy River Watershed if taken at this higher elevation than at Lake of the Woods.

Additional water stored by constructing large dams in the Rainy headwaters area and/or additional water could be imported to the Rainy River by pumping water from Lake Superior through a 25 mile pipeline constructed in Lake County to discharge into Stoney River. Birch Lake or White Iron Lake water could be diverted or pumped into Lake Vermillion to feed into the aqueduct system beginning at elevation ± 1,360 feet.

Studies for evaluation of water resource systems of this nature for irrigation are of such magnitude that the total water needs of the State must be evaluated. Consideration should be given to water needs for the generation of electricity from peat, coal or nuclear energy. The potential for pump storage should be considered along with the availability of power to pump water at non-peak periods.

<u>On-Site Water Resource Development</u>

In some areas of western Minnesota there exists the potential for constructing large capacity wells in glacial outwash materials or buried channels. In some cases, bedrock will yield sufficient water to provide water to modern irrigation equipment without the need for an on-site surface storage reservoir. In most cases, however, ground water in the better agricultural soils area of western Minnesota must be developed with relatively low yielding wells.

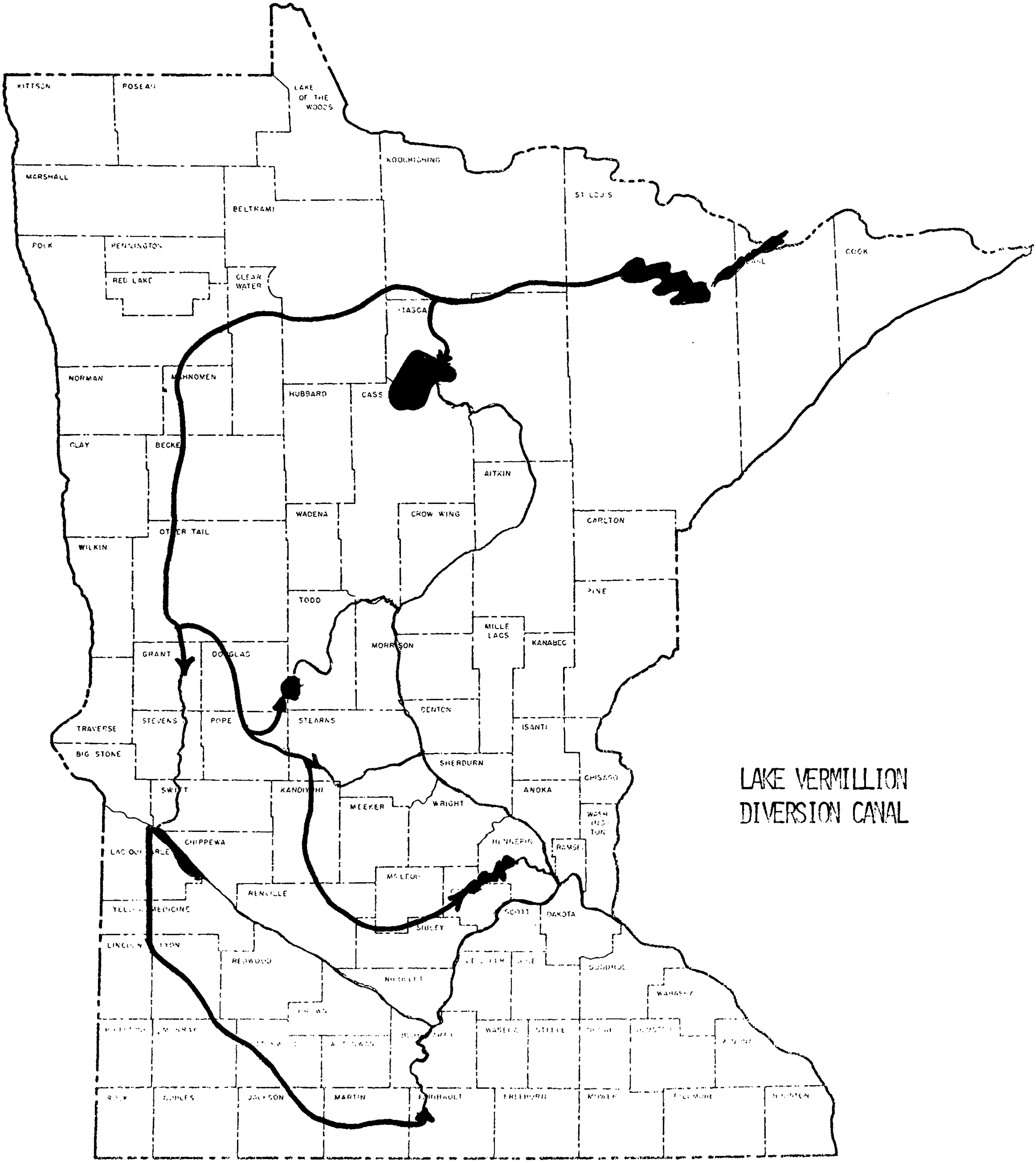

LAKE VERMILLION DIVERSION CANAL
KITTSON
ROSEAU
LAKE OF THE WOODS
KOOCHICHING
MARSHALL
BELTRAMI
ST LOUIS
POLK
PENNINGTON
RED LAKE
CLEAR WATER
COOK
ITASCA
NORMAN
MAHNOMEN
HUBBARD
CASS
CLAY
BECKER
AITKIN
WADENA
CROW WING
CARLTON
OTTER TAIL
WILKIN
PINE
TODD
MILLE LACS
KANABEC
GRANT
DOUGLAS
MORRISON
BENTON
TRAVERSE
STEVENS
POPE
STEARNS
ISANTI
BIG STONE
SHERBURN
CHISAGO
SWIFT
KANDIYOHI
ANOKA
MEEKER
WRIGHT
WASHINGTON
CHIPPEWA
HENNEPIN
RAMSEY
RENVILLE
MC LEOD
SCOTT
DAKOTA
SIBLEY
REDWOOD
JACKSON
MARTIN
FARIBAULT
FREEBORN
MOWER
WASECA
STEELE

Figure 7

Dr. Lowell Hanson of the Soils Department of the University of Minnesota has discussed with me and with the people in the Agricultural Engineering Department the possibility of developing on-site water supply for agricultural irrigation in western Minnesota. There is a possibility of constructing relatively small reservoirs on each 160 acre parcel to store sufficient water for supplemental irrigation. These small reservoirs could be replenished in some years with spring runoff or with small capacity wells. In some cases, the farmer's own existing well could provide a source of water. For example, if the water from a small yielding well was pumped continuously for one year and this water was stored in a small reservoir, this could provide over an inch of irrigation water to 160 acres of land. Five wells of this size or a well of fifty gallons per minute could provide a half a foot of water to 160 acres of land. For example, a one acre reservoir 16 feet in depth would provide sufficient water to apply over one inch of water to 160 acres of land.

Table 2 shows the amount of water that can be obtained in one year from small capacity wells, the amount of water that can be placed on 160 acres and the total storage depth for small impoundment areas. Except for extreme northwestern Minnesota, a potable water supply can ordinarily be developed from water wells; however, there are a few isolated cases where well drillers have not been successful. Even ten gallons per minute may be more than can be provided on any one site and, then again, there are wells of relatively high capacity completed in igneous rocks in southwestern Minnesota. In Pipestone, Minnesota, a well completed into the Sioux Quartzite yields over 400 gallons per minute. In some instances, there can be problems associated with some types of trace elements in water that can be harmful to crop production. The strictly economic constraints imposed upon this particular type of system have not been sufficiently evaluated.

I understand that the University of Minnesota will be beginning some preliminary studies of this during the next agricultural season. Although there may be some additional benefits for water fowl habitat derived from the excavation of numerous small irrigation reservoirs, the long-term hydrological impact should be studied to determine recharge rates to the ground water. Detailed hydrological and geological maps should be made from information gathered from water well contractors. Minnesota Law 156A requires that well contractors submit a well record within 30 days of completion of the well and a water sample prior to placing the well in service. This information is useful to several State and Federal agencies for geological, water resource and public health programs. It is apparent that an increased program in education and enforcement is necessary if this geological and hydrological data is to be obtained from the water well contractors.

Water Storage Requirements to Irrigate 160 Acres with Low Yielding Water Wells
for Application with Modern Center Pivot or Gun-Type Irrigation Equipment

GPM Well 365 Days	Feet	AF		Storage Area in Acres 1	2	3	4	5	6	7	8	9	10
10	.1	16		16	8	5.3	4	3.2	2.67	2.29	2	1.8	1.6
20	.2	32		32	16	10.6	8	6.4	5.33	4.57	4	3.6	3.2
30	.3	48		48	24	16	12	9.6	8	6.86	6	5.3	4.8
40	.4	64	D	64	32	21.3	16	12.8	10.67	9.14	8	7.1	6.4
50	.5	80	E	80	40	26.7	20	16	13.3	11.43	10	8.9	8.0
60	.6	96	P	96	48	32	24	19.2	16	13.7	12	10.7	9.6
70	.7	112	T	112	56	37.3	28	22.4	18.7	16	14	12.4	11.2
80	.8	128	H	128	64	42.7	32	25.6	21.3	18.4	16	14.2	12.8
90	.9	144		144	72	48	36	28.8	24	20.6	18	16	14.4
100	1.0	160		160	80	53.3	40	32	26.7	22.9	20	17.8	16.0

Table 2

DROUGHT, WEATHER TRENDS AND THE 1977 SEASON

Donald G. Baker
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University of Minnesota
St. Paul, Minnesota

SOILS, FERTILIZER AND AGRICULTURAL PESTICIDE
SHORT COURSE

Minneapolis Auditorium, December 15, 1976

1. SEVERITY OF THE DROUGHT, AREAS AFFECTED AND COMPARISONS WITH PREVIOUS DROUGHTS

Based simply upon precipitation records the summer of 1976 ranks as one of the four driest summers on record for Minnesota since National Weather Service Records began in 1891. The four summers were similar in precipitation totals, however, each covered different parts of the state. The 1976 summer is the driest on record in the west central and southwest, from Fargo-Moorhead south through Morris to Worthington and east to the Twin Cities; the 1936 summer was the driest in the northwest from Fargo-Moorhead north; the 1934 summer was the driest in the northeast from St. Cloud northeast; and the 1910 summer was the driest from the Twin Cities south.

The driest area in Minnesota during the 1976 summer (April through August) with precipitation 10 inches or more below normal was a triangle from just south of Fargo-Moorhead to Forest Lake to a point on the South Dakota line west of Marshall. The wettest area with precipitation less than 2 inches below normal was from East Grand Forks to Red Lake to International Falls. Goodhue and Wabasha counties represent a small, relatively wet area with precipitation less than 4 inches below normal.

The 1976 summer was the driest on record for Morris, Milan, Tracy and Worthington. These stations received 5.32, 4.06, 8.07 and 7.81 inches of precipitation, respectively. In contrast only two locations, both in the northwest, recorded precipitation above normal. Two State Forestry locations, Grygla and Wannaska, recorded 0.42 and 0.12 inches above normal, or a total of 14.84 and 14.62 inches of rainfall from April through August.

The center of the drought remained over northeastern South Dakota and gradually intensified and increased in areal extent. By early October the north-central drought area included all or parts of North Dakota, South Dakota, Minnesota, Wisconsin, Nebraska, Iowa, Illinois, Missouri and Kansas.

Although the 1976 drought has been as intense as other droughts of record and living memory (see Table 1), it has not yet reached the areal extent of four of the worst for which records are available: 1934, 1936, 1954 and 1956. The extent and intensity of the 1934 drought is impressive. It appears to have been the worst of the five, although on a state rather than national basis, 1976 may, when all of the data are in, prove to be the worst for Minnesota as a whole.

Table 1. Maximum intensity of the 1934, 1936, 1954, 1956 and 1976 droughts.*

Year	Maximum intensity as of		Approximate location of peak intensity
1934	July 1	-8	WC Minn.; NW Ill.; NE Nev.; SE Idaho; NC Utah
	Oct. 1	-8	WC Minn.; NE and NC So. Dak.; SC No. Dak.
1936	July 1	-5	NW So. Dak.
	Oct. 1	-7	SC No. Dak.; NC So. Dak.
1954	July 1	-6	EC Mo.; WC Ill.
	Oct. 1	-7	C Wyo.
1956	July 1	-6	C and SW Ia.
	Oct. 1	-6	SC Wyo.; SC Colo.; C Kan.; WC and SE Ia.
1976	July 1	-6	C Calif.
	Oct. 1	-7	WC Minn.; SE No. Dak.; NE So. Dak.

*Based on Palmer Drought Index maps from the July 7 and Oct. 5 issues of the Weekly Crop and Weather Bulletin.

2. SOIL WATER CONDITIONS

Because plants cannot use water directly but must absorb it through their roots, the importance of soil moisture reserves to agriculture cannot be overemphasized.

The hydrology of soil water usually is a matter of a relatively rapid and steady drawdown that lasts from June through August. From September to the soil freeze-up in early December is the most efficient of the two recharge periods. While soils are frozen, from December to early April, little water is added to soils because most over-winter precipitation is lost as runoff in the spring. From spring thaw until early June is the second, but ordinarily less efficient, soil water recharge period.

Concentrating our attention upon southwestern Minnesota we find that very nearly optimum years with respect to both soil water and precipitation occurred in 1972 and 1973. Corn yields reflected the high soil moisture content with the yield in Redwood and Cottonwood counties, for example, averaging about 100 bushels per acre.

With adequate soil moisture supplies a relatively acceptable yield can be obtained even when there is little or no precipitation during the growing season. This was very nearly the case in both 1974 and 1975 in southwestern Minnesota. From mid-June to the end of the growing season in both 1974 and 1975 little rain of consequence fell. By the end of the growing season all of the plant available water had been extracted from the soil. Corn yields from Redwood and Cottonwood counties averaged about 60 bushels per acre for the two years.

The 1976 soil moisture was a disaster over most of Minnesota for three reasons. First, the autumn soil moisture recharge period failed to make up the growing season losses; second, the 1976 spring recharge period failed to materialize; and finally, even the growing season precipitation was nearly nil. The yield in the hard pressed counties of Redwood and Cottonwood is estimated to be 25 bushels per acre.

Water within the soil remains at a level well below the mean for this time of year. The soil is about 4 1/2 inches below average as of mid-November 1976 at the Southwest Agricultural Experiment Station at Lamberton. Even drier conditions have been found in a Lyon County soil near Marshall. Soil water measurements from other areas indicate that most soils are below to much below normal for this time of year. A few exceptions have been noted such as southeastern Minnesota and a few scattered areas which received some showers during the growing season.

The gravity of the dryness of the subsoils lies in the inherent difficulty in rebuilding these reserves. Slow but steady rains of some magnitude are required. These are most common in the autumn. Spring rains are of value, but in many cases these rains are too intense to be efficiently used or the rains fall on an already saturated topsoil.

3. RAINFALL AND SOIL WATER PREDICTIONS FOR 1977

The usual type of meteorological prediction cannot be made for any period longer than about two weeks in advance, much less 3, 6 or even 12 months in advance. Thus, any kind of forecast for the 1977 season must rest upon historical records and probabilities derived from such records. For example, historical records indicate that for any one year the probability of low yields induced by weather factors ranges from about 10% to 25%. That is, chances range from about 1 in 4 years to 1 in 10 years of having yields reduced at least 10% below the mean as a result of the weather (1).

Another kind of study showed that weather events once established tend to persist in western Minnesota for 26-30 months. In eastern Minnesota no such tendency was found (3).

In any case there is no method, including sunspot occurrences or climatological probabilities that permit a forecast to be made for a specific year such as the 1977 growing season. However, it might be inferred from historical records, persistence and probability studies, that probably 1976 was the peak drought year, and that the drought intensity will decrease markedly in 1977. The persistence study cited earlier would tend to substantiate the latter point for the drought is in its second or third year depending upon the locality.

Even though the drought may have bottomed out in 1976 this is not to be taken that 1977 will be necessarily a "good" year. Looking at the 1977 growing season from the distance of November 1976 there are several factors working against the 1977 season. First, because of the unusual dryness of the soil above normal precipitation is required. Second, the 1976 autumn recharge has failed to materialize, placing greater importance upon the usually less efficient spring recharge period. And finally, because many subsoils are so low in water an almost ideal rainfall distribution will be called for during next July and August in order to compensate for the subsoil deficits.

Both of the previously cited studies point out something that should not be forgotten, which is that precipitation becomes increasingly marginal in moving westward across the state. According to one study recently made the Corn Belt has undergone a remarkable succession of good weather seasons that extended from approximately 1957-1972 (2). As a result agriculture should be prepared for a series of more normal years in which the weather reverts to its more characteristic variation that occurred previous to 1957.

4. THE POSSIBILITY OF ALLEVIATING DROUGHT

Cloud seeding (weather modification) in order to augment precipitation can be effective only if the proper kind of clouds and atmospheric moisture are present. The proper atmospheric conditions are seldom present during a drought, and therefore cloud seeding should not be considered as a means of appreciably increasing water supplies.

Given the proper quantity and quality of underground and surface water resources irrigation could be considered.

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FORECASTING THE FUTURE OF WEATHER FORECASTING

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Minneapolis, Minnesota

INTRODUCTION

Meteorology is a very old and a very young science. Though Aristotle prepared a massive book on "meteorology" almost 2500 years ago, it is a relatively modern discipline. Precise measurements of pressure and temperature were unavailable until the inventions of Torricelli and Galileo in the late 16th century. Meteorological data taking was a sporadic operation until the mid-19th century. And it was not until 1869, more than twenty years after the invention of the telegraph that synoptic data collection began by the U.S. Signal Corps, the predecessor of the modern U.S. National Weather Service. The establishment of a high-density weather observing network in Scandanavia during World War I allowed the discovery of fronts and air masses, and it was not until the late 1930's that these were even plotted on official U.S. weather maps. World War II's high-flying bombers first encountered the jet stream. After the war's end, technological advancements proliferated, including high-speed computers, radar, and weather satellites - all of which greatly increased our capability to collect and process vast amounts of data.

Yet with the total Federal expenditure on atmospheric sciences exceeding $700 million annually, we frequently hear the public crying, "Why, with all their satellites and radars and computers can't I get a more accurate weather forecast?" The reason is, like the atmosphere, complex. Forecasting has in fact steadily improved over the last two decades. The general public would be rather impressed with our ability to forecast precise conditions for a given location within 36 hours - if only the information could reach them in a readily utilizeable form in enough time to be employed for planning purposes. While certainly not 100% accurate (85% is a frequently used number), today's weather has greatly under-utilized economic potentials - and the next 5-10 years may see startling advances in our ability to serve agribusiness.

FORECASTING: ITS CURRENT STATE

Data from surface and upper air stations, radar,and satellites are collected by the National Weather Service/National Oceanic and Atmospheric Administration (and supplemented by Armed Forces sources). Much of the data are fed directly into massive computers at the National Meteorological Center, Suitland, Maryland, where national forecasts for the next 12 through 48 hours (with extensions to 5 days) are routinely prepared. Severe storm watches and warnings are prepared and issued by the National Severe Storm Forecast Center (Kansas City) and the National Hurricane Center (Miami). All public forecast information is routed to state and regional NWS offices from whence it is interpreted and distributed to the public via teletype, NOAA weather radio, and other appropriate means (Cressman, 1971). It should be noted that the NWS serves to protect the general public welfare as a whole, but is neither staffed nor empowered to give specialized forecasts to individuals, groups, or commercial operations (except by special authorization, i.e., aviation forecasts, etc.). These same data and forecasts are considered public domain and can be acquired at cost by any qualified private consulting meteorologist. The private forecaster may then in turn re-evaluate the federal information, add that additional information, and issue specific forecasts tailor-made for a given client at any appropriate professional fee.

Private forecasters, while existing for over 30 years, have only in the last decade started to become a major factor in providing meteorological services (Wallace, 1971). They have primarily worked with public utilities, highway departments, private aviation, construction and shipping firms, and legal/insurance investigators. Both the private sector and the NWS has been relatively inactive in providing detailed services to agriculture, although the efforts of state climatologists, the NWS Fruit Frost Forecast Program, and others can be mentioned as exceptions.

It is invisioned however, that the next decade will see an explosive growth in the quality and quantity of agrimeteorological services, led primarily by vigorous non-government consulting/forecasting groups.

SOME PROBLEMS

The major problem is data. There is simply not enough information to clearly describe certain phenomena - yet the data stream currently available is saturating any forecaster's ability to properly assess it in near real-time. In regard to the data dearth, this is with regard to mesoscale atmospheric phenomena, those of sufficiently small size that they might occur undetected between two observing stations (75-100 miles spacing). These however include such major events as severe thunderstorms,hailstorms, flash floods, tornadoes, mountain/valley and land/sea breezes, fog and frost pockets, etc., all of which may profoundly affect crops or agricultural operations. Radar and satellite data fill much of the "data gap" between surface stations, but again the sheer volume of information to be processed often precludes a clear assessment of an event before its life cycle concludes (after 1 hour or less).

The National Weather Service recognized that since as much as 40% of its field office personnel hours are spent simply tearing, sorting, clipping and filing yard upon yard of teletype and facsimile paper, what was needed was a "paper-free" weather forecating operation. The AFOS program (Automation of Field Observations and Services), to be implemented in the next several years, replaces teletype and facsimile communication with CRT (Cathode Ray Tube) TV-like displays interconnected by a computer-controlled National Digital Circuit (NDC). This allows the forecaster to receive data in a portion of the time previously required and in a format much more easily assimilated. Thus there will be more time to inspect the national computer-derived forecasts and interpret them for local conditions. Also warning response time decreases dramatically.

This is all being made possible by the development not of bigger, but rather smaller computers. The mini-computers, with dramatically lowering prices, and ever-increasing speed and storage capacities, are ideally suited to process meteorological data streams in real time.

A NEW ERA?

The introduction of the mini-computer into the local forecast has important implications for all users of meteorological services. The era of "nowcasting" is dawning. "Nowcasting" means the rapid assessment of complex local weather systems (say, a thunderstorm squall line) in near real-time and thus being able to issue and rapidly update short-range forecasts. It has been conservatively estimated that weather related economic losses to the U.S. economy are $12 billion annually, and that more accurate short-range forecasts could ameliorate at least $2 billion of this total (Suomi, 1974). The value of precise long-range forecasts (30-day, seasonal, yearly) would of course be even greater, but the problem is one of such staggering scientific complexity it seems prudent to suggest that 30-day outlooks of the precision of our current 72-hour prognoses are <u>at least</u> several decades into the future. Thus the most immediate payoff in the application of meteorological science and technology can be obtained in attacking the 0-3 hr, 0-12 hr, and 0-24 hr forecast problem, as well as having up-to-the-minute climatological data bases available for immediate use.

If this is to be done, even <u>more</u> data is needed. Precipitation, temperature, winds vary considerably day to day, month to month, and year to year over even short distances. Any farmer knows "things are different" in the adjoining county, and reliance on reports and forecasts for an "official NWS" station 75 miles away can be a cause for frequent exasperation. Reports are needed for an individual farm (which may be in a low-lying frosty "cold spot" or a terrain-incurred wet zone). Yet reliable meteorological instruments are expensive (though nothing like a single $80,000 combine or even the cost of one aborted aerial spraying mission). But more importantly, the data needs to be processed and interpreted. Few modern agribusiness personnel have time or the inclination to do so, as valuable as the data may be.

New technology once again may change the picture dramatically (Pike, 1974). Rapidly improving and less costly sensors could be controlled by micro-processors ("computers on a chip"), which could produce a steady stream of valuable data which could be displayed on a home TV screen.

Such data as continually-updated temperature, humidity, wind, precipitation, growing degree days, livestock safety index, wind chill, etc. could be on hand at the press of a button any time. As the price of these electronic components continues to plummet, the cost of such a system will decrease so drastically, that rather than not being able to afford one, it will be a matter of not being able to exist without one.

STILL MORE

As visionary as the above may seem, it is only the tip of the iceberg. Even if an agribusiness generates own local observations,these still do not provide forecasts.

Meanwhile the forecaster has available highly sophisticated computer-controlled color TV screens showing the detailed state of the atmosphere on a county by county basis. Satellites detect cloud growth and motion almost minute by minute, while computer controlled radars not only observe rain, but could continuously update the total rainfall that has occurred within 125-mile radius area. Furthermore, all weather data and forecasts can be stored on digital disks on site. Rather than waiting three weeks to assess the magnitude of a severe rainstorm or drought, the computer can display a map of conditions as current as five minutes ago! Computations of soil moisture indices, growing degree days, etc. can be updated daily, as opposed to weekly in current practice.

These data can likewise serve as input into various crop growth models under development.

But unless the information at the forecaster's fingertips can reach an agribusiness operation in time to be of use, it is of little value. Warning of a heavy rainstorm only 45 minutes away from a large farm where aerial spraying (or irrigation, or haying, or...) is about to begin now might take 60 minutes to reach that site.

It is neither the proper role of the National Weather Service nor within its power, to provide specific farms or businesses with detailed meteorological data or forecasts. Aside from the special case of severe weather watches and warnings, it is expected that private consulting services will perform this vital role.

Another technological revolution, that of communications, now must be considered. Using the computer combined with telephone or radio communications, it is even now possible to provide any specific agribusiness with a table-top CRT scope that continuously, or on command, flashes weather information for that specific location, and without reams of extraneous information now found on current weather teletype systems. The private consulting meteorologist, in addition to having available all NWS data, can also generate special detailed forecasts in terms the client understands, and in time for the client to react to prevent or minimize weather-related economic losses.

The agribusiness operator, at 9 PM or 6 AM, while planning the upcoming day's operations, could sit at a keyboard connected to a terminal (just like at airport reservation desks) and ask questions of a computer from an available menu of items: "What is the forecast of wind and temperature today for southern Goodhue County?" "What is the radar rainfall estimate for this county from last night's storm?" "What is the current 5 and 30-day outlook?" "How many base-55 degree growing degree days has my farm accumulated?", etc. And no special expertise other than hunt-and-peck typing, and a healthy curiosity, would be necessary.

A COST EFFECTIVE POSSIBILITY?

Is all the above possible? With the current march of technology, it should be entirely possible for such a system to be implemented within the next 5 years. The price to a user of such local CRT weather terminals is estimated at several hundred dollars per month. It has been estimated that even marginally more accurate forecasts could save North Central State canneries some $5 million annually. For larger farms, grain elevator operators, cooperatives, and those in many sectors of the weather-sensitive agribusiness economy, this cost, as compared to potential benefits derived could be easily justified.

While not all weather related losses can be eliminated even with perfect forecasts, appropriate measures <u>can</u> often be taken (not seeding two hours before a deluge, harvesting before an almost certain hard freeze, protecting cattle from extreme heat stress, etc.).

The American farmer certainly will never stop talking about weather, and now we can start doing more about it, and for once, stop crucifying the meteorologist and begin working as a highly and mutually beneficial team.

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Foliar Feeding of Soybeans

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Although foliar fertilization of pineapple with urea and of some tree crops, primarily with micronutrients, are common practices, very little success has been obtained from foliar fertilization with the macronutrients for soybeans. However, because plants can (1) effectively absorb nutrients through their leaves and (2) during seed-filling N,P, K, and S are translocated from the leaves to the developing grain depleting the leaves so photosynthesis is restricted, foliar applications of these nutrients during seed-filling would appear to have real potential for increasing yields.

Field experiments in Iowa from 1974 to 1976 have shown that soybean yield increases of 8 to 12 bu/A can be obtained with appropriate methods of foliar applications of N,P,K,S solutions during seed-filling. Field trials in 1976 by the 12 Extension Area Agronomists showed yield increases of 6 to 8 bu/A in 1/2 of the trials, where moisture was not severely limiting, and no yield increases (and some yield decreases) in the other 1/2 of the trials, where moisture was limiting. Preliminary reports from researchers in other states have indicated that yields were seldomly increased and often decreased by foliar fertilizer applications. Foliar applications often resulted in serious "leaf burn".

Obviously, we have much to learn before this new practice should be generally recommended to farmers. But, because of the potential and the successes that have been obtained, research should be continued.

Present results indicate that:

1. To be successful the foliar treatment should supply all four elements--N,P,K, and S. The ratio of these nutrients in the foliar spray should be about 5:1:1.5:0.25 of $N:P_2O_5:K_2O:S$. The fertilizer solution should contain a suitable adjuvant. Spray applications should be made at 2 to 4 times during the seed-filling period and each application should not exceed 20 to 25 lbs N/acre. Urea, potassium polyphosphate (0-26-25), and potassium sulfate can be used to supply the needed nutrients.
2. Foliar fertilizer spray applications should <u>not</u> be made when the plants are under a moisture stress. This may occur, even where soil moisture is adequate, during mid-day on hot, dry days.
3. Since each bushel of soybeans contains about 4 lbs N (and amounts of P,K, and S as indicated by the above ratio), a yield increase of 10 bu/A would require 40 lbs N/A if the N is utilized completely in the yield increase. Therefore, effective application rates would be expected to supply 40 to 80 lbs N/acre to produce this yield increase.

Research is needed to determine:

1. the most effective time and rate of application
2. forms of nutrients that are effective
3. the most effective adjuvants
4. factors that result in leaf burn
5. factors that limit yield increases
6. the effects of dew, urease, etc.

Until more research to answer these questions has been conducted, we recommend that foliar fertilization of soybeans be conducted strictly on an experimental basis.

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CLEAN WATER ACT, SECTION 208
NON-POINT SOURCE POLLUTION

WHEREAS standards for the development of clean water programs must recognize all three - environmental, economic and social impacts with equal authority. Environmental improvement can be made within reasonable planning for goals, time, costs and maximum livestock, crop and forest production, and

WHEREAS "Non-Point Source Pollution" from agriculture and forestry must be recognized at reasonable tolerance levels. Farmers and foresters should participate in the planning process through Soil & Water Conservation Districts so rural Minnesota concerns reach the Minnesota Pollution Control Agency, now

THEREFORE be it resolved that the Minnesota Plant Food & Chemicals Association recommends to the Minnesota Pollution Control Agency that the established 92 Soil & Water Conservation Districts each with a 5 member board be the agencies to provide input to MPCA, further that MPCA discontinue programming this for the Regional Development Committees. The later would be in conflict with established Soil & Water Conservation Districts and a waste of taxpayer monies.

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USER FEES

WHEREAS the Congress of the United States debated the proposal of user fees on the Mississippi River this past session, and

WHEREAS some 80% of the barge traffic is transporting grains, fuels and fertilizer for farmers, and

WHEREAS said user fees would increase the already high farm production cost on both the out-shipment of grain and the in-shipment of farm supplies, now

THEREFORE be it resolved that the Minnesota Plant Food & Chemicals Association recommends that the Minnesota delegation vigorously oppose user fees on the Mississippi River.

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LOCK AND DAM 26

WHEREAS the Mississippi River serves a highly important function in the transportation of both fuels and fertilizers into the Upper Midwest and moves farm grain crops down river to the Gulf Port area. These constitute 80% of the barge traffic and provide a basis whereby Upper Midwest growers may be competitive on the world grain markets, and

WHEREAS barge traffic has been seriously delayed at the old lock and dam 26 at Alton, Illinois. This bottleneck in river transportation costs the shippers both time and money and threatens complete stoppage of river transportation,

THEREFORE be it resolved that lock and dam 26 has deteriorated and must be replaced. The Minnesota Plant Food & Chemicals Association recommends to the Minnesota Congressional Delegation the passage of a law authorizing a new lock and dam 26 at the earliest possible date in the first session of the new 95th Congress in January, 1977.

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PESTICIDES AND FOOD PRODUCTION

WHEREAS pesticides play a significant role in the production of agricultural and forest crops, and

WHEREAS the use of pesticides by farmers and foresters does prevent waste to pests of weeds, insects, diseases and rodents. This has resulted in more economical production, less energy consumption and higher quality of food and fiber for America, and

WHEREAS EPA at the Federal level and Minnesota Department of Agriculture at the state level, now have stringent regulations controlling the use of pesticides. Certain pesticides may be stricken from further use because EPA has failed to recognize and establish safe levels in food, and

THEREFORE be it resolved that the Minnesota Plant Food & Chemicals Association recognizes the need for and supports efforts to establish the safe level (tolerances) for each pesticide for each crop. Minnesota Plant Food & Chemicals Association supports re-evaluation of and repeal of the Delaney Amendment to the Federal Food & Drug Act, since modern technology can now measure in parts per billion.

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SOIL AND CROP RESEARCH AND SPACE EXPANSION FOR SOIL SCIENCE AND AGRONOMY DEPARTMENTS, MINNESOTA AGRICULTURAL EXPERIMENT STATION

WHEREAS, research is needed in the areas of soil erosion and sedimentation, water quality, soil pollutants, irrigation and soil management for needed and efficient crop production;

WHEREAS, groups engaged in land use planning and soil management require interpretive soils information in order to plan and manage soil and water resources effectively;

WHEREAS, the lack of research in breeding, selection and management of agronomic crops in Minnesota not only undergirds the increasing need for food throughout the world but the State's economy as well;

AND WHEREAS, the buildings now occupied by the staff members and students of the Soil Science, Agronomy and associated Departments are wholly inadequate with staff members crowded into inefficient working units and in several non-contiguous buildings which makes needed cooperative efforts difficult;

THEREFORE, BE IT RESOLVED, that the Minnesota Plant Food & Chemicals Association request Congress and State Legislatures to unite in support of necessary funding to implement and accelerate these urgently needed Federal-State soil resource research and management programs and further that the State Legislature be asked to provide essential funding during the forthcoming legislative session for needed Soils and Crops building additions at the Universitv of Minnesota.

WHAT NOW?

Farmers have always been accused of moaning and groaning about how bad things are for them and as a result few are now listening to their rising chorus of financial woes. The data shows there is every good reason for not only the farmers to in fact be complaining but that their city brothern better listen and pay heed.

Consider the farmers side. He has been urged by no less a personage than the President of the United States to produce to the maximum. Church groups, internationalists -- the list is endless -- have all pleaded for maximum farm output to stabilize or lower U. S. grocery prices and for humanitarian purposes in the have-not nations. Farmers around the world have responded in remarkable fashion for on a principal food grain, wheat, the following world record obtains:

Year	World Production (Mil. of tons)
1976	409.5
1975	352.0
1974	N A
1973	371.0

U.S. wheat, corn and soybean harvests now complete were at all-time record highs. Our U.S. farmer did everything that was asked of him and more -- alas, to his detriment. City people believe only their costs go up, but farmers costs are rising at

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Remarks of Edwin M. Wheeler, President, The Fertilizer Institute, 1015 - 18th Street, N.W., Washington, D. C. 20036, presented at the Combined Soils and Fertilizer Short Course, University of Minnesota, St. Paul, Minnesota, December 15, 1976 least as rapidly as those in the urban area. With farm costs rising let us see what he received a year ago and what he is being offered for his labors today:

	11/15/75	11/15/76
Wheat (bu)	$3.58	$2.46
Corn (bu)	$2.33	$2.02
Rice (cwt)	$8.59	$6.44
Soybeans (bu)	$4.45	$6.11
Potatoes (cwt)	$3.84	$3.10

Only in soybeans did he receive a reasonable price -- the rest were going down while he paid his suppliers more. Assuming that production costs for wheat are $3.00 -- $3.25 and corn is in the $2.00 -- $2.15 range, even the most blatant anti-farmer bloc can see serious trouble at hand.

How did our city supermarket oriented friends come out? Not a bit of decrease in grocery prices. Just a slowing in the steady upward grocery price is all. Truly, the allegations of the farmer being a "profiteer" have been demolished. Should this picture long endure the farmer will be impaired to the point where food plenty would likewise be endangered!

Both farm and city dweller alike have a mutual interest in seeing that the new administration and Congress move quickly to bolster our farmers economic picture. Rather than follow the pattern of urban vs. farmer interest, these two groups must merge their efforts to see that our farmers continue to pour out the cornucopia of products while at the same time not destroying himself, his family and finally the consumer-public itself.

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