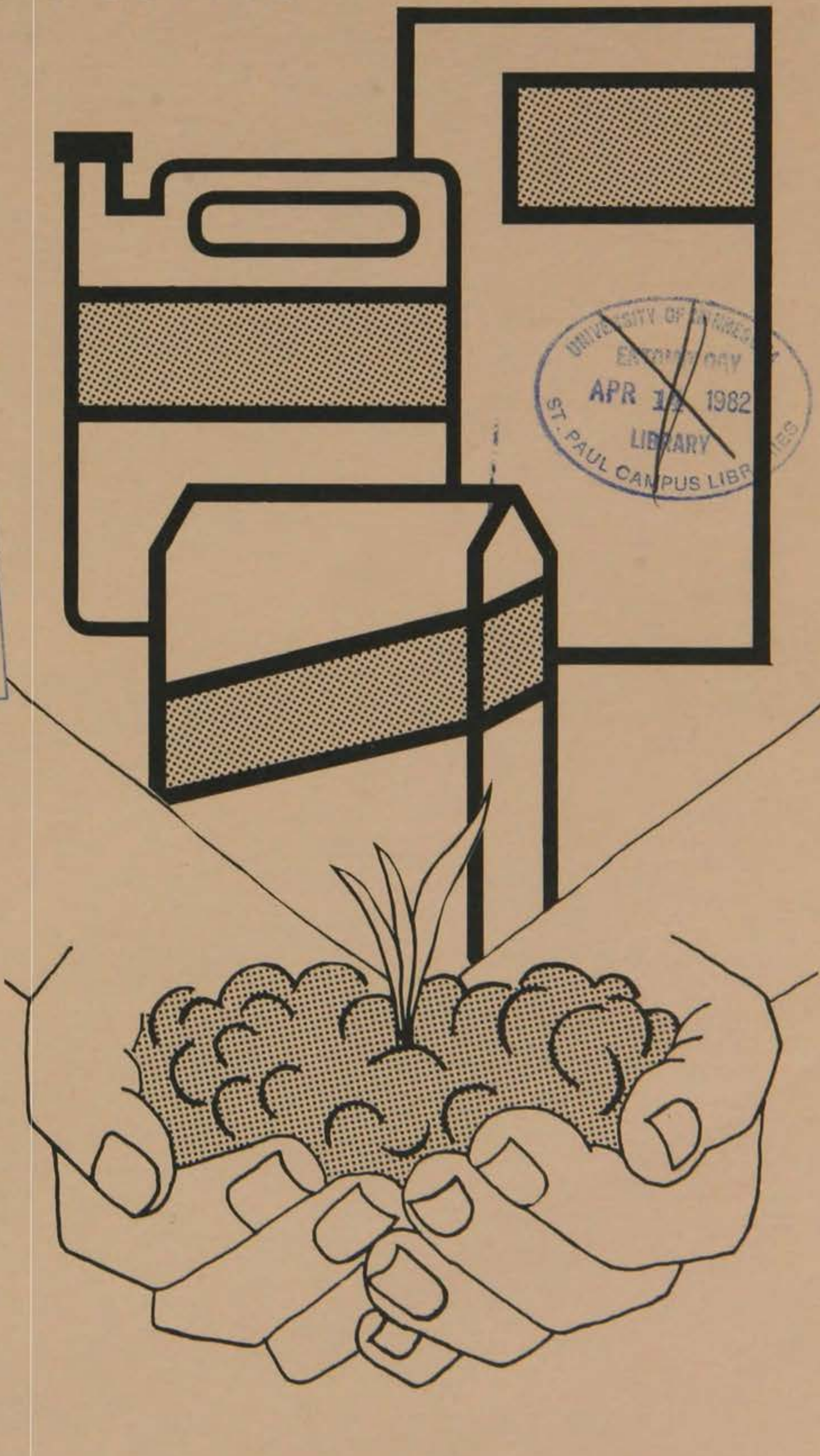
Soils, Fertilizer and Agricultural Pesticides Short Course Proceedings



December 15-16 1981
Minneapolis Auditorium

PROCEEDINGS

SOILS, FERTILIZER AND AGRICULTURAL PESTICIDES

SHORT COURSE

December 15-16, 1981

Minneapolis Auditorium

Presented by the
University of Minnesota
Institute of Agriculture, Forestry and Home Economics
Office of Special Programs
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In Cooperation With
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A QUARTER CENTURY OF PROGRESS IN SOIL SCIENCE*

W. P. Martin, Head
Department of Soil Science

This is a windup capsule report, as I near retirement, on the status of the department and some illustrative research accomplishments, with projections, for your consideration.

Minnesota's multi-billion dollar agricultural, forest and recreation industries depend on the soil and associated water resources. In recognition of the importance of soils, Soil Science is a major natural resource department in the College of Agriculture of the University of Minnesota. The Department has the responsibility for training soil scientists and for teaching others both in resident instruction and in out-reach or extension activities and in conducting both basic and applied researches.

Minnesota has some 21 million acres of cropland. It ranks among the nation's top 10 states in production of most major farm and horticultural commodities. Forests cover almost two-fifths of the land surface or some 20 million acres. Minnesota soils vary in their productivity and physical characteristics and are among the best in the nation (23 percent in "class 1"). There are more than 50 associations with large acreages of high organic matter prairie soils in the west and south, gray-forest soils in the northern half, outwash sands, peats, loessal silts along the Mississippi and Minnesota Rivers and lacustrian silts and clays in the Red River Valley. Many are calcareous and some strongly acidic. This kaleidoscope of soil types and conditions has presented both opportunity and challenge to our soil and crop management research staff, and major problems remain to be solved!

Soil Science began at Minnesota in 1907 in the Division of Chemistry and Soils, and in 1913 it was established as a separate department. It is headquartered in a modern Soil Science building which was completed in 1957, but staff and students have increased in numbers and are spread out into some three other buildings, mostly in temporary quarters. Fortunately, this situation will be remedied when the building additions for the Agronomy, Plant Pathology and Soil Science departments can be completed. This appropriation was approved by the last Legislature, working drawings and specifications are ready to go; all that is needed is for the bonds to be sold and this is dependent on interest rates, hopefully coming down soon. We are anxious to bring our staff back together again for efficiency of operation and esprit-de-corp. Many of you helped on the building addition appropriation and it is greatly appreciated!

You will be interested, I'm confident, in the breadth and scope of staff interest and research activities in the four major disciplinary areas of Soil Science, i.e., soil genesis-classification-survey; soil chemistry-fertility; soil physics-climatology-management; and soil microbiology-biochemistry. Let me first set the stage as regards the importance of food and what is happening to production levels, correlated in part with the loss of our basic soil and water resources. Some illustrative research accomplishments in the above disciplinary areas will then be outlined with ramifications for the future.

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*Presented at the 27th Annual Soils, Fertilizer and Agricultural Pesticides Workshop, Minneapolis Auditorium, December 15, 1981.

The Department recently held both a conference and a workshop on our "Soil Fertility and Management Priorities for the 1980's and Beyond," which has been most helpful in this discussion.

Food is the first basic necessity of life and without it, all other things become relatively unimportant. Food, obviously, starts with the agronomic and horticultural crops grown on the soil and dependent on water and other climatic relationships. For the first hundred years or so of agriculture in the U.S., crop yields varied with the weather and farming was labor intensive. During the last 50 years, progress made in new crop varieties and in use of fertilizers and other management inputs including mechanical equipment, have increased yields several fold. But yield curves have flattened, not plateaued, for our major crops of corn, soybeans, wheat and others; and this has occurred at a time when soaring energy costs have increased production costs to the point where the farmer is hardput to maintain a reasonable profit margin. We badly need some crop production breakthroughs. We need to maintain our more than $40 billion in agricultural exports. We need food at reasonable prices for the consumer and it has been estimated that we must increase production by some 50% or more if we are to supply food for the U.S. population alone, estimated to be over 300 million by the year 2030, an increase of 85 million from today - and what about the rest of the world!

So we have our work cut out for us and you all have an investment and interest in what we do. Most of our agricultural soils are now being utilized though improvements in the way we manage our soils are obviously important. We see accelerated erosion still active, decreasing the depth of our topsoils and adding sediment to our water sources. We see urban encroachment cutting into prime farmland. We are aware of the public's demand for the use of production inputs which are energy conserving and which do not degrade air and water quality. Again, the challenge is before us!

Illustrative major accomplishments...and continuing.

1. <u>The accelerated soil survey</u>, or inventory with interpretations (coop. SCS and FS-USDA).

   Detailed soils maps and reports, part of the National Cooperative Soil Survey, to be available for all Minnesota counties in the next 10-12 years; now roughly half complete; supported in part by legislative appropriation through the LCMR. Soil Atlas Project (same format as Geological Survey) now complete to provide generalized information on Minnesota's soil resources.

   A tremendous amount of information on soil landscape and profile characteristics, including field and laboratory data, generated by the survey is going into modern computer data banks for retrieval and use in simulation models and for interpretive purposes. This information system is essential for deciding the location, extent and suitability of soils for intensive cropping, for preservation as prime farmlands, for drainage and fertility needs, for tax equalization purposes based on crop equivalent ratings, for cropping practices and tillage to reduce soil erosion, for waste disposal, for site indexing in forestry, and related. It is our reference base for most of the other work in soil science.

And in addition, we are now able to use and research newer techniques which add discernment and provide application to other geographical areas in our international agricultural program area; and this is the technique of remote sensing via sattelite or farm level overflights. Special activities involve a rapid assay of the increase in salinity in the Red River Valley and soil management changes based on assayed overall soil moisture parameters.

2. <u>Soil chemistry-fertility</u>

Soil chemistry and fertility research in Minnesota in addition to demonstrating the need for fertilizers to supply deficient plant nutrients for maximizing crop production, established the basis for our computerized soil testing program and subsequent adoption in principle by the commercial laboratories. Use of commercial fertilizers is perhaps the most striking of our success stories in Minnesota; and it has been objectively attributed to account for a third of the total crop production increases achieved in Minnesota since 1950. It is also responsible for about a third of the total energy input into current production processes. Farmers used more than 2½ million tons of fertilizers last year (about the same for the last several years) on some 21½ million acres. This is an increase from approximately 300,000 tons 25 years ago. We haven't done as well on agricultural limestone use. Some years ago we estimated a need for over 3 million tons over a two-three year period and continuing and we are using only about 10% of that amount each year. A lot of work is still left to be done.

Our soil fertility researches through the years have increased our understanding of crop and location needs for secondary and micronutrients such as sulfur in the northern gray-wooded soil areas (It's interesting that concern for so-called "acid rain" which is high in sulfur is in those same areas where sulfur is deficient in the soil.), zinc and iron (chlorotic soybeans, for example) in the high-lime soils of western Minnesota, copper in some peat soils and a few others including boron and magnesium. A lot of attention has also been given to the specific needs of new and specialized crops such as wild rice under bog-soil conditions, grass seed, malting barley, sugar beets and related. In cooperation with the plant breeders, new varieties responsive to fertilizer applications are being developed. A good illustration is Era wheat which responds well to high levels of nitrogen, and which accounted for 60% of the wheat acreage in Minnesota last year. It returned some $40 million in profits over previous varieties for at least the past two years.

Future work will not only refine and tighten the above activities but via computer modelling, there will be more integration with other production factors to improve our extension recommendations. Recommendations will be tied more specifically to soil associations and crop varietal responsiveness; laboratory methods will be refined including micronutrient methodology; improved tests for nitrogen via profile sampling will be extended to most crops; and improved application methods to increase crop use efficiencies will be had. We haven't given up on foliar fertilization as such but much more research is needed. The energy crunch has mandated a major effort to improve fertilizer use efficiencies. Nitrogen losses, for example, are in the 50% range largely as a result of denitrification. Research on nitrification inhibitors such as N-Serv is in full swing so as to reduce denitrification losses and make fall-applied nitrogen more reliable and attractive.

3. Soil Physics and Management Research.
(Coop. Federal ARS-USDA, Morris and St. Paul.)

Researches have concentrated on problems of compaction, reduced or conservation tillage, erosion and sediment control with correlated water quality studies, and water management including irrigation. With the increased understanding we now have of many of our Minnesota soil-plant-water (climate) relationships and how these interact with environmental factors, computer modelling for improved management decision making is a major effort in the Department right now. This work will continue and be expanded as more of the production factors are brought into the model. A tillage and residue management effort is receiving most attention. This involves soil organic matter-soil structure relationships...a most complex research area. Reduced tillage systems are receiving emphasis and are becoming more widely utilized and accepted to conserve energy and reduce soil erosion. There are problems yet to be solved relating to the disposal of crop residues in reduced tillage systems (insect disease and fertilizer methodology problems) but progress must be made as the control of soil erosion (permissable soil losses) and sedimentation to improve water quality are likely to be mandated legislatively.

Agriculture is the largest user of water in Minnesota and in other parts of the U.S. and irrigation acreages are increasing rapidly (over 250,000 acreas in Minnesota). More efficient use of water in the production of crops is increasingly important and here, too, the soil physicist and climatologist in collaborative studies with the engineers and crop scientists can better understand soil-water-plant relationships to improve transport and reduce stress.

4. Soil Microbiology-Biochemistry

Research has concentrated on what we call the ecology of microorganisms in the soil-plant environment, on organic matter relationships including the disposition of crop residues, animal manures, sewage sludge and other organic waste products. This work is closely aligned to soil fertility as the release of and/or mobilization of plant nutrients during decomposition is of particular concern. Relationships to soil tilth, available soil water and tillage are also important. As noted earlier, reduced tillage practices do result in more use of pesticides (herbicides, insecticides, etc.) which must quickly decompose in the soil. Researches in the department on the longevity and residual influence of pesticidal residues are continuing and the interaction with plant nutrients will receive emphasis.

An important effort has been on nitrogen fixation with emphasis on soybeans but including other leguminous plants which support nitrogen-fixing bacteria in root nodules. This work will continue to find out how leguminous plants may utilize more atmospheric nitrogen to increase yields and protein quality, and leave more in the soil for use by other crops. Symbiotic relationships (mycorrhiza and free-living nitrogen fixers) with non-legume crops will be researched together with crop variety relationships. Genetic engineering to implant N-fixing capabilities in corn, for example, may in time be possible.

5. Agricultural climatology and soil microclimatology.

Climate and water relationships are so intimately associated with the soil-plant-climate complex that major attention has been given to the elaboration and refinement of Minnesota's climatic parameters. Data collecting networks and improved equipment have been installed at Branch Stations and in other locations throughout the State and a tremendous amount of statistical information on precipitation, soil and air temperatures, wind velocities, solar radiation and related has been data banked on the computer for use in climate-management models to improve crop production recommendations. A soil moisture network combined with the above makes possible a monthly forecast of crop available water in the profile to guide planting decisions, fertilizer rates, and irrigation scheduling, among others.

A notable achievement has been the establishment of a bi-weekly Agricultural Weather Advisory to alert farmers to potential weather problems in all areas of the State. Provides weather summaries, forecasts and crop management recommendations. Coop. with NWS and released over AP, UPI, and NWS wire services plus 2-dozen radio stations and newspapers. Coordinated closely with a State-wide Integrated Crop Pest Management Extension effort. Future work will involve refinements in the above including methodologies for improved forecasting such as drouth, flooding, frost, insect invasions (related to climate), excessive temperatures such as during pollination, etc.

6. Organic waste disposal and utilization.

Excellent research in this area has been done by departmental, including adjunct ARS-USDA, researchers. Soils activities have not only included information on site locations for sanitary land fills and septic tank activities, but methodologies and constraints in the safe use of these materials on agricultural lands. Animal manures, sewerages, canning wastes and related have been studied. Safe use is concerned principally with the buildup of heavy metals such as cadmium. Strict control of the amounts used is necessary. Nutrients in the waste materials are of course important as is the organic matter as such but the amounts likely to be used are modest, as regards the fertilizer needs of crops and should not be competitive.

7. Biomass for energy.

Another current important research area concerns the use of crop residues as raw materials for biomass. One phase concerns an evaluation of the amount of crop residue produced that could be removed for energy conversion without seriously depleting the organic matter levels in soil and also, when combined with tillage residue management practices, reduce soil erosion to acceptable levels. This is also cooperative with our ARS-USDA staff. The other phase involves not only the survey and classification of Minnesota's extensive peat deposits (some 7,000,000 acres) so as to locate those most ameniable to commercialization consistent with environmental constraints, but utilization for the production of rapidly growing biomass plants such as willows, alders, poplars, and other plants which can be harvested for gasification. Peat can of course also be used as an organic material if required and peat land reclamation studies are also underway. This area has only begun to be critically researched.

8. Computer modelling for improved management recommendations.

Although modelling has been noted in earlier sections, special emphasis is appropriate. This is the computer age and our present ability to make tillage, fertilizer, irrigation and other management recommendations for improved crop production on Minnesota's many soil types, when combined with other land use related operations will depend on an expanded data base and use of appropriate models. We must continue to accumulate accurate information on soils and on their physical, chemical and biological makeup which, together with information on soil-crop-climate relationships can improve management recommendations and also their accesibility through the computer to our farmer clientele.

The above briefly outlined researches have been conducted by the dedicated research leaders in the Department including those at the Branch Experiment Stations and our Federal and State staff colleagues and their many research assistants. For me, it has been a most rewarding association through the past more than 25 years. Here are included names you know well because of their out-State activities or appearances on this program: Drs. Rust, Caldwell, Malzer, Overdahl, Fenster, Grava, Nelson, Randall, Evans, Meredith, Farnham, Baker and Larson to name only those mostly in the soil fertility and management areas. Cooperation with researchers in related production departments has been excellent and is strongly encouraged at Minnesota.

As noted above, a lot of the research is conducted with the help of student assistants, including many of your sons and increasingly your daughters, on both the graduate and undergraduate levels. This relates directly to our perhaps most significant activity and that is in the training and education of our students. We currently have almost 100 students majoring in Soil Science including those with double majors such as Agronomy or say Agricultural Engineering. We also have some 35-40 graduate students. In spite of recession, job opportunities remain strong and we want to have more of your young people pointed our way. We can offer tham a rewarding professional course of study.

Recession is hurting! Professor Caldwell has recently retired and Dr. Simkins has accepted a permanent position with US-AID in Washington, D.C. Both positions are frozen and we cannot replace them at the present time. Drs. Bauder and Ham, who resigned last year, are fortunately being replaced, i.e. by Dr. Moncrief, a tillage specialist, from Wisconsin and by Dr. Graham, an authority on nitrogen fixation and the nutrition of soybeans among other legumes, formerly from Australia, respectively. Dr. Holt also retired as director of the Morris, MN USDA Soil and Water Research Station and he has been replaced by Dr. Benoit, from Maine. Other staff additions this past year at the Morris Station are Dr. Casky, a soil microbiologist, and Dr. Olness, a soil biochemist to work on crop residue-soil physical and chemical relationships.

Finally, I must note with regret and commendation for a full and productive life and career, the passing of Professor Jack MacGregor, just a few weeks ago. We will miss his gentlemanly counsel and association greatly.

THE SOIL NITRATE TEST FOR CORN

Gary L. Malzer
Soil Science Department
University of Minnesota

If you were to send a soil sample to the University of Minnesota Soil Testing Laboratory and inform them that you wished to grow corn; you would, along with other test results, receive a fertilizer nitrogen recommendation. This recommendation is based upon the yield goal that you provided, your previous cropping history, and a organic matter estimation. In many years this would provide the producer with a very statisfactory estimation of nitrogen need. During 1976 Minnesota experienced a very severe drought over a large portion of its corn growing region. This drought resulted in corn yields far below the fertilized yield goal. Producers asked very pertinent questions concerning the amount of fertilizer nitrogen remaining in the soil and how much they should apply for the coming growing season. The existing nitrogen recommendations could not reflect the nitrogen needs following this poor year so "Rules of Thumb" were established to aid the producer in estimating fertilizer carryover. It became readily apparent that if a soil test could be developed which would reflect the nitrogen supplying ability of a particular soil or field better fertilizer nitrogen recommendations could be made for that producer.

RESEARCH WITH THE SOIL TEST

Field research experiments were established in Western Minnesota in the fall of 1976. The research experiments consisted of replicated nitrogen rate studies conducted both on producer fields and on the University of Minnesota Experiment Stations (Southwest - Lamberton - and West Central - Morris). To examine a wide range of soil, climatic, and management conditions the largest number of locations were on farmer production fields.

When the experiments were established (in the fall if weather permitted) soil samples were obtained to a depth of five feet, separated into one foot increments and analyzed for nitrate nitrogen. Similar samples were also obtained in the spring before planting and again in the fall after harvest. Other parameters measured or evaluated included organic matter content, organic nitrogen, soil moisture, previous soil and crop management practices, production practices, leaf nitrogen, and grain yields. This extensive field survey was continued through 1980 and is currently being continued only on the experiment stations.

The soil nitrate nitrogen in the surface five feet of soil varied considerably from location to location and from year to year. The nitrate nitrogen content ranged from as low as 30# of NO_3 -N/A 5 ft to in excess of 500 # of NO_3-N/A 5 ft. The residual impact of the drought and other management practices was reflected in the next two to three years to the extent that 75-80% of the experiments that were established showed no positive yield response to the addition of fertilizer nitrogen. The nitrate nitrogen present in the soil profile was found to be an important consideration whene evaluating the probability of obtaining a yield response.

CONSIDERATIONS AND COMPONENTS OF THE SOIL NITRATE TEST FOR CORN

A soil nitrate test for predicting the nitrogen needs for corn has been implemented and is available for the shaded area on Map 1. The soil test attempts to predict the nitrogen supplying ability of the soil (NI - Nitrogen Index) by predicting the yield on a field where no nitrogen would be applied. The difference between this zero N yield prediction and the yield goal desired is used in making the nitrogen recommendation. The three major components that have gone into the development of the soil test include contributions from residual nitrate nitrogen, mineralization of nitrogen from organic matter, and previous cropping history. The assumptions and assessments of each are as follows:

Residual Nitrate Nitrogen- Three assumptions were made in assessing the contribution of residual nitrate for corn production in Western MN: 1) Corn rootings systems have the ability to go as deep as 5 ft into the soil profile to obtain No_3-N. 2) Nitrate nitrogen is contained in the soil water and supplied to the plant root with the convective flow of water (Mass flow) 3) In Western Minnesota water recharge into the zone more than 24" below the surface is minimal once the growing season starts. These assumptions were useful in determining that nitrate nitrogen is less accessible the deeper it is in the soil profile. The major reasons for this are due to limited water availability and a lower frequency of water recharge in the deeper regions of the soil profile. Based upon long term moisture recharge and water extraction patterns, it is estimated that 90% of the NO_3-N in the 0-2 ft depth and 25% of the NO_3-N in the 2-4 ft depth would be accessible to the crop. This information provided much better correlations of residual nitrates with grain yield than did total nitrate nitrogen in the soil profile. Subsoil nitrate nitrogen, although the percentage is low, may still supply substantial quantities of nitrogen to the crop if high nitrate quantities are present and moisture content of the subsoil is adequate. The difference in nitrate accessibility also stresses the importance of taking separate samples of surface soil (0-2 ft) and subsoils (2-4 ft). Total nitrate as well as where the nitrate nitrogen is in the soil profile must be considered.

Mineralization of Nitrogen from Organic Matter- This was found to be significant factor in supplying nitrogen to the crop. Depending upon the yield potential this fraction could supply one-half or more of the nitrogen required by the corn crop. The quantity of nitrogen mineralized will vary from year to year and location to location depending on the climate encountered. On the average it was determined that approximately 20 pounds of N become available during the growing season per one percent organic matter content of the surface soil.

Previous Cropping History- The nitrogen index underestimated the potential yield of corn when grown following soybeans and other legumes. This is probably because many of the nitrogen rich residues produced by the legumes have not decomposed to be reflected in the nitrate nitrogen portion, but will be decomposed much more rapidly than the native organic matter in the soil. The soil test will therefore make a credit based upon previous cropping history.

WHEN WILL THE NITRATE TEST BE MOST ADVANTAGEOUS

There are a number of restrictions and recommendations that should be considered when determining the success of the nitrate test for each situation. Apart from these, the fertilizer recommendations produced from the nitrate soil test will have the greatest effect following a year where weather conditions (drought, hail, etc) have reduced the yields from those that were anticipated. It is also a useful tool to evaluate previous management practices (high N application rates, long term manure applications, tillage, etc). The test therefore allows much greater flexibility in adjusting nitrogen fertilizer recommendations for individual situations than the previously recommended procedures.

OTHER FACTORS TO CONSIDER

The soil nitrate test for corn can be no better than the sample obtained. Sampling procedures should be similar to those used with the nitrate test for small grains. Samples may be taken in the spring or fall. If taken in the fall they should be obtained after September 15th to ensure that a large build up of nitrate nitrogen does not occur after sampling.

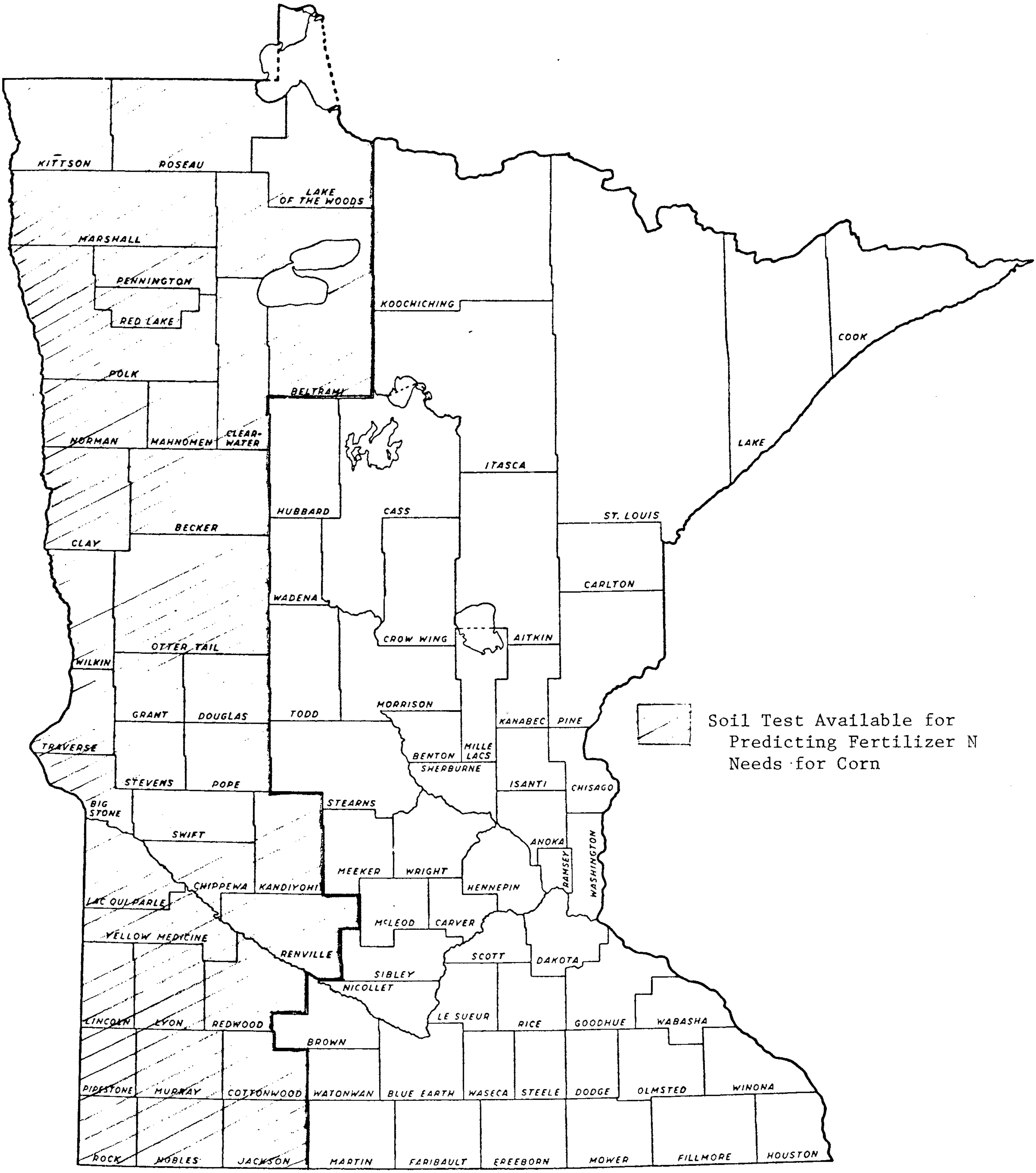
The test has been established to accept samples either from 0-2 ft or 0-2 ft and 2-4 ft depths. If only a 0-2 ft sample is submitted, the computer will automatically calculate a conservative subsoil nitrate contribution. Subsoil nitrates normally will not fluctuate greatly from year to year depending on the weather. If you sample the 2-4 ft zone and find low nitrate nitrogen it probably would not be necessary to resample the subsoil for 2-3 years. A 0-2 ft sample would be recommended on a yearly basis.

The nitrate test results are dependent on the analysis of nitrate concentrations which will change only slightly after the time of sampling. Nitrate nitrogen may be lost from the soil profile through leaching and/or denitrification. Poorly drained or coarse textured soils should therefore be avoided.

The nitrogen recommendation that will be obtained is the result of the difference between the projected yield with no nitrogen and your yield goal. Research has established in Western Minnesota that it takes about 2.5 pounds of fertilizer nitrogen to produce one bushel of corn over and above what the soil can supply. The yield goal is a very important aspect of the recommendation and should be both opimistic and realistic.

NITROGEN RECOMMENDATIONS FOR OTHER AREAS OF MINNESOTA

The Western portion of Minnesota is currently the only part of Minnesota where fertilizer recommendations will be based upon soil test results. Preliminary research would suggest that residual nitrate nitrogen is also an important consideration in the other areas of Minnesota. For example, very seldom do we obtain a nitrogen fertilizer response when the 0-2 ft nitrate test is over 150 pounds of NO_3-N. For this reason a screening test (0-2') will be implemented for corn in Central and Eastern Minnesota. This test will adjust the fertilizer nitrogen recommendation down if a high NO_3-N test is obtained. If this screening test is below 150#NO_3-N in a 0-2 ft sample or if no sample is obtained from Western Minnesota, the fertilizer nitrogen recommendation will be based on yield goal, previous cropping history and organic matter content. Additional research will be required to determine if the nitrate test can be expanded to Central or Eastern Minnesota.


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

MAP 1

CONSIDERATIONS FOR TILLAGE AND FERTILIZER IN SOUTHWESTERN MINNESOTA

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Tillage-the manipulation of soils so as to aid in the production of crops. The amount of tillage that is required will vary a great deal, depending upon the soil texture, slope, rainfall, fertility, weeds, past management, and weather related problems that have occured in the past 2 or 3 years, say nothing of machinery and etc.

Tillage is one of the many factors involved in crop production. It must also protect the environment and save the soil that it took centuries to make. It is important, therefore, that tillage be a management tool to bring out the best of all the factors that go into crop production and minimize the deficiencies or short areas. It is thus important that tillage be used as a management tool.

A background of Minnesota soils and climate is essential. The soils in southwest Minnesota were developed primarily in calcareous glacial till material of recent origin. The exception is windblown loess in the southwest corner. They developed under limited rainfall which means they are not deeply leached and the native vegetation was prairie. This gives us a dark colored high organic matter soil that is not very acid and has a high nutrient holding capacity. This combination also has a good water holding capacity available for plant use of approximately 2 inches per foot. The topography is relatively level with approximately 2/3rds less than 2% slope.

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

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

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

WHY TILL?

I think this is the one area that we first of all have to ask is "Why have we tilled in the past and what did we gain when we did these tillage operations".

PREPARE SEEDBED:

The primary thought in many people's minds on tillage was that it prepared a seedbed for the crop to be planted. This allowed the use of equipment and the horsepower we had to prepare as good a seedbed for the planting of seeds and the growth of the resulting crop. The art of tillage perhaps goes back as long as the history of crop production, that is controlled by man. Perhaps the options and alternatives with tillage due to changes in equipment, power, and other input factors have never been as great as they have in the last 10 to 20 years. Ultimately, however, we must be able to have our seeds placed in an environment that is favorable for their growth and it is very important that this growth be uniform.

CONTROL OF PESTS:

Tillage has always been used as a means of controlling pests or competition with the crop we are growing. These include the control of weeds, insects and diseases. This is accomplished by rooting out the newly emerged and growing weeds so they can not compete, by turning under the weed seeds or the parts of plants so that they could not grow or making them so late in growing and germinating that they could not compete and reproduce successfully. This also applies to insects and diseases to prevent the rapid buildup of these pests.

WATER MANAGEMENT:

Tillage has been used very effectively for the infiltration of water during storms, rains, and etc. as well as the management of excess water so that you can get it drained off without effecting the soil and the crop. In southwestern Minnesota we tend to be in the area of either too much or too little and for crop production we need to maintain almost all of the average 25 inches of moisture that is obtained for crop production. We need to have a high rate of infiltration from the surface so that we get it stored in the root zone of approximately 5 feet and thus prevent it from evaporation in the top 6 to 8 inches. Tillage should leave a rough enough surface with clods or residues to prevent wind and water erosion of the soil particles themselves. There can be a tradeoff in these areas and clodiness under many conditions can substitute for plant residue.

MANAGE AIR:

Most plant roots have to have air in order to grow and develop. The ideal soil would have 25% air out of the whole volume. This would not be in large voids, but in pores so that plant roots can carry out respiration. Part of this is tied in with compaction eliminating the larger pores in which we have our air stored and exchanged.

TEMPERATURE:

Being in the northern part of the corn belt, everything we do is determined a great deal by temperature and we can modify this somewhat with our tillage operation. This is interdependent with the amount of water we have in the surface part of the soil as well as the amount of residue and color of the soil to absorb energy during the season. A black soil with partial exposure to the south without excess moisture warms up at the fastest rate. The normal date of last frozen soil in southwestern Minnesota usually occurs about the end of the first week of April. A rough fall plowed soil will be usually the first area under similar moisture conditions to lose its frost. The last area would be with a heavy covering of light colored residue that was smooth. In order to have full length and make maximum use of our growing season, I feel that the corn and soybeans should be planted as soon after April 25th as possible and all planting should be finished by the 15th of May for long term maximum yields.

TIMELINESS:

One of the reasons for tillage is to put together a system that will allow operations to be completed in a timely manner and one that will maximize opportunity for reproduction.

PRO-TILLAGE:

Any tillage method that we utilize and will use for a long time must meet and fit into a pro-tillage system.

	TECTIVE	
	FESSIONAL	
	DUCTIVE	
	ENVIRONMENTAL	
PRO -	FICIENT	TILLAGE
	GRESSIVE	
	SCRIPTION	
	FITABLE	
	SPER	

If a tillage system is to succeed and be used widely, it must meet all of these criteria and this it must be tailored for each individual area or field. I believe that within not too long a time, at least by the end of the 1980s, farmers will have to be considering these tillage factors on soil types across a farm and perhaps have many tillage systems even on the same field. The equipment will be adaptable enough to plant under various tillage systems, we will use the systems then to control the weeds, water, wind erosion, infiltration, reduce compaction, manage temperature, and air to the best advantage of the crops.

NITROGEN MANAGEMENT OPTIONS WITH CONSERVATION TILLAGE

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INTRODUCTION

The need for conservation tillage is justified by: improved soil moisture conservation, energy requirements, time savings, and most important, erosion control. Conservation tillage systems are different and require special management techniques to make them successful. Farmers practicing conservation tillage must choose soil fertility management options (such as nitrogen source, methods of placement, and rate) compatible with the tillage system used.

COST

In choosing a nitrogen source, cost is a concern regardless of tillage. The cost per ton of material and pound of N for five N sources is shown in table 1. The range in cost per pound of N is greater than a factor of 2. From a cost standpoint, anhydrous ammonia is by far the most attractive. Urea is intermediate in price. Ammonium nitrate and ammonium nitrate-urea solutions (UAN-28% N) are about the same. In evaluating ammonium sulfate, the value of the sulfur must be considered.

VOLATILIZATION AND IMMOBILIZATION LOSSES

Nitrogen is a very transient nutrient that can assume many forms after application, some of which are gases and subject to loss. One such N form is ammonia (NH_3). If N is surface applied as urea or UAN-28% N and not incorporated, as is the case with several conservation tillage systems, substantial losses can occur. These losses can be mitigated however if about .50 inches of rain occurs within two to three days after application.

The results of a volatilization-N loss study with no till corn in Pennsylvania is shown in table 2. It is apparent from these data that when surface applying these sources of N with tillage systems that don't allow for incorporation you incur a risk of substantial N losses. This study included four years of no till corn data. In two of the four years significant increases in N uptake and grain yields resulted with non urea sources of N because there was insufficient rainfall close to application to move in the urea sources. The other N sources studied were ammonium nitrate and ammonium sulfate.

In a similar study from Maryland four N sources were studied with corn grown under a no till tillage system (table 3). Ammonium nitrate proved superior in percent recovery of applied N and again it was speculated that substantial losses of other sources studied were due to volatization of NH_3-N. The effect of N source on grain yield and protein content of corn grown under a no till system in Ohio are shown in table 4. When surface applying N, ammonium nitrate was better than sources containing urea.

Another possible N loss with tillage systems that leave large amounts of crop residue on the soil surface (till plant and no till systems) is immobilization. Immobilization is the conversion of applied N from plant available forms (mineral forms - NH_4^+ and NO_3^-) to unavailable forms (incorporation into microbial tissue - organic forms). The bacteria that tie up applied N utilize the organic carbon of crop residues as an energy source. Nitrogen losses due to immobilization are only temporary. Eventually this N will return to the plant available N pool. If a farmer chooses to surface apply N with high residue tillage systems the usual recommendation is to apply 10 to 20% in excess of the that under a moldboard system as ammonium nitrate for the first few years. With tillage systems that allow for incorporation such as chisel plow or disk operations, farmers who prefer broadcast N applications should use urea.

INJECTION OF APPLIED N

An effective N placement technique for conservation tillage systems is injection. This serves two purposes. Applied N is below the surface crop residue and subsequently the possibility of immobilization is lessened.

The other objective of N injection is to prevent volatilization losses with urea N sources. The ammonia that results from the intermediate steps in the breakdown of urea is converted to nonvolitile forms. The results of an N source and placement method study on no till corn in Indiana are shown in table 4. Anhydrous ammonia and an injected UAN-28% N resulted in the highest yields under this tillage system. The cost of anhydrous ammonia and its placement method makes it by far the most economical source of N for conservation tillage. With no till and till plant systems special applicators with coulters preceeding each knife prevent clogging by crop residue. Sealing wings on applicator knives help to ensure minimal anhydrous loss. With a chisel plow system many farmers prefer to "put down" anhydrous behind chisel shanks. If about a foot of plastic tubing (split for the last four inches) is left to trail behind each shank losses are prevented.

NITRIFICATION INHIBITORS

Another possible mechanism for loss of applied N is denitrification. This is the conversion of N from the nitrate (NO_3^-) form to gaseous nitrogen (N_2 or N_2O) which is unavailable to corn. Nitrification inhibitors prevent ammonium conversion to nitrate eliminating the risk of denitrification loss. It has been shown that there is a higher risk of denitrification under conservation tillage because of higher moisture levels. The bacteria responsible for denitrification also require an organic carbon energy source (crop residue and soil organic matter). Data from Wisconsin compares two N sources (anhydrous ammonia with a nitrification inhibitor and ammonium nitrate) and three tillage systems (till plant, chisel, and moldboard). Corn grown under a till plant system had more N uptake with the anhydrous ammonia source (Moncrief and Schulte, 1982).

SUMMARY

1. Urea and urea-ammonium nitrate solutions when broadcast and unincorporated can result in substantial N loss due to volatilization. These N sources should not be used unless your tillage system allows for incorporation.

2. Ammonium nitrate is the preferred source of surface applied unincorporated nitrogen.

3. Injecting N sources is the preferred placement with conservation tillage. Anhydrous ammonia is attractive because of its cost.

4. A nitrification inhibitor can reduce the possibility of N losses with conservation tillage due to leaching and denitrification in high rainfall areas with poorly drained or coarse textured soils.

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Table 1. Estimated cost of nitrogen fertilizer - Spring of 1982.

N Source	Cost: Dollars/ton material	Cost: Dollars/lb N
ammonium nitrate	210	.31
urea	230	.26
anhydrous ammonia	275	.17
ammonium sulfate*	170	.40
28% N solution	165	.29

*The value of the sulfur is not included in the calculation for this N source.

Table 2. The effect of time and precipitation on volatilization loss of N from surface applying urea and UAN-28% N with no till corn (After Fox and Hoffman, 1981).

Rain Inches	Days After Application	N Loss
.40	2	insignificant
.40	3	less than 10%
.15	5	10-30%
.30	9	10-30%
none	6	greater than 30%

Table 3. The effect of N source on percent recovery of applied N with no-till corn (After Bandel et al., 1980)*.

N Source	Location: Wye Institute	Location: Forage Farm
ammonium nitrate	50	70
average of other sources (prilled urea, granular urea, urea-ammonium nitrate solution - 30% N)	29	57

*Percent recovery is based on the difference in N uptake from fertilized and unfertilized plots.

Table 4. The effect of surface applied N sources on grain yields and protein content of corn grown under a no till system (After Eckert, 1980).

N Source	Grain Yield bu/A	Grain Protein %
ammonium nitrate	160	9.63
28% UAN	152	9.31
urea	136	8.31

Table 5. The effect of N source and method of placement on corn grain yields with a no till system (After Mengel, 1980).

N source and placement	year		
150 lbs/A N applied as:	1979	1980	average
	bu/A		
anhydrous ammonia	150	148	149
28% injected	150	152	151
28% surface	140	131	136
urea	140	130	135

MAINTAINING HIGH P AND K LEVELS WITH REDUCED TILLAGE SYSTEMS

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Maintaining high P and K levels throughout the plow layer is a concern that faces farmers, fertilizer dealers and researchers as we shift toward reduced tillage methods. The purpose of this discussion is to: a) present the justification for this concern, b) define what we mean by high P and K levels, and c) present some ideas on how we can provide sufficient P & K for optimum crop production with reduced tillage.

JUSTIFICATION

Numerous long-term tillage studies have shown P and K to become stratified or accumulate near the soil surface with reduced tillage. The reason is straightforward--with reduced tillage crop residue and surface-applied, immobile fertilizers are left near the soil surface whereas with the moldboard plow all is incorporated throughout the plow layer. The degree of that surface accumulation is dependent on the type of reduced tillage, the length of time since moldboard plowing, and the amount of fertilizer P and K applied.

The results shown in Table 1 indicate that with the reduced tillage treatments much of the added P and K along with the P and K brought up by the roots and recycled into the crop residue was concentrated in the top 4 inches of the soil profile. On the other hand, P and K with moldboard plowing were distributed evenly throughout the 0-12" profile. Continuous chisel plowing resulted in P and K incorporation to a depth of 4-6" after 8 years. A single spring disking or continuous no tillage for 8 years resulted in most of the P and K accumulating in the top 4".

A conservation tillage study which was started to evaluate till-plant systems (Buffalo till planter with and without ridging) was intensively sampled after three years in continuous corn. Results shown in Table 2 indicate very little incorporation of either P or K below 2 inches with the till-plant systems. This would explain why farmers with low soil P and K fertility levels who switch to till-plant systems frequently run into plant nutrition problems and yield depressions. Row placed fertilizer with the ridged system may help alleviate the situation by making the fertilizer more positionally available. Chisel plowing resulted in incorporation to a depth of 4 inches over the three year period.

Table 1. Influence of continuous tillage methods on the distribution of soil P and K within the 0-12" profile at Waseca after eight years.

Depth	Moldboard plow	Chisel plow	Disk[1/]	No tillage
	Primary Tillage			
inches				
		P (ppm)		
0-2	28	57	68	69
2-4	29	52	53	43
4-6	32	38	25	22
6-9	35	18	14	17
9-12	22	9	8	12
		K (ppm)		
0-2	135	265	290	300
2-4	125	195	160	175
4-6	135	135	110	105
6-9	130	95	90	95
9-12	125	90	85	100

[1/] One trip with light 20" diam. disk blade each spring.

Table 2. Soil P and K distribution as influenced by three years continuous tillage for corn at Waseca.

Depth	No tillage	Moldboard plow	Chisel plow	Till-Plant Ridge	Till-Plant No Ridge
inches					
			P (ppm)		
0-2	36	17	27	31	20
2-4	18	22	22	17	11
4-6	15	28	16	13	10
6-9	10	20	10	9	10
9-12	4	5	2	3	3
			K (ppm)		
0-2	245	155	240	260	205
2-4	120	190	175	150	120
4-6	115	210	135	120	120
6-9	115	190	125	120	110
9-12	105	135	110	115	110

HIGH P AND K LEVELS -- HOW HIGH?

Since 1973 studies have been conducted at three Minnesota locations (Lamberton, Morris and Waseca) to assess the response of corn to fertilizer P and K additions to soils already testing high in these nutrients. Another objective was to measure the "drawdown" when P and K were not applied to these soils which were moldboard plowed.

At Lamberton, the data in Table 3 indicate that the soil test P and K levels have been drawn down to 13 ppm P (26 lb/A) and 75 ppm K (150 lb/A) when neither P nor K have been applied to these high testing soils since 1973. The 1977-80 corn average yields were not affected by the P and K additions. Residual soil P and K at levels greater than 25 lb P/A and 150 lb K/A have been able to sustain optimum corn yields at Lamberton.

Table 3. Soil P and K in 1980 and the four-year corn yield average as affected by P and K additions to high testing soils at Lamberton.

Treatment		Soil Test[1/]		Corn Yield
P	K	P	K	1977-80 Avg.
lb P_2O_5 + K_2O/A		---ppm---		bu/A
0	0	13	75	110
0	100	10	105	109
50	100	15	100	108
100	100	24	105	114
100	0	25	80	111
100	50	24	95	111

1/ Initial P=29 ppm & K=140 ppm in 1973.

Results from Morris (Table 4) show that soil test P was reduced from 9 to 5 ppm without any addition of P since 1973 and was increased to 16 and 30 ppm with annual additions of 50 and 100 lb P_2O_5/A, respectively. Soil test K was relatively unaffected. The average corn yields from 1977-80 would indicate that a soil test P of somewhere between 5 and 16 ppm (10 and 32 lb/A) would be adequate for optimum corn production.

Table 4. Soil P and K in 1980 and the four-year corn yield average as affected by P and K additions to high testing soils at Morris.

Treatment P	Treatment K	Soil Test[1/] P	Soil Test[1/] K	Corn Yield 1977-80 Avg.
lb P_2O_5 + K_2O/A		---ppm---		bu/A
0	0	5	190	104
0	100	5	235	102
50	100	16	230	111
100	100	30	235	115
100	0	30	195	114
100	50	24	200	113

1/ Initial P=9 ppm and K=230 ppm in 1973.

The Waseca data also indicate a reduction in soil test P when P was not applied (Table 5). Soil test P was maintained at the original level with an annual fertilizer P application of 50 lb P_2O_5/A. This same P rate also optimized corn yields. Yields were unaffected by the K additions.

Table 5. Soil P and K in 1980 and the four-year corn yield average as affected by P and K additions to high testing soils at Waseca.

Treatment P	Treatment K	Soil Test[1/] P	Soil Test[1/] K	Corn Yield 1977-80 Avg.
lb P_2O_5 + K_2O/A		---ppm---		bu/A
0	0	12	100	152
0	100	11	120	154
50	100	20	115	162
100	100	30	130	164
100	0	30	110	159
100	50	26	100	163

1/ Initial P=22 ppm and K=150 ppm in 1973.

In summary, the data from these three locations indicate that optimum corn yields can be obtained at soil test levels at or above 25 lb P/A and over 200 lb K/A. Further research should be continued to determine whether these levels are adequate under reduced tillages

METHODS FOR MAINTAINING HIGH P AND K LEVELS

To maintain P and K levels at a high level, one must first start with high levels throughout the profile. This is best done by annual broadcast applications that are incorporated into the plow layer. Once this has been accomplished the following methods can be used:

(1) periodic moldboard plowing after broadcasting

(2) use of row-placed starter fertilizer

(3) injection of liquid, suspension and dry fertilizer materials or manure.

A. Moldboard plowing

We must remember that tillage is site-specific. One or two forms of tillage cannot and should not be recommended for all crop conditions. There are many areas in Minnesota where the periodic use of the moldboard plow would be considered a "best management practice". The poorly drained, level, fine-textured soils which are not susceptible to wind or water erosion would fit this category.

A corn-soybean rotation involving the moldboard plowing of corn residues in 1 of 4 years would be a tillage system that would incorporate P and K satisfactorily throughout the plow layer. Other crop production systems which would include moldboard plowing every other year or as seldom as 1 in 6 or 8 years may be satisfactory.

B. Starter fertilizer

There is some indication that yield response to starter fertilizer may occur more frequently under reduced tillage conditions than under conventional tillage systems. (University of Minnesota trials during the past decade seldomly showed a response to starter fertilizer under conventional tillage when soil test P and K were adequate.)

A conservation tillage study with continuous corn was conducted on a Webster clay loam at Waseca from 1975-1981. It was modified to include a "no starter" fertilizer treatment in 1979. Results from the 7 years shown in Table 6 indicate slightly less than a 5 bu/A difference between the moldboard plow and the till-plant (ridge) system. Equal yields were obtained between chisel plow tillage and till planting without a ridge. No tillage yields suffered.

Table 6. Influence of tillage methods and starter fertilizer on continuous corn yields at Waseca.

	Corn Yields		
	1975-81	1979-81	
Tillage Treatment	Starter[1/]	Starter	No Starter[1/]
	------------bu/A------------		
No Tillage	128	141	135
Fall plow, f.cult.	152	170	170
Fall chisel, disk, f.cult.	142	161	153
Till-Plant (Ridge)	147	160	154
Till-Plant (Flat)	143	153	155

1/ 140 lb 9-23-30/A

The comparison between the two starter fertilizer systems over the last three years showed no advantage for starter fertilizer with moldboard plowing or till planting without a ridge (Table 6). However, yield increases of 8, 6 and 6 bu/A were obtained with the use of starter fertilizer under chisel plow, till-plant (ridge) and no tillage systems, respectively.

Data obtained by Schulte, et al. in Wisconsin showed a large response to starter fertilizer (primarily K) especially under no tillage (Table 7). Yields with starter fertilizer were increased by 14 bu/A on the plowing but were increased by 35 bu/A on the unplowed plots. These data along with those from other trials indicate that potassium (K) is the nutrient to particularly watch. Even in Minnesota trials where soil K was high, plant K was the first nutrient to show some depression with continuous reduced tillage.

Because K may be needed at rather high quantities as compared P, we can see that depending on liquid starter fertilizers to supply the K will present a problem. The P:K ratios are generally high to prevent salting out and thus sufficient K will not be met by the sole use of liquid starter fertilizers. Alternatives would be dry or suspension starter materials or a combination of liquid starter fertilizer and broadcast K (plowed down) or injected K.

Table 7. Effect of plowing and row-applied fertilizer on corn yield in 1975 in Wisconsin.

Row fertilizer			Yield	
N	+ P_2O_5	+ K_2O	Plowed	Unplowed
-------lb/A-------			------bu/A-------	
0	0	0	104	57
40	40	40	118	92

1/ 80 lb K_2O/A broadcast annually from 1972-1976 on this soil which initially tested 65 ppm (L-M).

C. Fertilizer injection

At the present time there has been little research and/or farmer use of injected P and K fertilizers in Minnesota. As we shift toward more reduced tillage, I see greater emphasis being placed on the injection of all fertilizer materials. This could be accomplished with dry, liquid and suspension forms. It may be preferable to inject on an alternate year basis. Maybe a high rate every 5 or so years will be advantageous from a time and application standpoint. These and other research areas, i.e. depth, spacing, fertilizer materials, etc. must receive further research.

Dual placement of N and P is presently being used by a number of Great Plains wheat growers. This technique should perhaps be considered for Western Minnesota soils with high soil K levels. Where K levels are lower, some method of introducing K will be needed.

DISCUSSION

The uniform vertical distribution of broadcast-applied fertilizer is important because of both economic and environmental reasons. From an environmental standpoint, runoff and erosion of surface soils containing high amounts of unincorporated fertilizers is extremely detrimental. Surface water contamination generally results from this non-point pollution and the fertilizer and agricultural industry suffers.

Economically, the equal distribution of fertility throughout the plow zone provides insurance against positional unavailability, especially in dry years when root activity in the surface layer may be reduced.

A number of cases have been reported throughout the Corn Belt where farmers have abandoned conservation tillage systems after having tried the system for only a short time. In many instances, low soil fertility has been diagnosed as the causual problem. As a preventative measure, we must build our soil fertility to high levels throughout the plow profile before switching to reduced or conservation tillage systems. Unless this is done farmers may become dissatisfied with the tillage system for reasons other than tillage. Profits will be reduced. As a result, they will switch back to their old conventional tillage system and in the process may sacrifice erosion control and future productivity.

PESTICIDES AND PEST CONTROL: AN HISTORICAL PERSPECTIVE

by

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I am an entomologist by training and thus feel I have been in on the ground floor of a major evolution in pesticides and pest control, including the development of the Integrated Pest Management (IPM) concept. In fact, at the risk of irking some of my plant pathology and weed science colleagues present, I would like to give entomologists credit for starting IPM. However, in doing so, it would not be fair if I did not qualify that statement. We were in more trouble than the other plant protection scientists! While the use of chemical pesticides has dramatically increased the production of food and fiber, the fallacy of the view that pest problems could be solved with pesticides alone became apparent as problems of resistance, disruption of natural enemy action, pollution, and undesirable residues multiplied. These problems were particularly severe as associated with the use of insecticides, which were being more widely used than other pesticides and are more toxic to humans and other warm-blooded animals. Thus, it is understandable that entomologists were the first of the pest control specialists to take overt action to reorient their research and extension efforts. The necessity for reorientation was more urgent than in the case of plant pathology, nematology, or weed science, but not necessarily more desirable from an academic view. Weed scientists are now experiencing a proliferation of synthetic organic herbicide usage similar to that which occurred with insecticides in the 1950's and early 1960's.

Integrated pest management, an interdisciplinary approach to solving the complex pest problems confronting modern agricluture, has been evolving over the past several years. Recent successes with IPM for key pests in a few agroecosystems project considerable promise for the future. We can document some dramatic cases where yields have been stabilized or even increased, while reducing the farmer's costs and minimizing pesticide contamination of the environment. However, the rosy picture which many so easily paint with words is largely a composite generalized goal which is realized only partially for a few pest situations at present. Nevertheless, it is an important conceptual framework for the development of improved procedures for managing pest situations on a wide array of commodities.

I think we can learn a valuable lesson by taking an historical diversion, from a sociological perspective. I want to look back at the developing pesticide problem - how we got into the problem we did with pesticide misuse and abuse, which in turn led us into the now emerging era of pest management, including improved strategies for pesticide use and management. I would like to consider the problem with respect to: (1) the social taboos about insects and disease that pervade our society; and (2) the equally strong set of taboos that permeate our society about poisons; and to approach the problem by exploring what happens when the tabooed poisons are used to combat the tabooed bugs. For example, consider any picnic of city people where the mother tells the child not to handle a bug because it might sting or bite. Did you know that the term "bug" until the 17th century was an English word for "evil spirit". After that it came to be defined as an insect, a creepy, crawling thing. But it still has its connotation of the devil. And this shows up in our culture in many ways. For example, consider "bogeyman," remembering that bogey is derived from the same root as bug. World War II fighter pilots called an enemy airplane a bogey at two o'clock. We talk of a bogey in golf as a less than desirable score. Did your mother ever suggest you would drive her to the bughouse? And we talk about removing the bugs from a new car, and about bugaboos. We learn that the American Embassy in Moscow has been bugged.

There has always been a related taboo, the social taboo on disease and decay. If you think it no longer exists, recall an experience of finding a worm in your broccoli or lettuce. And we have all seen movies in which a gypsy put a live cockroach in his food, after he had consumed most of the meal, to avoid paying. Or the old question, "What is worse than finding a fly in the cake you have been eating?" -- "To find half a fly."

These taboos find their way into law. In 1906 the first pure food law (The Food & Drug Act) was passed. It contained the rationale that it would protect citizens from food that is filthy, putrid and unfit for human consumption. Are grasshoppers and fly maggots really unfit? Is it so unrealistic to ask, why not eat insects? But that is another story.

In 1930 the FDA tolerance for contamination in canned pie cherries was 7 cherry maggots per can. Of course, this was before the dawn of synthetic organic pesticides. Cherry growers could not get all of the maggots out, and thus a tolerance was necessary -- just as speed laws have a tolerance of 5 mph over, and of course we now have tolerances for pesticide residues.

An interesting result of the social taboos on bugs and disease is the establishment and cultivation by society of the protective sciences of entomology and plant pathology. My whole professional life rests on the fact that the public is willing to pay for entomologists and plant pathologists to protect them from food that is filthy, putrid and unfit for human consumption, whereas, weed science was perhaps more directly the result of the need to enhance yields. As a result, we in these sciences were flattered and stimulated to get on with the job of extirpating the devils. We were Sir Galahads riding in search of the Holy Grail. And so we began to fight the bugs and the blights with all the tools we had. We released lady bugs to eat aphids, we drained swamps to control mosquitoes, we bred parasites and liberated them, and we plowed under corn to get rid of corn borers. But -- on came the bugs! We never did find parasites that gave good commercial control of the codling moth or pea aphid. And we found no really resistant varieties that would control potato blight and apple scab.

So we turned to poisons! The organisms that we fight are alive, so we said, we will poison them -- selectively. We will use poisons that will poison the pest under the conditions of use but will not poison people under conditions of consumption. We did poorly for the first 100 years after sciences of entomology and plant pathology were first established. We had ancient remedies available, such as inorganic pesticides containing arsenic, mercury, sulfur, copper, and zinc. We also acquired derris (rotenone), pyrethrum, and nicotine, naturally occurring insecticides, but they did not give us really good control. On came the bugs, the Colorado potato beetle marched from the Rocky Mountains to the east coast. The San Jose scale nearly wiped out the citrus industry in California.

And then in the 1940's we had success beyond our wildest dreams with DDT, Zineb, and some of the early phosphate pesticides, which controlled the potato beetle and late blight, and the typhus epidemic in Italy. And we kept malaria down. There were no more bedbugs, or flies in cow barns, or maggots in cherry cans. The tolerance for maggots in cherries eventually dropped to zero maggots per can. We in the "protective" sciences busted our buttons, and rightly so. Potato yields tripled. Agriculture became more efficient. For the first time in the history of man, a culture could produce more food than it could consume. We forgot the lean years of the 1930's in the Great Plains, when grasshoppers and rust took the wheat; the years became fat years. No longer did the bugs sit down first at the table and consume our food before we had a chance at it. We were proud, and the grateful world gave Herman Műller a Nobel Prize in 1948 for discovering the insecticidal properties of DDT. The taboo on DDT was yet to be called down. The field of entomology had reached the peak of social laudos. We had fulfilled our charge and had Beelzebug on the run!

The force that would claw down this achievement would arise from the taboo on poisons. This taboo is built just as deeply into our culture as the taboo against insects. People slowly woke up to the fact that some pesticides are, in fact, poisons. They knew that pesticides were poisonous to insects, but did not realize that they might be poisonous to people. This is due in part to city people being far from agricultural reality. But eventually, we began to hear more and more people say, "Don't eat that sprayed food, it might be poisonous". We in the protective agricultural sciences did not really sense early enough this rise in importance of the poison taboo. There was a first faint signal in 1938, when the British stopped buying North American apples because of arsenate of lead. Of course, they also wanted their own apples to sell better on the local market. This almost killed the Nova Scotia apple industry. In the mid 1950's we saw another signal, in the form of legislation with the Miller Bill and the Delaney Amendment.

In 1957 there was a strong signal, when the Plant Pest Control Division of USDA sprayed DDT all over Long Island and Westchester County (near New York City) for the control of gypsy moth. Large acreages were sprayed rather indiscriminately with airplanes in an attempt to eradicate the gypsy moth. This was probably the most powerful incident in provoking rapidly rising opposition to the use of poisons.

In 1962, much of this rising opposition was brought into focus with the publication of <u>Silent Spring</u> by Rachel Carson. The anti-spray people zeroed in on DDT, which was probably the least poisonous to man of all the powerful insecticides. Why then was DDT chosen? Perhaps because it had climbed the highest on the totem pole and everyone could see it. DDT was widely known but it was also reasonably safe. Yet Miss Carson zeroed in on DDT. What did she start? What has happened? The farmer is more careful about pesticides than he used to be. He should occupy a high position in social thinking because he feeds the citizen. But I don't think he does. The farmer is under strong economic pressure from processors, distributors and consumers of food to produce food that is not filthy, putrid and unfit for human consumption.

But most people do not associate the requirement of food that is free of "filth" with the need for pesticides. When a housewife goes to the market, her social taboos against contaminated food force her to buy pest-free food. Therefore, if the farmer, in attempting to deal with the taboo on poisons, lets his food go to the market with pests on it, he runs hard into the taboo against contaminated foods. He is between the devil and the deep blue sea. He has to use pesticides to compete with neighboring farmers, to grow food of high enough quality to market.

The issue of the vicious circle created by Federal and State regulatory laws pertaining to food bears mention too. How far will FDA and EPA go in insisting on maggot-free cherries and a zero tolerance on residues of the pesticide used to control the pest?

We have changed too. We are not so anxious now to eradicate pests or to necessarily kill 99% of them. Some people are more anxious to keep poison out of their food than bugs out of the farmer's field. Of course, we in the plant protection sciences, in response to consumer demand, created the "clean field syndrome" among farmers. And we still fight that syndrome as we attempt to change grower practices from a philosophy of unilateral pest control with chemicals to integrated pest management.

Entomology was hit very hard. We were, and still are, called Stone Age scientists, inadequate, incompetent, poor in judgment, devoid of any spark of human kindness in our systems, unconcerned about the environment, guilty of having sold our souls for a few paltry dollars. Of course, we rushed into unilateral biological control. This was politically smart, but the chances of any rapid success were small in most cases.

The various social pressures are surely changing our laws. Laws have tightened so that it is difficult to produce new pesticides just at the time when we need safer, more selective ones. Chemical companies are reducing their new product development because they are spending more and more resources to defend older products. And the profit incentive is evaporating and the risks increasing with regard to new product development.

We face the problem of using something we cannot see (chemical pesticides) to rid food products of something we can see (pests). Increased production is relegated to more of a side benefit rather than the main objective. The educational challenge is one of reorienting the city dwellers, and the grower as well. I do not have a ready solution, but we surely need to begin facing the challenge! You can help us.

The points I have covered thus far have been contributing factors to the dramatic changes we have seen in pesticide use and pest control practices in the last five years. Now, a brief look at the present and the future.

In the process of growing a crop or raising livestock, a producer must make many deicisions, of which only a few are related directly to pest management. The point I wish to make is that in our agriculture, the producer ultimately makes his own decisions -- he is the final integrator of the managment information available to him. But in our modern agricultural system, the producer faces three problems regarding that available information.

1. The quantity of information is growing so rapidly that he cannot afford the time that would be required to make the best use of it.

2. The information is becoming continually more technical and therefore beyond complete comprehension by the average producer.

3. Much of the information is specific to particular locations or situations and thus may lack direct applicability to his needs.

How do we help producers to overcome these problems? This is where you come in. For the past 60 years, producers have received considerable assistance from state extension services. The network of extension specialists and county agents has screened, synthesized, interpreted and communicated information to our producers. And the extension contribution to the present condition of U.S. agriculture remains unquestioned. But the efforts of extension alone to transmit usable information in an interdisciplinary decision-making mode to meet today's crop and animal production needs, including pest management, are increasingly hindered. Thus, we see an emerging cadre of private consulting firms and now the more recent interest of computer corporations such as Control Data in IPM. Extension still has a major role as the primary link with a university's academic and research resources, but we need to strike a balance and a cooperative spirit between the private and public sectors.

Despite those who accuse IPM as being the most abused and overused acronym in agriculture today, I like it and the concept it represents. We must also recognize that pesticides are often the major tactic for managing many of our key pests. Thus, successful pesticides management is a major component of successful pest management. At the same time, let's not become too self-centered. Crop management is our final goal. It does no good to save a producer's crop from pests if it is lost to drought, improper fertilization or mistiming of harvest. Yes, IPM philosophically represents a concept around which a better approach to pesticides management and total crop management can evolve -- and you can help make that happen. Good luck, and thank you for your attention.

MINNESOTA EUROPEAN CORN BORER FALL SURVEY 1981

DISTRICT	NO. COUNTIES	% PLANTS INFESTED	% SHANKS INFESTED	NO. BORERS /100 PLANTS	
				1980	1981
WC	6	28	6	43	22
C	6	37	11	29	44
EC	5	12	3	30	18
SW	5	27	9	34	25
SC	5	25	6	36	28
SE	5	30	7	28	29
STATEWIDE	32	26	7	33	28

MINNESOTA CORN ROOTWORM ADULT SURVEY 1981

DISTRICT	NO. COUNTIES	NO. FIELDS CORN/CORN	NO. BEETLES/ACRE		NORTHERN:WESTERN SPECIES	PERCENT LODGED
			1980	1981		
WC	12	39	32,510	32,333	94:6	0.3
C	9	36	34,920	27,828	99:1	1.8
EC	5	23	4,124	3,860	94:6	0
SW	9	27	68,920	52,162	82:18	Trace
SC	9	34	43,696	24,141	92:8	0.3
SE	5	21	52,301	24,253	88:12	0.4
STATEWIDE	49	180	39,412	27,429	91:9	0.5

From the Division of Plant Industry, Minnesota Department of Agriculture.

Minnesota

1981 Corn Rootworm Control Trials

Southern Experiment Station - Waseca

(Lueschen & Miller) Trap Crop 1980, Planted May 1

(Averages of 4 Replications)

Treatment	Rate oz. per 1000 ft of row	Placement	Av. Root Rating (1-6)	Av. Yield Bu/A
BASF 263-11-I 10G	9 oz	Band	2.05	191.2
BASF 263-11-I 10G	12 oz	Band	2.15	192.7
Furadan 15G	8 oz	Band	2.30	188.3
BASF 263-11-I 10G	12 oz	Furrow	2.35	204.4
Amaze 20G	6 oz	Band	2.45	189.9
Thimet 15G	8 oz	Band*	2.55	196.0
BASF 263-11-I 10G	9 oz	Furrow	2.60	192.8
Furadan 10G	12 oz	Band	2.60	200.9
Thimet 20G	6 oz	Band*	2.65	173.0
Counter 15G	8 oz	Furrow	2.65	194.7
Counter 15G	8 oz	Band	2.70	184.3
Landrin 15G	8 oz	Band	2.75	195.6
Furadan 15G	8 oz	Furrow	2.85	183.5
Mocap 15G	8 oz	Band*	2.85	180.5
Lorsban 15G	8 oz	Band	3.05	195.1
Tattoo 10G	12 oz	Band	3.25	184.0
Dyfonate 20G	6 oz	Band*	3.55	178.1
Check			4.90	148.9

*Thimet, Mocap and Dyfonate were applied with a rear mounted bander followed by chain incorporation on MaxEmerge Planter. Other bands applied ahead or press wheel.

Minnesota

1981 Corn Rootworm Control Trials

West Central Experiment Station - Morris

(Warnes) Furadan history field, Planted May 7

(four replications)

Treatment	Rate oz. per 1000 ft or row	Placement	Av. Root Rating (1-6)	Av. Yield Bu/A
BASF 263-11-I 10G	12 oz	Furrow	2.00	117.0
Amaze 20G	6 oz	Band	2.00	120.4
Counter 15G	8 oz	Band	2.00	118.8
Counter 20G	6 oz	Band	2.00	121.6
BASF 263-11-I 10G	12 oz	Band	2.05	120.4
BASF 263-11-I 10G	9 oz	Band	2.05	121.1
BASF 263-11-I 10G	9 oz	Furrow	2.05	120.3
Counter 20G	6 oz	Furrow	2.10	118.2
Lorsban 15G	8 oz	Band	2.10	121.8
Counter 15G	8 oz	Furrow	2.15	121.7
Thimet 20G	6 oz	Band	2.15	118.9
Thimet 15G	8 oz	Band	2.30	117.0
Dyfonate 20G	6 oz	Band	2.35	116.0
Landrin 15G	8 oz	Band	2.40	118.1
Furadan 15G	8 oz	Furrow	2.55	118.7
Furadan 15G	8 oz	Band	2.75	121.1
Tattoo 10G	12 oz	Band	2.75	119.0
Furadan 10G	12 oz	Band	2.95	122.0
Mocap 15G	8 oz	Band	3.05	114.2
Check			3.65	107.0

LONG TERM PERFORMANCE OF ROOTWORM INSECTICIDES
(1971-1981 LAMBERTON, MORRIS, WASECA)

PRODUCT (NO. OF OBSERVATIONS YRS + LOCATIONS)	AV. ROOT DAMAGE RATING (1-6)
COUNTER (20)	2.10
AMAZE (11)	2.13
FURADAN (16)	2.15
THIMET (23)	2.29
DYFONATE (20)	2.30
MOCAP (20)	2.47
LORSBAN (20)	2.48
CHECKS (24)	3.50
FURADAN ON FURADAN "PROBLEM" SITES (9)	3.54

SUMMARY OF 1982 SUGGESTIONS FOR
THE USE OF INSECTICIDES TO CONTROL MAJOR CROP INSECTS

CROP	PEST	CHEMICAL	RATE ai/A	LIMITATIONS Preharvest interval
Alfalfa				
	Alfalfa weevil	azinphosmethyl (Guthion)	½-3/4 lb.	21 days, one application per cutting
		carbofuran (Furadan)	¼-½ lb	7 days-¼lb 14 days - ½lb
		methyl parathion	¼ lb	15 days
		phosmet (Imidan)	1 lb.	7 days, one application per cutting
		methidathion (Supracide)	½ lb	10 days
		mixtures of methoxychlor plus diazinon or malathion	1+½ or 3/4 + 3/4	7 days
	Aphids and Leafhoppers	diazinon	½ lb	7 days
		dimethoate (Cygon, et al)	¼-½ lb	10 days, one application per cutting
		malathion	1 lb.	none
		parathion	¼ lb	15 days
	Cutworms	carbaryl (Sevin)	1½ lb	none
		malathion	1 lb	none
		trichlorfon (Dylox, Proxol)	1 lb	7 days
		methomyl (Lannate, Nudrin)	¼-1 lb	7 days for grazing, none for hay.
	Potato leafhopper	azinphosmethyl (Guthion)	¼-½ lb	14 days
		carbaryl (Sevin)	1 bl	none
		diazinon	½ lb	7 days
		methoxychlor	1 lb	7 days

	malathion	1 lb	none
	methidathion (Supracide)	½ lb	10 days
	phosmet (Imidan)	1 lb	7 days, one application per cutting
	mixture of methoxychlor with diazinon or malathion		7 days
Grasshoppers			
	azinphosmethyl (Guthion)	½-3/4 lb	14 days-½ 21 days-3/4
	carbaryl (Sevin)	1-1½ lb	none
	carbofuran (Furadan)	2 to 4 oz	7 days, one application per season
	diazinon	½ lb	7 days
	dimethoate (Cygon, et. al)	¼-½ lb	10 days, one application
	malathion	1½ or ½ lb ULV	5 days ULV none dilute
Corn, Field			
Armyworm			
	carbaryl (Sevin)	1-2 lb	None
	malathion	1-1½ lb	5 days
	methomyl (Lannate, Nudrin)	¼-½ lb	3 days forage; none grain
	toxaphene	2 lb	None for grain Do not use stalks, husks, leaves for feed for meat or milk animals.
	trichlorfon (Dylox, Proxol)	1 lb	None
Corn root-worms		Ounces of formulation per 1000 ft. of row	
	carbofuran (Furadan 10 G)	12 oz	
	chlorphyrifos (Lorsban 15 G)	8 oz	
	ethoprop (Mocap 15 G)	8 oz	

fonofos	6 oz
(Dyfonate 20 G)	6 oz
isofenphos	6 oz
(Amaze 20 G)	6 oz
phorate	
(Thimet 15 G)	8 oz
(Thimet 20 G)	6 oz
terbufos	
(Counter 15 G)	8 oz

Apply in 6 to 7 inch bands over the rows lightly incorporated at planting time. Liquid formulations should be applied in bands as granules or in split bands at or above seed level away from the seed.

Those products labelled for basal post emergence application should be applied about June 10-20 but may not give adequate control under dry soil conditions.

Do not apply carbofuran (Furadan) in successive years in the same field.

Cutworms

Some soil insecticides such as Dyfonate 20 G, Lorsban 15 G, and Mocap 15 G, are labelled for cutworms and may give control of light to moderate infestations when applied at planting time as for rootworms. Heavier infestations may require a postemergence rescue treatment.

	carbaryl (Sevin)	1 - 2 lb spray or bait	None Apply spray in 12 inch bands over rows. Broadcast or band apply bait.
	chlorpyrifos (Lorsban 4E)	1 - 1½ lbs	None. (50 days forage, silage) Broadcast by air or ground equip. Lightly incorporate under dry conditions.
	trichlorfon (Dylox, Proxol)	1 lb	None Apply spray in 12 inch bands over rows,
European Corn Borer, 1st brood			
	carbaryl (Sevin	1½lb	None Spray or granules
	carbofuran (Furadan)	1 lb	Granules; no more than 2 applicitions.
	diazinon	1 lb	granules. None for grain, 10 days forage.
	fonofos (Dyfonate)	1 lb	30 days, granules
	phorate (Thimet)	1 lb	30 days, one application granules

	toxaphene	2 lb	corn for grain only. granules
Grasshoppers			
	carbaryl (Sevin)	1½ lb	none
	chlorpyrifos (Lorsban 4E)	¼-½ lb	No more than 3 pints 4E per season
	diazinon	½ lb	none
	malathion	1 lb or ½ lb ULV	5 days
	toxaphene	1½ lb	corn for grain only
Seed corn maggot, seed corn beetle, wireworms	diazinon 1oz/bu. lindane ½-1 oz/bu		seed treatment only
seed corn maggot	chlorpyrifos (Lorsban)	1 lb	Band in row at planting time. Lorsban and Amaze and Counter may be placed in furrow.
	fonofos (Dyfonate)	1 lb	
	isofenphos (Amaze)	1 lb	
	terbufos (Counter)	1-2 lb	
Wireworms	carbofuran (Furadan)	2 lb	Row treatment at planting time. Furadan, Lorsban, Amaze Counter may be placed in furrow Some of these chemicals plus diazinon are registered for broadcast pre-plant incorporated treatment
	chlorpyrifos (Lorsban)	1-2 lb	
	ethoprop (Mocap)	1 lb	
	isofenphos (Amaze)	1 lb	
	terbufos (Counter)	1-2lb	
	fonofos (Dyfonate)	1 lb	
White grubs			
	chlorpyrifos (Lorsban)	2 lb	Broadcast ppi., band or furrow treatment at planting
	isofenphos (Amaze)	1 lb	furrow or band at planting
	terbufos (Counter)	2 lb	furrow or band at planting

Most of these products will aid in reducing white grub damage but may not control heavy infestations.

Soybeans				
	Bean Leaf beetle	carbaryl (Sevin)	1 lb	none
	Cutworms	carbaryl (Sevin)	1½ lb	none
		toxaphene	1½ lb	21 days, do not feed forage
	Grasshoppers	acephate (Orthene)	¼-½ lb	14 days, do not feed forage
		carbaryl (Sevin)	1½ lb	none
		dimethoate (Cygon, et al)	¼-½ lb	7 days
		malathion	½ lb ULV	7 days
		toxaphene	1½ lb	21 days, do not feed forage
	Green clover worm	azinphosmethyl (Guthion)	6 to 8 oz	45 days
		<u>Bacillius thuringensis</u> (Dipel, Sok Bt., Thuricide, Biotrol)		as labelled
		carbaryl (Sevin)	1 lb	none
		dimethoate (Cygon, et al)	¼-½ lb	7 days
		fenvalerate (Pydrin)	0.05-0.1 lb	21 days
		malathion	1 lb	7 days
	Seed corn maggot	diazinon	1 oz/bu	seed treatment only
		lindane	1/2 to 1 oz/bu	" " "

Small grains

Aphids			
	malathion	1 lb	none
	methyl parathion	4 oz	none
	Penncap M	6-8 oz	15 days
	parathion (ethyl)	4 oz	15 days
	dimethoate (Cygon, et al)	¼-1/3 lb	wheat only 60 days
	disulfoton (DiSyston)	¼-3/4 lb	wheat only 30 days do not graze
Armyworm			
	carbaryl (Sevin)	1-1½ lb	wheat only
	malathion	1 ½ lb	21 days
	methomyl (Lannate, Nudrin)	¼-½ lb	7 days
	trichlorfon (Dylox, Proxol)		21 days, no more than 3 applications
	toxaphene	2 lb	for grain only do not use straw for feed or bedding
Grasshoppers			
	acephate (Orthene)	1/6 lb	wheat only
	dimethoate (Cygon)	¼-½ lb	wheat only 60 days
	malathion	1 lb or ½ lb ULV	7 days
	methyl parathion (Penncap M)	½ lb	15 days
	toxaphene	1½ lb	for grain only; do not use straw for feed or bedding for meat or milk animals.
Wireworms			
	lindane	½ to 1 oz/bu	seed treatment only

Corn, Sweet				
	Aphids	diazinon	½ lb	None
		malathion	1 lb	5 days
		parathion (ethyl)	½ lb	12 days
		oxydemeton-methyl (Meta Systox-R)	6-8 oz	7 days
	Armyworms	carbaryl (Sevin)	1½-2 lb	None
		malathion	1 lb	5 days
		methomyl (Lannate, Nudrin)	¼-½ lb	none for corn, 3 days for forage
		trichlorfon (Dylox, Proxol)	½-1 lb	none
	Cutworms	carbaryl (Sevin)	2 lb bait or spray	none
		chlorpyrifos (Lorsban 4E)	1-1½ lb	None for grain (50 days forage, silage)
		diazinon	4 lb	broadcast ppi
		trichlorfon (Dylox, Proxol)	1 lb	none
	European Corn borer	carbaryl (Sevin)	1½-2 lb	none
		diazinon	1½ lb	none
		methomyl (Lannate, Nudrin)	¼-½ lb	none (3 days forage, silage)
		methyl parathion (Penncap M)	½ lb	3 days (12 days forage, silage)
	Corn rootworm	chlorpyrifos (Lorsban) ethoprop (Mocap) fonofos (Dyfonate) isofenphos (Amaze) phorate (Thimet) terbufos (Counter)		Same as for field corn

	Seed corn maggot, beetle, wireworm	diazinon lindane	1 oz/bu ½-1 oz/bu	Seed treatment only
Sugar Beet				
	Beet webworm	carbaryl (Sevin)	1½ lb	14 days, tops
		endosulfan (Thiodan)	1 lb	Do not feed tops
		methomyl (Lannate, Nudrin)	¼=½	7 days (30 days tops)
		parathion	4-8 oz	15 days
		trichlorfon (Dylox)	1 lb	14 days
	Cutworms	carbaryl (Sevin)	1-2 lb spray or bait	14 days tops
		chlorpyrifos (Lorsban)	1 lb	row treatment at planting time or broadcast spray postemergence.
		Trichlorfon (Dylox, Proxol)	1 lb	14 days
	Root maggots	aldicarb (Temik)	1½-2 lb	Row treatment at planting time. Some products are also registered for side dressing at the time of fly activity.
		carbofuran (Furadan)	2 lb	
		chlorpyrifos (Lorsban)	1½ -2 lb	
		diazinon	1-2 lb	
		fonofos (Dyfonate)	1-1½ lb	
		terbufos (Counter)	1-2 lb	

Wireworms

(Some of the root maggot insecticides will also provide wireworm control)

diazinon	4 lb	Broadcast ppi
fonofos (Dyfonate)	4 lb	" "
lindane	½-1 oz/bu	seed treatment

Sunflower	Soil insects	lindane	1-1½ oz/bu	Seed treatment. 2-3/4 oz DB green/bushel.
	Cutworm	Toxaphene appears to be ineffective. Emergency request will be made for effective material, when needed.		
		chlorpyrifos (Lorsban)	1 lb.	For seed production fields only
		Treat when stand reduction approaches 25% of recommended stand and larval numbers exceed 1 per 2 sq. ft.		
	Stem weevil	methidathion (Supracide)	½ lb.	50 days before harvest
		methyl parathion	1 lb.	30 days before harvest
		Two adults per plant at 10-20 leaf stage		
	Grasshoppers Sunflower beetle Thistle caterpillar			
		carbaryl (Sevin)	1¼-2½ lb.	60 days prior to harvest
		toxaphene	1½-2 lb.	Not more than 2 applications. Do not feed or graze plants.
		Plants can be defoliated up to 25% with no effect on yield.		
	Seed weevil	methidathion (Supracide)	½ lb.	50 days before harvest
		methyl parathion	1 lb.	30 days before harvest
		10 to 20 adults per plant. First treatment when 60 to 80% of plants show bloom. Efficacy will be poor when first treatment is made after bloom in entire field is 60 to 70% complete. Second treatment may be necessary. Pollinator activity is of benefit to grower so make every possible attempt to avoid beekills.		
	Sunflower moth Banded sunflower moth			
		endosulfan (Thiodan)	1 lb.	No more than 3 applications. Highly toxic to bees.
		methidathion (Supracide)	½ lb.	2 treatments at least 50 days prior to harvest

methyl parations	1 lb.	No more than 3 applications. 30 days before harvest. Highly toxic to bees.

Action levels for sunflower moth = 2 adults per plant at time migrant moth arrives. Banded moth = 8 adults per plant. Banded moth adults are very difficult to monitor.

Sunflower midge	Presently labeled compounds have not provided midge control even when applied at short intervals during adult midge flight. When attempting to produce sunflower in the Red River Valley either delay planting or plant on more than one date using midge tolerant hybrids.

HEAD SMUT OF CORN AND CHEMICAL CONTROL

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Head smut of corn caused by *Sphacelotheca reiliana* (Kühn) Clint, was recognized on August 1, 1980 in a field at the Staples AVTI in Wadena county. Surveys that fall identified additional infected fields in Otter Tail, Stearns, and Todd Counties. Head smut was present in 1981 in all locations except Stearns county; in this county the fields infested in 1980 were either planted to grain or soybeans. Since this disease differs from common smut in that head smut is soilborne and infects the corn plant in the seedling stage, seed treatment and or soil treatments were tested as a control method.

Corn hybrids known to be susceptible and moderately susceptible to head smut were planted in artificially infested soil on each of three planting dates, 4/28, 5/12 and 5/27. Chemicals as seed treatments, granules over the furrow, or granules in the furrow and as a spray were applied. The plants were examined on 9/23, 9/24 and 10/8 for head smut sori on either the tassel and/or the ear. Data is reported as percentage infection.

A group of selected hybrids were also evaluated for resistance to this disease in a similar manner. The hybrid performance was averaged over the three planting dates and ranked into four groups; resistant - no smut, moderately resistant - up to 5% smut, moderately susceptible - 5.1 - 10% smut, and susceptible - over 10% smut. This information is offered to the public to aid those growers in making appropriate hybrid selections.

Head smut differs from common smut, caused by *Usilago maydis*, in that the head smut pathogen is primarily soilborne. The teliospores (smut spores) from the smutted tassels or ears disseminated by wind, rain and/or harvesting equipment overwinter in the soil and are the source for infection in succeeding corn crops. It is also believed that fields may be infested by planting seed contaminated with head smut spores. The head smut fungus infects the corn plant in the seedling stage. Once the plant is infected, symptoms are not exhibited until the tassel and/or ears are developed. The tassel and/or ear of infected plants are transformed into smut sori. Inside the sorus (smut galls) are millons of dark brown to black teliospores. In addition to the teliospores are the remains of the vascular tissue of the tassel and ear. The vascular tissue appears as a "stringy mass". The head smut sorus, unlike the common smut sorus is not bounded by a distinct, persistent covering called a periderm. The head smut sorus is found on ears and/or tassels and rarely on leaves, while the common smut sorus can be found on leaves, stalks, tassels, ears or on individual kernels of the ear.

A head smut infected corn plant is reported to never produce a marketable ear, and therefore results in a direct yield loss. However, common smut reduces yield only when it infects the ear or kernel directly. In 1981, seeds planted in infested soil resulted in plants producing infected ears at one node and a marketable ear at a higher node. The most common symptom observed in 1980 was tassel or tassel and ear symptoms while in 1981 fewer plants had tassel symptoms and more had ear symptoms without a tassel symptom. This of course made survey work more difficult since one was required to peel back the husk to examine the ear for smut sori (galls).

Chemical control with registered seed treatment products is of little value. Vitavax did not protect against infection in this test and was reported to be of little value in a Canadian test. Seeds produced in a field were the pathogens present can become contaminated with teliospores during harvesting and shelling. These seed, (contaminated) coated with teliospores could possibly introduce the pathogen into a previously uninfested field and chemical seed treatments may be of value in preventing this type of disease dissemination.

In assessing a control strategy it is important to realize that Sphacelotheca reiliana is not seed borne, i.e. it does not grow within the seed (even though it may be present on the seed as a contaminant). The pathogen infects the susceptible corn plant in the seedling stage. In Minnesota, where head smut was found, the most popular hybrids plants are thought to be some of the most susceptible. This factor, plus continuous corn production on soil suitable for infection can set up conditions favorable for the head smut organism after it is introduced.

Clearly, resistant hybrids and rotation offer the best means to control head smut. Chemical treatment, either as a seed treatment or as a in-furrow granule (when registered) also can be used to manage this corn disease. For the present, growers with fields known to have head smut should select lines resistant or moderately resistant to this disease.

PERCENT OF HEAD SMUT

	Hybrid					
	Susceptible			Moderately Susceptible		
	Planting Dates					
	4/28	5/12	5/27	4/28	5/12	5/27
Check	26.1	30.8	34.3	12.9	10.2	8.7
Vitavax 34 4 oz/100 #	34	26.2	20.8	11.4	10.8	11.1
Baytan oz ai/100#						
0.25	16.1	15.5	13.9	4.1	6.2	13.6
0.50	7.1	8.6	4.3	5.3	4.8	4.5
0.75	4.1	5.8	1.5	0.8	0.7	2.6
1.0	0	2.3	0.9	2.5	2.9	2.1
Ciba Geigy 88531 gm ai/Kg						
0.25	27.9	31.1	27.2	5.3	9.6	5.3
0.50	15.2	23.7	11.3	3.3	6.4	6.8
1.0	15.0	32.6	13.4	8.9	7.0	3.4
Ciba Geigy 64250						
Spray 100 gm ai/A	28.9	29.4	22.3	5.0	15.4	9.7
Granule in furrow 100 gm ai/13,081 row ft.	0	0.8	0	0	0	0
Granule-Surface band 100 gms ai/13,081 row ft	--	4.8	3.5	--	2.9	1.7

Head Smut Hybrid Rank

Resistant	Moderately Resistant	Moderately Susceptible	Susceptible
Cenex 2203	Pfizer T-950	Cenex 3138	Holden's CB59G
Cenex 3015	Dekalb EX1212	Midland M-2087	A 671
Cenex 3139	NK X6668	Dekalb XL-11	MN4201
Dekalb XL-14AA	MN8301	Blaney B607	Cenex 2155
Funk's G-4256	Holden's L632	Dekalb EX1112	NK PX24
Lester Pfister 1430	Dekalb EX3333	Pfizer T-930	Code 47
McCurdy M-X956	Blaney S6389	NK PX11	Funk's G-5048
NK PX37	Payco SX-442-N	Kaltenberg KX58	Dekalb XL-12
	Midland M-1085A	RBA Super 4+	Blaney S4800
	Funk's G-4435	A654	NK PX7
	Payco SX-431-N	Kaltenberg KX31	NK PX449
	Ramy X-13	MN7301	Ramy EX14739
	NK PX419	Payco SX-411-N	NK PX485
	Kaltenberg KX59	Kaltenberg KX390	MN5301
	X117	Lester Pfister 1428	Kaltenberg KX362
	Cenex 2110	Wilson 1300	Payco 3X-155-N
	McCurdy M-4855	Blaney S3242	Ramy X-135
	Funk's G-4180	W153R	Code 7
	Dekalb XL-23	Dekalb XL-314	C0109
	Blaney S4402	Lester Pfister 1222	Payco SX-599-N
	Funk's G-4085	Ramy X-150	Payco 3X-227-N
	Cenex 3018	A554	Holden's LH39
	Dekalb XL-36	Pfizer T-X90	
	Blaney B101	MN6305	
	Cenex 3011	RBA Super 80	
	Cenex 2108	Ramy X-200	
	A661	Wilson 1100B	
	NK PX443	Midland M-1051TY	
	Blaney S2184	Payco SX-637-N	
	Ramy X-22	Ramy X-16	
	McCurdy M-5596	Payco SX-555-N	
	Blaney S2202	Payco SX-711-N	
	Midland M-1088	Midland M-3080	
	CM105	Kaltenberg KX53	
	Cenex 2004		

continued on page 2 (all columns Moderately Resistant)

Moderately Resistant	Moderately Resistant	Moderately Resistant	Moderately Resistant
Funk's G-4315	Sokota MS27	Midland M-3093	Code 48
A661 X A665	Dekalb XL-13	Midland M-3090B	Kaltenberg KX44
Midland M-3095A	Midland M-1090B	Holden's LH38	Cenex 3121
Ramy X-14	Cenex 2111	Payco SX-680-N	NK X6392
Cenex 2106	Cenex 2119	Pfizer T-1000	McCurdy M-3410
Blaney S5602	Funk's G-4224	Code 97	Cenex 3123
RBA Super 4	Sokota 78-A	Ramy X-20	Blaney S2101WX
McCurdy M-4436	Cenex 2093	Ramy X-33	LP 7801
Dekalb XL-32A	Midland M-1051DR	Funk's G-4426	Cenex 3094
A634	Payco SX-620-N	Blaney S4406WX	Funk's G-4323
Dekalb XL-15	C0109 X CM105	RBA 3040	Payco SX-386-N
Holden's LH74	McCurdy M-46	RBA 94	Blaney S2322
RBA 94+	Midland M-1080	Pfizer T-1069	Blaney B606
RBA S3060	Dekalb XL-6	Midland M-1001B	RBA 104+
Blaney S6595A	Funk's G-4143	Dekalb XL-18	Cenex 2091
Code 8	Sokota TS20	Kaltenberg KX33	Funk's G-4141A
Pfizer T-1058	Dekalb XL-25A	Kaltenberg KX54A	Blaney S3306
Kaltenberg KX47	McCurdy M-4664	MN 5202	RBA 105+
A632	Cenex 2134	Cenex 3103	MN4202

NIGHTSHADES AND THEIR CONTROL

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IDENTIFICATION AND DISTRIBUTION

The taxonomy of the weedy nightshades of the United States has recently been revised and divided into a number of different species (Ogg et.al.). Two different species are found in Minnesota, eastern black nightshade and hairy nightshade. Both of these weeds are annual, much-branching plants with small white flowers in clusters of 3 to 6, ovate (egg-shaped) leaves and juicy berries at maturity. Eastern black nightshade usually has black berries and few hairs on stems and leaves, while hairy nightshade produces berries which don't turn black, but are dark green or brown, and is densely hairy on leaves and stems.

Eastern black nightshade is by far the most common of the two species in Minnesota, and is found throughout the southern half of the state and up into the West central counties. Hairy nightshade is much less common, with scattered infestations reported in a few central and north central counties (such as Hubbard, Wadena, and Becker counties). The harvest problems caused by these two weeds are similar, but there are some differences in herbicide susceptibility.

THE PROBLEM-HARVEST DIFFICULTIES

Although very severe nightshade infestations can reduce yields, their control is important primarily because of the harvest problems they create in soybeans and dry edible beans. Nightshade foliage is not killed by light frost and is still green when beans are ready to harvest. They produce copious amounts of sticky, juicy berries. (A single plant can produce 1000 berries). The weed foliage and berries plug combine rotors and sieves, stain and discolor bean seeds, and can increase the moisture of harvested beans, causing potential storage problems.

Because low populations of nightshades can cause serious harvest problems, they require higher levels of control than some weeds. One plant/10 ft. of row in soybeans has caused harvest difficulties in soybeans (Majek). Nightshades cannot be tolerated in peas because of the reputed toxicity of the berries. Dry edible beans can be docked when 4% of the beans are stained by nightshade berries. A good soybean stand will sometimes compete with nightshades and repress their growth early in the season, but the weed can develop rapidly when beans begin to senesce or if a hailstorm reduces the soybean canopy. Nightshades can germinate later into the growing season than many weeds, which complicates control.

CONTROL (See tables 1 and 2)

Soybeans

Nightshades are not controlled by dinitroanalines, such as fluchloralin (Basalin), pendimethalin (Prowl) and trifluralin, or by metribuzin (Sencor). Alachlor (Lasso), metolachlor (Dual), or chloramben (Amiben) can control nightshades. Preemergence applications work better than preplant incorporated, partially because the herbicide is applied later and thus will provide control later into the season, controlling late-germinating nightshade.

The best postemergence treatment for nightshades in soybeans depends on the nightshade species. Acifluorfen (Blazer) works best on eastern black nightshade and bentazon (Basagran) will control hairy nightshade. The nightshades must be sprayed before they have more than four true leaves for consistent control, and must be thoroughly wetted with the herbicide spray.

Corn and small grains

Nightshades in corn can be controlled by preplant incorporated or preemergence applications of alachlor or metolachlor tank-mixed with atrazine or cyanazine (Bladex). Small nightshades can be controlled postemergence by atrazine + oil, cyanazine, dicamba (Banvel) or bentazon (Basagran).

Nightshades usually are not a problem in small grains, but can be controlled if necessary in oats and wheat with Bromoxynil (Buctril, Brominal) applied before the crop reaches the boot stage and while the weeds are small. If the nightshades are past the small seedling stage, MCPA, 2,4-D, or MCPA mixed with bromoxynil will give better control.

LITERATURE CITED

Majek, Bradley A., 1981. Nightshade control in field crops. Agric. Ext. Service. Ext. Folder 603.

Ogg, A.G., Jr., B.S. Rogers, and E.E. Schilling, 1981. Characterization of black nightshade (*Solanum nigrum*) and related species in the United States. Weed Sci. 29:27-32.

Table 1. Effectiveness of herbicides for nightshade control. (from Majek)

	Preplant incorporated						Preemergence					Early postemergence							
	alachlor (Alachlor)	Atrazine	chloramben (Amiben)	cyanazine (Bladex)	EPTC (Eptam or Eradicane)	metolachlor (Dual)	alachlor (Lasso)	Atrazine	chloramben (Amiben)	cyanazine (Bladex)	metolachlor (Dual)	acifluorfen (Blazer)	Atrazine and oil	bentazon (Basagran)	bromoxynil (Buctril, Brominal)	cyanazine (Bladex)	2,4-D	dicamba (Banvel)	MCPA
Eastern black nightshade	G/F	G	F	G	F	G/F	G	G	G/F	G	G	G	G	F	G	G	F	G/F	F
Hairy nightshade	G/F	—	F	—	—	—	G	—	G/F	—	—	P	—	G	—	—	—	—	—

G = good; F = fair; P = poor; N = none; — = insufficient information.

Table 2. Tolerance of crops to herbicides effective for nightshade control. (from Majek)

	Preplant incorporated						Preemergence					Early postemergence							
	alachlor (Alachlor)	Atrazine	chloramben (Amiben)	cyanazine (Bladex)	EPTC (Eptam or Eradicane)	metolachlor (Dual)	alachlor (Lasso)	Atrazine	chloramben (Amiben)	cyanazine Bladex)	metolachlor (Dual)	acifluorfen (Blazer)	Atrazine and oil	bentazon (Basagran)	bromoxynil (Buctril, Brominal)	cyanazine (Bladex)	2,4-D	dicamba (Banvel)	MCPA
Corn	G	G	—	F	G	G	G	G	—	F	G	—	G	G	—	F	F	G	—
Dry edible beans[1]	G	—	G	—	G	—	—	—	G	—	—	—	—	G	—	—	—	—	—
Oats	—	—	—	—	—	—	—	—	—	—	—	—	—	—	G	—	F	G	G
Soybeans	G	—	G	—	—	G	G	—	G	—	G	F	—	G	—	—	—	—	—
Sunflowers	—	—	G	—	G	—	—	—	G	—	—	—	—	—	—	—	—	—	—
Wheat	—	—	—	—	—	—	—	—	—	—	—	—	—	—	G	—	G	F	G

G = good; F = fair; P = poor; N = none; — = not cleared for use.

[1]Do NOT use alachlor or EPTC on Adzuki beans.

OBSERVATIONS ON HERBICIDE/INSECTICIDE INTERACTIONS

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Many farmers in west central Minnesota grow continuous corn and use insecticides to control Northern and Western corn rootworm larvae (Diabrotica longicornis and Diabrotica virgifera). Repeated annual treatments with the carbamate insecticide carbofuran (Furadan) or the thiocarbamate herbicide EPTC + R-25788 (Eradicane) both result in reduced effectiveness of these pesticides. Furadan control of corn rootworms is reduced as is Eradicane control of wild proso millet. The loss in effectiveness of Eradicane is attributed to a more rapid soil deactivation by microorganisms and can be prevented by the addition of a chemical that inhibits deactivation. The loss in effectiveness of Furadan with repeated use is similarly attributed to a more rapid deactivation by microorganisms.

For three years at the West Central Experiment Station at Morris, Minnesota, various insecticides have been compared for control of corn rootworm larvae. These plots were conducted in a field with a previous history of Furadan use. Two carbamate insecticides--Furadan and another carbamate insecticide, bendiocarb (Tattoo)--frequently failed to control corn rootworms in these experiments.

Experiments on wild proso millet control were conducted over three years near Milan and Morris, Minnesota, by the West Central Experiment Station in fields with a previous history of Eradicane use. Eradicane was not effective in controlling wild proso millet, however, EPTC + R-25788 + R-33865 (Eradicane + Extender, an experimental herbicide from Stauffer Chemical Company) was effective in controlling wild proso millet in corn.

A study was conducted at the West Central Experiment Station, Morris, Minnesota, to see if there was a herbicide effect on the control of corn rootworm larvae by carbamate and phosphate insecticides. This study was initiated in 1980 and repeated again on the same plots in 1981 in a field with a history of failure of carbamate insecticides. Thirteen treatments included check plots and insecticide-herbicide combinations; three herbicides were used--alachlor (Lasso), EPTC + R-25788 (Eradicane), or EPTC + R-25788 + R-33865 (Eradicane + Extender, an experimental herbicide from Stauffer Chemical Company)--in combination with four insecticides--isofenphos (Amaze), carbofuran (Furadan), bendiocarb (Tattoo), or cloethocarb (BASF-263-I, an experimental insecticide from BASF Wyandotte Corp.). A randomized complete block design with six replications was used. Corn root damage ratings, percent corn lodging, and corn yields were used to evaluate corn rootworm control (Table 1).

Corn rootworm populations were high enough in both 1980 and 1981 to cause significant differences in corn root damage ratings and percent corn lodging. Corn yields were significantly different only in 1981. Differences in corn

Table 1. Effect of herbicide-insecticide combinations - Morris - 1980-81.

Herbicide	Rate #/A	Insecticide	Rate oz/1000'	1-6* Root Rating 1980	1-6* Root Rating 1981	Percent Root Lodging 1980	Percent Root Lodging 1981	Yield Bu/Acre 1980	Yield Bu/Acre 1981
Eradicane	4	Furadan	12	2.1	3.6	27	81	120	107
Eradicane	4	Tattoo	12	2.3	3.7	20	88	125	95
Eradicane	4	BASF-263-I	12	1.9	2.1	28	41	125	103
Eradicane	4	Amaze	6	2.1	2.4	18	42	123	106
Eradicane	4	Check	-	2.5	4.7	30	90	123	94
Lasso	3	Furadan	12	2.4	3.7	25	91	117	100
Lasso	3	Tattoo	12	2.2	4.1	22	89	119	99
Lasso	3	BASF-263-I	12	2.0	2.1	22	38	119	114
Lasso	3	Amaze	6	2.1	2.3	22	52	118	105
Lasso	3	Check	0	2.6	4.1	17	82	116	101
Eradicane + Extender	4	Furadan	12	2.1	3.7	20	77	124	98
Eradicane + Extender	4	Amaze	6	2.1	2.4	18	29	124	106
Check	-	Check	-	2.4	4.0	27	88	118	91
Average				2.2	3.3	22.8	68.3	120.8	101.5
F Value				6.07**	9.04**	3.10**	13.42**	.95 NS	3.31**
LSD_{05}				.23	.85	7.0	18.4	-	9.8

*See Table 2 for definition of root damage ratings.
**Significant at the .01 level.
NS Differences are not significant.

root damage ratings, percent corn lodging, and corn yields were more pronounced in the second year of the study. Corn root damage ratings, percent corn lodging, and corn yields were not equally effective in measuring differential feeding by corn root worm larvae. The timing of critical stress factors on corn such as moisture stress or strong winds occurring after root pruning by corn rootworm larvae determines the kind and extent of yield losses caused by the root pruning. Plants with pruned roots in a moisture stress situation may result in yield loss due to reduced uptake of moisture and nutrients. Plants with pruned roots that result in lodging may or may not result in less yield produced but harvesting losses may result. Roots of healthy corn plants regrow rapidly which minimizes the potential yield loss from root pruning. Root damage ratings of about 3-3.5 on a scale of 1-6 usually cause corn yield reductions.

Insecticides were not equally effective in controlling corn rootworm larvae. In this study Amaze, a phosphate insecticide, and BASF-263-I, a carbamate insecticide, gave the most effective control of corn rootworm larvae and Furadan and Tattoo (both carbamate insecticides) gave the least effective control. There were no consistent differences in effectiveness of insecticides when used in combination with any of the herbicides. Eradicane applied without insecticide resulted in more corn rootworm damage than did Lasso applied without insecticide. Additional research is needed to determine whether these herbicides effect the degree of corn rootworm control by carbamate and phosphate insecticides.

Table 2. Root damage rating definitions.

Root Damage Rating	Definition
1	No sign of feeding
2	Some signs of larval feeding nitches on roots
3	At least 2 roots pruned to within 1½" of stalk
4	Equivalent of 1 complete node pruned back
5	Equivalent of 2 complete nodes pruned back
6	Equivalent of 3 complete nodes pruned back

Lofgren rated 5 plants per plot and averaged for each plot.

Rated in July before much regrowth of corn roots.

UPDATE ON WILD PROSO MILLET

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Wild proso millet has been present in Minnesota for 50 years. However, in the past 10 years it has spread rapidly and is now rated as a serious weed with infestations in about half of the counties in the state. Wild proso millet tolerance to atrazine and the better control of competing weeds are believed to be the reasons for its increase. Fact Sheet No. 35 "Identification and control of wild proso millet" has been included with this update for your review.

Much research in progress in Minnesota is being undertaken to study growth habits of wild proso millet. These studies include measurements of longevity of seed in the soil, time of seed germination, depth from which seedlings can emerge, and seed dormancy factors. Information on wild proso millet growth and development will aid in developing more effective control measures.

The effort to develop improved herbicide treatments for wild proso millet control continues. These studies have shown that, in corn, repeated annual use of EPTC(+) (Eradicane) results in reduced effectiveness of wild proso millet control because EPTC degrades more rapidly in the soil when it is used for several years. Rotation of crops is suggested as a means of reducing the loss of persistence of EPTC(+). The loss in EPTC(+) effectiveness has been prevented by adding a compound, an extender, that increases the longevity of EPTC(+) in the soil. The EPTC(+)-extender combination is not commercially available at this time but efforts to obtain clearance are under way. Presently available chemicals must be used in combinations to obtain satisfactory wild proso millet control in field corn. Preplanting incorporated applications of EPTC(+) followed by early postemergence treatments of cyanazine (Bladex 80W) plus pendimethalin (Prowl), alachlor (Lasso), or metalachlor (Dual) are effective treatments. Currently only the cyanazine-pendimethalin combination is labeled for this use but present EPA clearances also allow use of the alachlor or metalachlor combinations with cyanazine. These early postemergence treatments should not be applied if the corn is beyond the 2-leaf stage because of possible injury to the corn. These treatments are effective whether or not the wild proso millet has emerged. If late germinating wild proso millet seedlings should emerge, they should be controlled by a lay-by cultivation. This decreases wild proso millet seed production which reduces the infestation the following year.

In soybean several experimental herbicides have given excellent wild proso millet control when applied postemergence. In 1982, one of these compounds, BAS-9052 (Poast) may be available in limited quantities under an experimental use permit. Combination treatments using preplant incorporated applications of trifluralin (Treflan) combined with chloramben (Amiben) or metribuzin (Sencor) or vernolate (Vernam) combined with chloramben have given satisfactory control. Preplant incorporated treatments of trifluralin or vernolate followed by a delayed preemergence application of chloramben, alachlor (Lasso) or metolachlor (Dual) have given effective control of wild proso millet, also. As in corn, if late germinating wild proso millet seedlings emerge they should be controlled by a lay-by cultivation.

AGRICULTURAL EXTENSION SERVICE
UNIVERSITY OF MINNESOTA

AGRONOMY
FACT SHEET No. 35

O.E. STRAND and R. BEHRENS

Identification and Control of Wild Proso Millet

Wild proso millet (*Panicum miliaceum L.*) was first identified as a serious weed problem in Minnesota in 1970. Since then it has been found in about 20 Minnesota counties ranging from Dakota and Chisago in the east to Lincoln, Lac Qui Parle, and Wilkin in the west. Found mainly in corn and soybean fields, wild proso millet is a prolific seed producer and a vigorous competitor in row crops.

Cultivateo proso millet (*Panicum miliaceum L.*), also called "Hog Millet," is grown as a feed grain and bird seed crop in Minnesota and in several other states. Since it is similar to oats or barley in feed value, in some countries of the world proso millet is used as human food.

The exact origin of wild proso millet is unknown. Some evidence exists that it may have come from Asia, or it may have developed a weedy growth habit over time from one of the many cultivated varieties. Wild proso millet resembles the seed and panicle type of an old proso millet variety, "Crown," which was grown widely in Minnesota in the 1940s and 1950s. One farmer in Stevens County, Minnesota reported that he had observed wild proso millet in several patches on his farm since the 1930s, when he purchased seed and grew a mixed millet emergency hay crop on his farm.

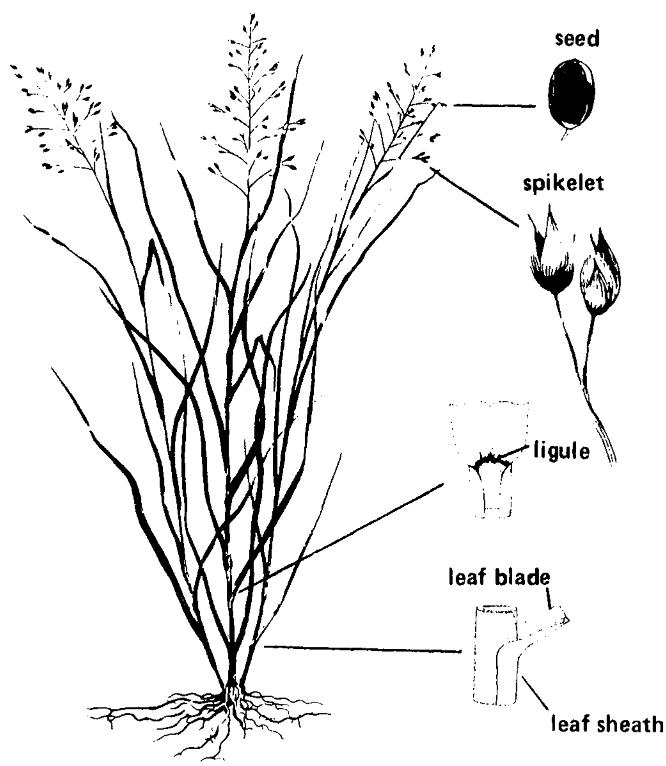
DESCRIPTION AND TAXONOMY OF WILD PROSO MILLET

Wild proso millet is a very competitive branching annual that grows from seed each year. It is erect in growth habit, growing from 2 to 6 feet tall, but some culms (stems) may be decumbent (prostrate) at the base. It has leaf blades that are hairy on both surfaces and range from ½ to ¾ inch wide. The leaf sheaths (which encircle the stems) are round, split, and have long, spreading hairs. The ligule (projection at base of leaf blade) is a dense fringe of hairs fused at the base and about 2 mm. long. Each culm is topped by a spreading panicle 6 to 12 inches wide, which often is not fully extended from the leaf sheath. The spikelets, composed of the seed and surrounding glumes, are 4 to 5 mm. long, ovate, pointed at the tip, and strongly nerved with 7 to 9 nerves. There is one fertile floret (seed) per spikelet with a hardened lemma and palea (hulls) and the caryopsis, or grain, within. The seed is smooth and shiny, olive-brown to brownish-black in color at maturity, and about 2½ to 3 mm. long by 1½ to 2mm. wide with definite nerves or veins visible on the surface.

Wild proso millet is in the *Paniceae* (millet) tribe of the grass family, closely related to the corn and sorghum tribes. These three tribes make up one subfamily of the grasses as classified by A.S. Hitchcock, a noted authority on grasses, in *Manual of the Grasses of the United States.* Like corn, the first internode of wild proso millet elongates during emergence, permitting this weedy grass to germinate from depths of 2 or more inches in the soil. The readily identifiable seed of wild proso millet usually does not deteriorate after germination. If the plant is carefully removed from the soil the seed can often be found among the roots to aid in identification of the plant. Also like corn, wild proso millet is tolerant of atrazine and has been increasing rapidly in areas where atrazine has been used widely as the principal corn herbicide.

Unlike cultivated proso millet, the wild strain has definite weedy characteristics. Several panicles are produced on each plant, some from the axils of the upper leaves which ripen later than the terminal inflorescence over a several-week period. Seed production usually continues until a killing frost stops plant growth in the fall. The seed is easily shed from the plant when mature and normally does not germinate in the fall but remains dormant over winter to germinate the following spring. Wild proso millet produces a large quantity of seed per plant. It is common to find 500 or more seeds per square foot in infested areas. The seed is spread easily by harvesting equipment, especially in sweet corn production fields (where it has been spreading rapidly).

Wild proso millet (*Panicum miliaceum L.*).



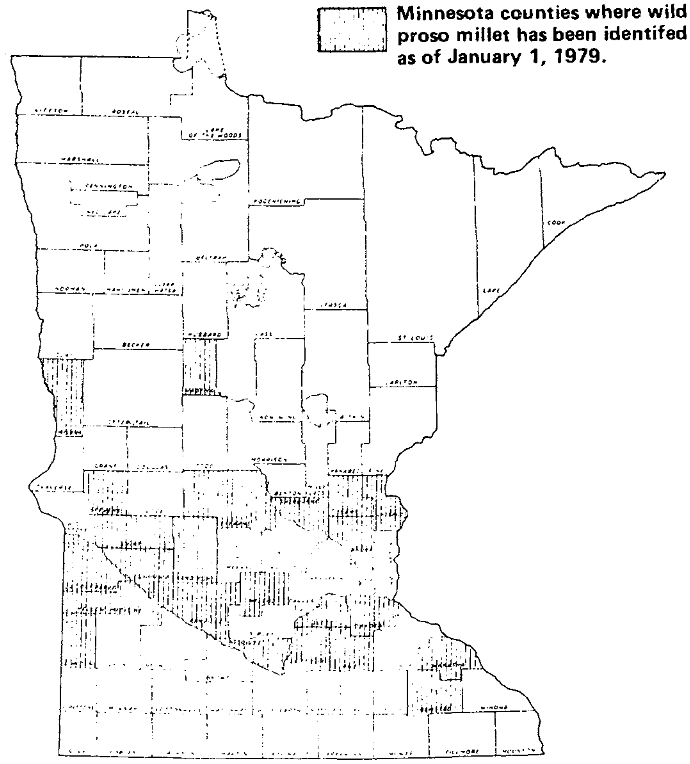
CONTROL OF WILD PROSO MILLET IN FIELD CROPS

Wild proso millet is a warm season grass that germinates most readily when soil temperatures are 50° F. or above. For that reason wild proso millet is less competitive if corn is planted early in narrow rows (30 inches wide or less) than if it is planted later in wide rows, as is usually the case with sweet corn.

Most field crops can be planted in wild proso millet infested areas if good weed control practices are followed and a good choice of herbicides is made.

Corn

Wild proso millet germinates readily from deep in the soil (2 to 3 inches or more). For this reason herbicides such as EPTC with protectant (Eradicane), butylate with protectant (Sutan Plus), alachlor (Lasso), or metolachlor (Dual), when applied at the full label rate for the soil type and incorporated into the soil before planting have given the best control of wild proso millet in Minnesota trials. Of these four herbicides EPTC has given the most consistent control. With more rainfall after application alachlor and metolachlor, applied preemergence, also have given acceptable control. However in western Minnesota with lower average annual precipitation or in drier years, a single application of any of these four herbicides has failed to control wild proso millet in corn. In two trials during 1978 a combination of EPTC (Eradicane) applied preplanting, incorporated followed by a band application of alachlor (Lasso) preemergence with one or two cultivations gave excellent control of wild proso millet.



Soybeans

The herbicides trifluralin (Treflan), profluralin (Tolban), dinitramine (Cobex), fluchloralin (Basalin), pendimethalin (Prowl), or vernolate (Vernam) applied preplanting and incorporated have given only fair control of wild proso millet when used alone. However if one of these herbicides is used preplanting, incorporated followed by preemergence use of alachlor (Lasso) or chloramben (Amiben), good control of wild proso millet usually has resulted. These preemergence herbicides may be banded and one of two cultivations used to control weeds in the row. Chloramben (Amiben) may be tank-mixed with trifluralin (Treflan) and the mixture incorporated. Alachlor, applied preplant and incorporated at the full label rate for the soil condition, also has given acceptable control in some trials when applied alone or in combination with chloramben as an overlay treatment.

For effective control of wild proso millet in soybeans the full label rate of each herbicide – for the soil condition – must be used.

Small Grains

If small grains are planted in April in Minnesota, with adequate fertility and soil moisture wild proso millet normally does not compete seriously with the crop. Small grains should not be planted late in areas known to be infested with wild proso millet as there is presently no effective herbicide for control.

Sunflowers

EPTC (Eptam) applied preplanting and incorporated at the full label rate has given fair to good control of wild proso millet in sunflowers if soil moisture conditions are favorable. Chloramben (Amiben) can be applied preemergence, banded or broadcast together with row cultivation to give additional control.

Dry Edible Beans

Preplanting applications of EPTC (Eptam), trifluralin (Treflan), profluralin (Tolban), or dinitramine (Cobex) or mixtures of EPTC with these herbicides should give fair to good control of wild proso millet in dry edible beans. However, do not use EPTC on Adzuki beans. Alachlor (Lasso) may be applied alone or in a tank mixture combination with trifluralin (Treflan) as a preplanting, incorporated treatment. The combination, when used at maximum label rates for the soil type, may give better wild proso millet control than any herbicide used alone. Row cultivation also may be needed to give additional control. Alachlor should not be used on Adzuki beans.

Flax

Flax does not compete well with weeds such as wild proso millet. EPTC (Eptam) or dalapon will suppress wild proso millet in flax but cannot be depended upon for adequate control. Therefore, flax should not be planted in fields where wild proso millet is a problem.

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AMMONIA TREATMENT AS AN AID TO LOW TEMPERATURE DRYING OF HIGH MOISTURE CORN

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Recent Research has shown that ammonia can be used to increase the storability of high moisture grain during drying with unheated air. This is commonly called the trickle ammonia process and can be used on corn that is delivered into a typical grain drying bin fitted with an elevated slotted drying floor. Ammonia gas (½ lb to 1000 lbs of corn) is taken from the head space of a standard applicator tank and introduced into a bin transition just down stream from the fan (Fig I). The blower continuously delivers air, through the bin of corn, therefore removing moisture. The Environmental Protection Agency approval allows a maximum of 5 lbs of ammonia in 1000 lbs of corn. Consequently, up to ten applications of ammonia gas can be made to any one bin of corn over the drying period.

The trickle ammonia process requires the conventional drying bin, a fan that can deliver 1-2 cubic feet of air per minute per bushel, a flowmeter, (or comprable flow-measuring device) and a hose to connect an ammonia fertilizer tank to the fan plenium (Fig. I). A flowmeter or a critical flow orfice and a regulator can be used to obtain the desired flow rate.

A research project was started in the fall of 1980 at Rosemount, Minnesota to demonstrate the effectiveness of this system under Minnesota conditions. Corn with an average moisture content of 25.4% was put into a bin on October 14 and 15, 1980. Ammonia was first applied on October 16 and was applied 5 additional (6 total) times using a total of 515 lbs of ammonia (Table 1). To assure complete fumigation it was necessary to detect when NH_3 fumes reach the top of the grain in the bin.

Two methods were used to determine the presence of ammonia gas at the top of the bin (Table 1). At a full rate of 12 - 14 lbs per hour of ammonia, a slight odor was detected at the top of the bin after 5 hours of operation. The intensity of the odor during the first application did not increase during the next hour and a half of application time. It was only after the second application that a very strong ammonia odor was noticed. The concentrations noted were not sufficient to cause enough absorption to the corn kernels to change the pH of the corn at the top of the bin. pH changes at the top of this bin was only noted after the flow rate was doubled (Table 1).

It took a total of 163 days to dry the 2724 bushels of corn in this bin to an average of 14.59% moisture. Approximately half of the bin was dried in the fall of the year, with complition in the spring. Fig. II indicates the drying regieme along with moisture contents at three different dates. The cost for drying this bin of grain, including the kilowatt hours and ammonia used, was 7.9 cents per dry bushel, (adjusted to 15½% moisture).

Samples of corn were cultured before and after each of the first 4 fumigations. During this time no potentially harmful fungi were found. The corn at the top of the bin had fungi in 8-28% of the kernels while the corn at the top of the bin had corn in 95-100% of the kernels throughout the fumigation period. On March 1, during the winter holding period, discoloration was noticed in a semi-circle area 2 ft from the center on the surface of the bin. This was an area where fines had collected. Fines restricted the air flow and can increase storage risk in any natural air drying system. Accumulations of bins in a bin can be prevented by screening the grain and/or by the use of grain spreaders. The restricted air flow, in this case, prevented adequate penetration of ammonia fumes and temperature adjustments. The fan was turned on at this time and left on until March 28 until the corn was dry. This area was the last to dry (because of restircted air-flow) and was 16% on March 28 when the bin fans were shut off. Cultures of the corn in this area revealed 60% of the kernels with Fusarium tricinctum, which is a potentially toxic fungi (especially to hogs). Its presence in corn could be a potential hazard when used in hog's rations. Cattle, however, are much less susceptible to the toxin produced by this mold.

Fusarium tricinctum can grow slowly at temperatures close to freezing and raise the temperatures to where a significant growth could occur. Closer observations of temperature rises in this area may have prevented this mold growth from occurring. Frequent observations of surface temperature in any natural air drying bin along with periodic fan operation during good weather at temperatures between 20-30^{o}F is important in maintaining quality of the grain on the bin surface.

The corn in this trial was fed to the entire dairy heard at Rosemount, Minnesota. With no effects. The rations were palatable and no negative production changes occurred. A palatability test using dairy calves showed that rations using the NH_3 treated corn were as readily accepted as untreated hot air dried corn.

More work is needed on the manipulation of ammonia concentrations at the surface of the corn in a bin, that would prevent toxic mold growth. Research is now being conducted at Rosemount, Minnesota to determine what different flow rates and NH_3 concentrations will have on the micro-flora of the corn stored in the top portion of the bin.

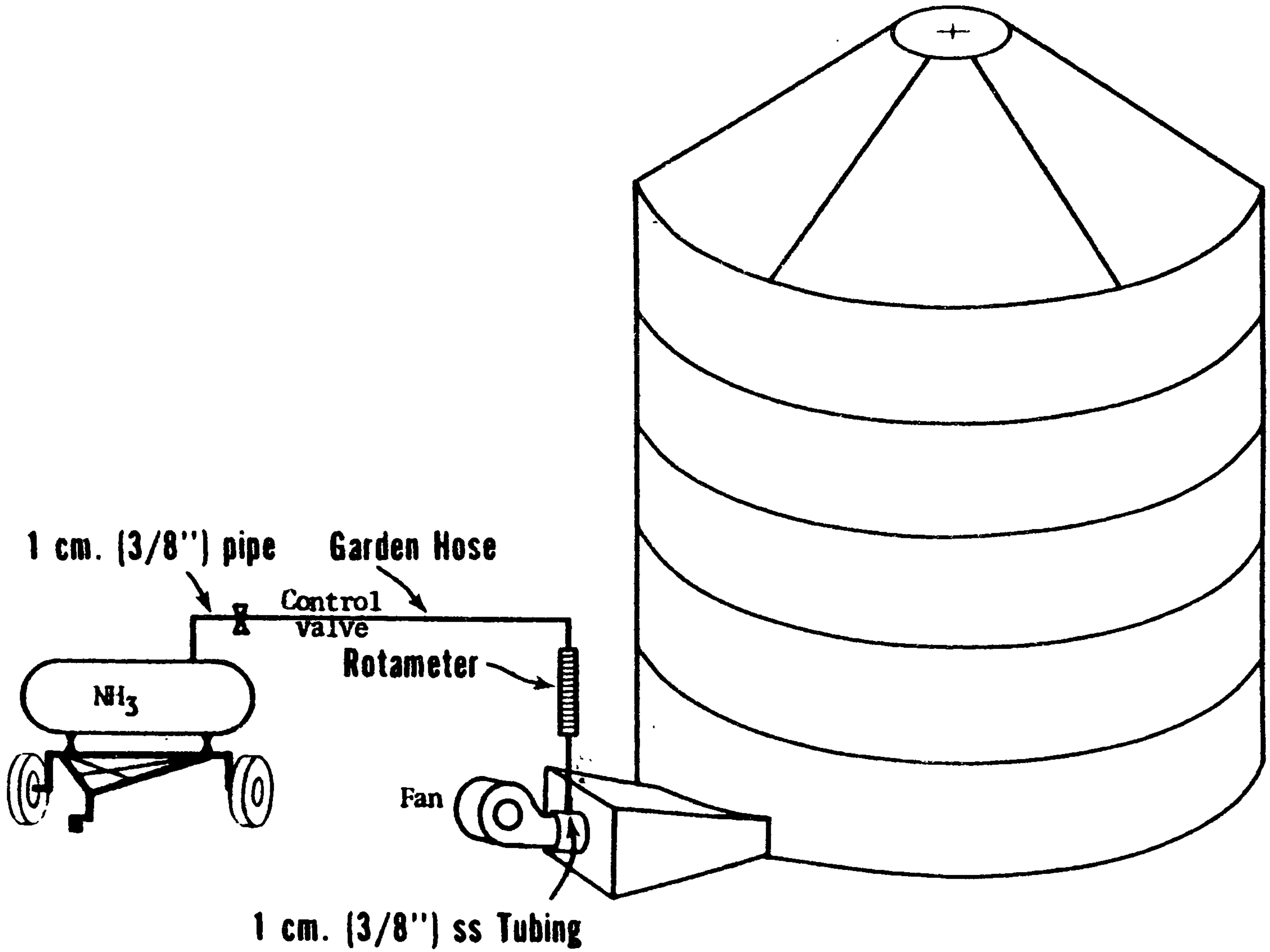

Fig. 1. Trickle Ammonia Process

Process Costs

TAP saved about 5.0 cents per bushel in field tests in 1978. In 44 days, 1493 bushels of shelled corn was dried from 26.8% to 14.5% moisture; 114.8 pounds of ammonia gas and 1129 Kwh of electricity were used. TAP drying cost totalled 4.7 cents a bushel. High-temperature drying would have cost 10.6 cents per bushel.

Safety and Other Factors

The hazards of handling high-pressure liquid anhydrous ammonia as a fertilizer are well known and are amply documented. The ammonia used with TAP was introduced in the blower air stream through a garden hose at little more than atmospheric pressure and in small amounts. At concentrations under 0.5%, ammonia was not corrosive to unprotected galvanized bin surfaces in our limited tests with galvanized bins. However, the possibility of corrosion exists if these ammonia levels are inadvertently exceeded. Accidental corrosion can be avoided by painting the inside of the bin with an epoxy-based paint. Electrical connections are particularly susceptible to ammonia corrosion.

Literature References

(1) Nofsinger, G. W., Bothast, R. J., Lancaster, E. B., and Bagley, E. B. 1977. Ammonia-Supplemented Ambient Temperature Drying of High-Moisture Corn. Transactions of the ASAE 20(6): 1151-1154, 1159.

(2) Nofsinger, G. W., Bothast, R. J., and Anderson, R. A. Field Trials Using Extenders for Ambient-Conditioning High-Moisture Corn. Transactions of the ASAE, Accepted March 6, 1979.

FIG. II. Average moisture content of various depths of ammonia treated bin on three different dates.

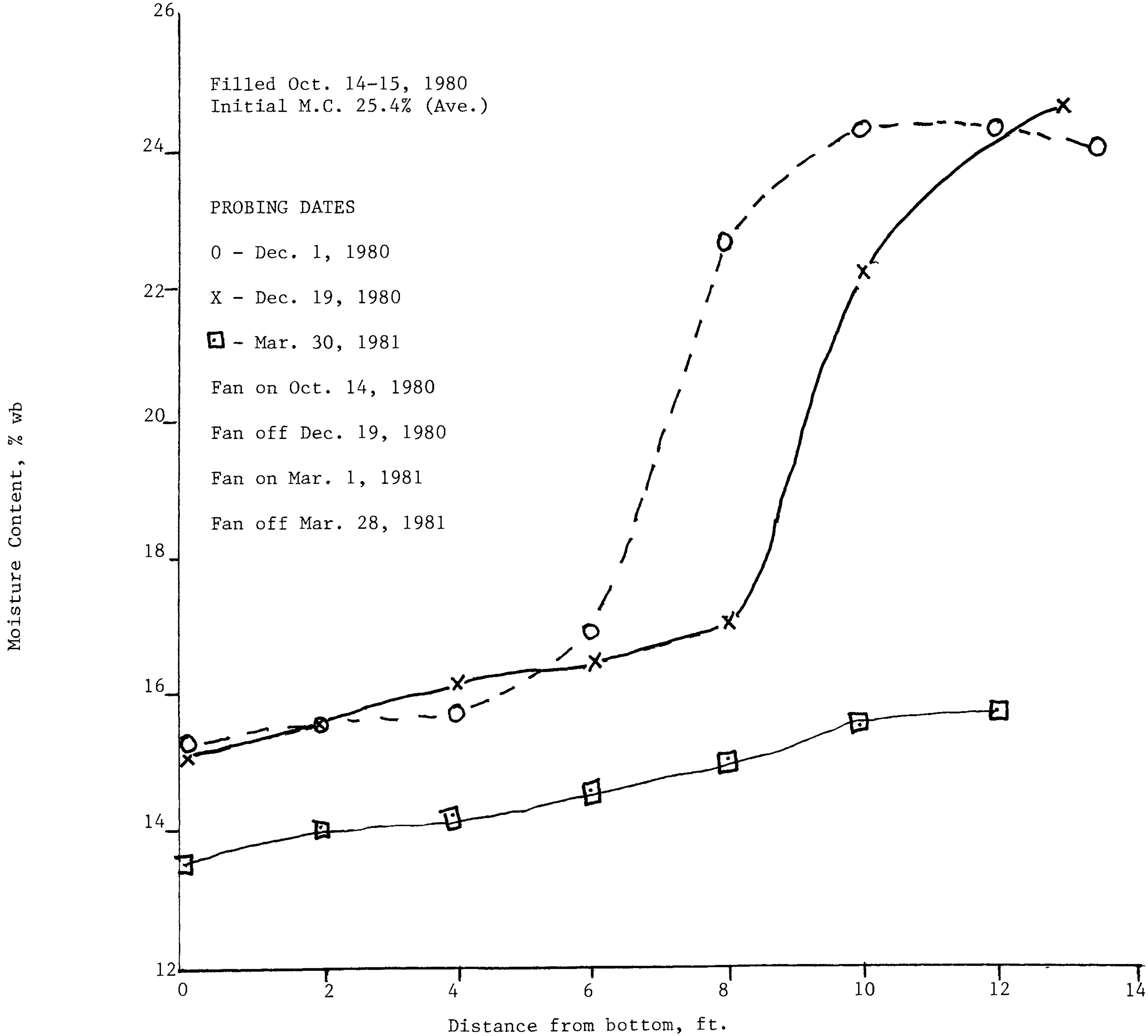

Table 1. Ammonia Applications, The Time Odor was Apparent at Top of Bin and Resulting pH Measurements.

Date	lbs Applied	Measured Flow Rate lbs/hr	[1] NH_3 at Top of Bin	pH[2] Top	Botton
Oct. 16	85	13.07	(slight) 5 hours	5.5 BE	8.5 E
20	85	14.17	5 hours	5.5 BE	6.0 B
21 (a.m.)			(very strong)		
27	80	12.31	N.R.[3]	5.5 BE	N.R.
Nov. 3	95	25.33[4]	N.R.	6 B - 7.5 E	N.R.
10	85	28.33	(very strong) 2.5 hours	6.5 B - 7.5 E	N.R.
17	85	28.33	N.R.	7. B - 8.5 E	9 B - 10 E
TOTAL	515				

1/ Time elapsed after start of fumigation that a NH_3 odor was apparent at the top of the bin.

2/ pH of water after corn soaked in it for 2 min. pH of water before soaking Treatment 6.0. E = end of fumigation, B = beginning.

3/ N.R. = Not recorded.

4/ Critical flow office changed from a dia. of .077 (#48 drill) to a dia. of .110 (#34 drill) lessen fumigation time. Both orfice openings were operated at full tank pressure (valve completely open).

CORN AND SOYBEAN WEED CONTROL

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

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

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

   The two weed species that are causing the most concern in Minnesota now are wild proso millet and nightshade. During the 1970's, wild proso millet spread rapidly through about one-third of Minnesota. It is an annual grass that closely resembles tame proso millet except that it has a darker seed, is generally taller, and shatters its seed. Its most characteristic features are hairy leaf sheaths, hairs along the leaf margins, a ligule that is a fringe of hairs, a branching open panicle, a height of 2 to 6 feet, and shiny olive-brown to black seeds. The seeds germinate in soil depths of 2 inches or more and germinate for an extended period through the spring and summer generally after soil temperatures remain above 50° F.

   Chemicals usually give only partial control of wild proso millet, and then only for the early part of the growing season. Careful crop selection and selected cultural practices should also be considered in fields with wild proso millet. The grass has spread rapidly in seed corn fields, sweet corn fields, and in fields where the only consistently used herbicide has been atrazine. Alfalfa, early seeded spring small grains, and early seeded, close-drilled peas have competed well with wild proso millet.

EPTC (Eradicane) has been the most effective chemical for controlling wild proso millet in corn fields. However, it appears to lose some effectiveness when it is applied repeatedly. An added chemical (extender) improves performance of repeated applications. Butylate (Sutan+), alachlor (Lasso), metolachlor (Dual), and cyanazine (Bladex) in combination with one of the other chemicals have given acceptable control in cultivated corn fields. Pendimethalin (Prowl) plus cyanazine (Bladex 80W) gives good wild proso millet control when applied early postemergence. In soybean fields, preplanting applications of trifluralin (Treflan), profluralin (Tolban), fluchloralin (Basalin), pendimethalin (Prowl), or vernolate (Vernam), followed by preemergence applications of alachlor (Lasso), metolachlor (Dual), or chloramben (Amiben) have given fair to good control of wild proso millet. The new chemical, BAS 9052 ("Poast"), has given excellent control of wild proso millet when applied from the seedling stage to a couple feet tall. Early planting, narrow rows, and timely cultivations help to provide adequate control.

During the last five years, nightshades have become an increasingly severe weed problem in Minnesota. Two species, eastern black nightshade (Solanum ptycanthum) and hairy nightshade (Solanum sarachoides) are present in Minnesota although the former is more prevalent. Nightshades germinate over most of the season, tolerate shading and remain green and succulent until a hard freeze. They present a tremendous harvest problem in soybeans and dry beans. Furthermore, the berries, seeds and juice cause a severe contamination problem in soybeans and edible beans and may prevent marketing of the crop. Some of our most widely used herbicides including the dinitroanilines and metribuzin (Lexone, Sencor) are not effective against nightshades. Alachlor (Lasso), metolachlor (Dual) and chloramben (Amiben) applied preplant incorporated or preemergence have given satisfactory control. Acifluorfen (Blazer) will control eastern black nightshade and bentazon (Basagran) will control hairy nightshade. Most of the commonly used herbicides for broadleafs in corn and small grains are effective against nightshade.

2. Conservation tillage systems offer the best possibility of reducing soil loss from erosion, but they are not always compatible with some of the weed management systems now being used. Preplant incorporation of herbicides has become a standard practice for corn and soybeans in many areas. Some reduced tillage systems leave a considerable amount of crop residue on the surface to protect the soil, but much of the surface residue is destroyed with the herbicide incorporation operations. Preemergence treatments are generally less successful where large amounts of residue are present as compared to a no residue surface. Often there are changes in weed populations associated with changes in tillage practices. Increases in perennial weeds, biennial weeds and annual grasses have occurred in reduced tillage systems. Herbicide systems can be adapted to conservation tillage systems. Growers will need to rely more on postemergence herbicides in many of the tillage systems that leave large amounts of crop residues on the surface and the selection of herbicides will need to be adjusted to the weed species in each field.

3. Improvements in postemergence herbicides may make it possible in the future to rely even more on chemicals for weed control. New postemergence herbicides for soybeans and small grains look very promising.

For soybeans, BAS 9052 ("Poast"), BASF Company, looks excellent for annual and perennial grass control. It is applied postemergence and controls emerged grasses over a wide size range. Some research indicates that drought-stressed weeds may not be as well controlled. An experimental use permit for limited farm use is expected for 1982 and full clearance is anticipated in 1983.

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

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

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

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

The information in Tables 1 and 3 shows the effectiveness of herbicides on various weed species and illustrates the need for properly identifying the weeds in a field before selecting the herbicide. In many fields, it is necessary to use mixtures of multiple treatments to attain broad spectrum weed control. Suggestions for herbicide treatments for corn and soybeans in 1982 are given in Tables 2 and 4.[1/]

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

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

	Preplanting						Preemergence							Postemergence							
	Alachlor (Lasso)	Metolachlor (Dual)	Butylate (Sutan +)	EPTC (Eradicane)	Cyanazine (Bladex)	Atrazine (AAtrex, others)	Alachlor (Lasso)	Atrazine (AAtrex, others)	Dicamba (Banvel)	Metolachlor (Dual)	Propachlor (Ramrod, Bexton)	Linuron (Lorox)	Cyanazine (Bladex)	2,4-D	Dicamba (Banvel)	Atrazine and oil	Cyanazine (Bladex)	Bentazon (Basagran)	Bentazon + atrazine (Laddock)	Pendimethalin (Prowl) + atrazine	Pendimethalin (Prowl) + cyanazine (Bladex 80W)
Corn tolerance —	G	G	G	G	F	G	G	G	F	G	G	F	F	F	G	G	F	G	G	F/G	F
Grasses —																					
Giant & robust foxtail	G	G	G	G	F	F	G	F	P	G	G	F	F	N	N	F	F	N	F	G	G
Green foxtail	G	G	G	G	G	G	G	G	P	G	G	F	G	N	N	G	G	N	F	G	G
Yellow foxtail	G	G	G	G	G	G	G	G	P	G	G	F	G	N	N	G	G	N	F	G	G
Barnyardgrass	G	G	G	G	F	F	G	F	P	G	F	F	F	N	N	F	F	N	F	G	G
Crabgrass	G	G	G	G	F	P	G	P	P	G	G	G	F	N	N	P	F	N	P	F/G	G
Panicum	G	G	G	G	F	P	G	P	P	G	F	G	F	N	N	P	F	N	P	F/G	G
Nutsedge	G	G	G	G	P	P	F	P	N	F	F	P	P	N	N	F	P	G	G	P	P
Quackgrass	N	N	N	F	P	G	N	G	N	N	N	N	P	N	N	G	P	N	P	P	P
Woolly cupgrass	G	G	F	G	P	P	G	P	P	G	F	P	P	N	N	F	F	N	P	F	F/G
Wild proso millet	F	F	F	F/G	P/F	P	F	P	P	F	F	P	P/F	N	N	P	P/F	N	P	F	F/G
Wild oat	P	P	F	F	F	G	P	G	N	P	P	G	F	N	N	G	F	N	G	G	G
Broadleafs —																					
Buffalo bur	P	P	F	G	P	P	P	P	P	P	P	P	P	P	P	G	F	P	G	G	F
Cocklebur	N	N	P	P	F	F	N	F	F	N	P	P	F	G	G	G	F	G	G	G	F
Kochia	P	P	P	F	G	G	P	G	F	P	P	F	G	F	G	G	G	—	G	G	G
Lambsquarters	F	P	P	F/G	G	G	F	G	G	P	P	G	G	G	G	G	G	F	G	G	G
Mustard	P	P	P	P	G	G	P	G	G	P	P	G	G	G	F	G	G	G	G	G	G
Pigweed	G	G	F	F	F	G	G	G	G	G	F	G	F	G	G	G	F	P	G	G	F
Ragweed	P	P	P	F	G	G	P	G	G	P	P	G	G	G	G	G	G	G	G	G	G
Smartweed	P	P	P	P	G	G	P	G	G	P	P	F	G	P	G	G	G	G	G	G	G
Velvetleaf	P	P	F	F	F	F	P	F	F	P	P	F	F	G	G	F	F	G	G	G	G
Wild sunflower	P	P	P	P	F	F	P	F	F	P	P	P	F	F	G	G	F	G	G	G	G
Canada thistle	N	N	N	N	P	P	N	P	N	N	N	N	P	F	G	F	P	F	F	P	P
Jerusalem artichoke	N	N	N	N	P	P	N	P	P	N	N	P	P	G	G	P	P	P	P	P	P
American germander	N	N	P	F	P	P	N	P	P	N	N	P	P	P	P	G	F	P	F	F	F

[1] G = Good, F = Fair, P = Poor, N = None

Table 2. Suggestions for chemical control of weeds in corn

Method of application Chemical–common name (Trade name[1])	Rate--lb/A of active ingredient or acid equivalent broadcast[2]	EPA registration limitations on crop use	Remarks[3]
Preplanting incorporated			
Alachlor (Lasso)	2 to 4	None	Preplanting application of alachlor or metolachlor at the high rates is suggested if nutsedge is a problem, but for annual grasses only, shallow incorporation or preemergence application is preferred. Incorporate butylate or EPTC immediately after application. Do not use butylate or EPTC on corn seed stock.
(Lasso II)	2.4 to 3.9		
Atrazine (AAtrex, others)	2 to 3	Do not graze or feed forage for 21 days after treatment	
Butylate (Sutan+)	4 to 6	None	
Cyanazine (Bladex)	2 to 4	None	
EPTC + protectant (Eradicane)	3 to 6	None	
Metolachlor (Dual)	1-1/2 to 3	None	
Atrazine + alachlor	1 to 2 + 1-1/2 to 2-1/2	Do not graze or feed forage for 21 days after treatment	
Atrazine + butylate	1 to 1-1/2 + 3 to 4	Do not graze or feed forage for 21 days after treatment	
Atrazine + EPTC (Eradicane)	1 to 1-1/2 + 3 to 4	Do not graze or feed forage for 21 days after treatment	
Atrazine + metolachlor	1 to 2 + 1-1/4 to 2-1/2	Do not graze or feed forage for 21 days after treatment	
Cyanazine + alachlor	1 to 2.2 + 2 to 2-1/2	None	
Cyanazine (Bladex) + butylate	1-1/2 to 2 + 3 to 4	None	
Cyanazine + EPTC (Eradicane)	1-1/2 to 2 + 3 to 4	None	
Cyanazine + metolachlor	0.8 to 2-1/2 + 1-1/4 to 2-1/2	None	
Preemergence			
Alachlor (Lasso)	2 to 3-1/2	None	Atrazine may carry over and affect crops the next year. Other chemicals do not carry over. Do not use preemergence applications of cyanazine, propachlor, dicamba, or linuron on sandy soils. Linuron is suggested for use only on soils between 1 and 4 percent in organic matter. Use dicamba only on medium and fine textured soils with more than 2.5% organic matter.
(Lasso II)	2.4 to 3.9		
Atrazine (AAtrex, others)	1 to 3	Do not graze or feed forage for 21 days after treatment	
Cyanazine (Bladex)	2 to 4	None	
Metolachlor (Dual)	1-1/2 to 3	None	
Propachlor (Ramrod, Bexton)	4 to 6	None	
Atrazine + alachlor	1 to 2 + 1-1/2 to 2-1/2	Do not graze or feed forage for 21 days after treatment	
Atrazine + metolachlor	1 to 2 + 1-1/4 to 2	Do not graze or feed forage for 21 days after treatment	
Atrazine + propachlor	1 to 1-1/2 + 2 to 3-3/4	Do not graze or feed forage for 21 days after treatment	
Cyanazine + alachlor	1 to 2.2 + 2 to 2-1/2	None	
Cyanazine + metolachlor	0.8 to 2-1/2 + 1-1/4 to 2-1/2	None	
Cyanazine + propachlor	1 to 1.8 + 2-1/2 to 6	None	
Dicamba (Banvel) + alachlor	1/2 + 2 to 2-1/2	Do not graze or feed silage prior to milk stage	
Dicamba + metolachlor	1/2 + 2 to 2-1/2	Do not graze or feed silage prior to milk stage	
Linuron (Lorox) + alachlor	1/2 to 1-1/2 + 1 to 3	Do not graze or harvest immature corn for feed within 12 weeks after treatment	
Linuron + propachlor	1 to 1-1/2 + 2 to 3	None	

(continued)

Table 2 (continued)

Method of application Chemical-common name (Trade name[1])	Rate--lb/A of active ingredient or acid equivalent broadcast[2]	EPA registration limitations on crop use	Remarks[3]
Postemergence			
Atrazine (AAtrex, others) + oil	1.2 to 2	Do not graze or feed for forage for 21 days after treatment	Apply atrazine when weeds are less than 1-1/2 inches tall.
Bentazon (Basagran)	3/4 to 1	None	Apply bentazon when weeds are 2 to 6 inches. Earlier application is more effective on most weeds.
Bentazon + atrazine (Laddock) + oil conc.	1/2 to 3/4 + 1/2 to 3/4 + 1 qt/A	Do not graze or feed for forage 21 days after application.	Controls only broadleafs. Apply when weeds are less than 2 to 4 inches and corn has 1 to 5 leaves.
Cyanazine (Bladex 80 W)	2	None	Apply cyanazine when weeds are less than 1-1/2 inches tall and before corn has more than 4 leaves. Use vegetable oil or surfactant under arid conditions only. See label.
Pendimethalin (Prowl) + atrazine	3/4 to 1-1/2 + 1 to 1-1/2	None	Apply spike to 2-leaf stage of corn and up to 1-inch weeds.
Pendimethalin + cyanazine 80W	3/4 to 1-1/2 + 1 to 2	None	
Dicamba (Banvel)	1/4	Do not graze or harvest for feed before milk stage	Apply dicamba before corn is 2 feet tall and not within 15 days of tasseling. Follow drift control precautions on label.
Dicamba + 2,4-D amine	1/8 + 1/4	Do not graze or harvest for feed before milk stage	
2,4-D amine	1/4 to 1/2	Do not forage or feed fodder for 7 days following 2,4-D application	Apply 2,4-D at these rates when corn is 4 inches to 3 feet tall. Use drop nozzles after corn is 8 inches tall. Earlier applications on small weeds are more effective.
2,4-D ester	1/6 to 1/3	Do not forage or feed fodder for 7 days following 2,4-D application	
2,4-D amine	1/2 to 1	Do not forage or feed fodder for 7 days following 2,4-D application	Apply 2,4-D at these rates only after corn is 3 feet tall. Use drop nozzles so only base of stalk is sprayed. Do not apply between tasseling and dough stage of corn.
2,4-D ester	1/3 to 2/3	Do not forage or feed fodder for 7 days following 2,4-D application	

[1] See table on herbicide names. Trade names are used to identify the herbicide discussed. Omission of other trade names of similar herbicides is unintentional. The inclusion of a trade name does not imply endorsement and exclusion does not imply nonapproval.

[2] These rates will need to be properly interpreted for the formulation you use and for band width and row width if the chemicals are not applied broadcast. See Agricultural Chemicals Fact Sheet No. 5, How to Calculate Herbicide Rates and Calibrate Herbicide Applicators. The proper rate depends on such things as soil characteristics, kinds of weeds, size of weeds and crop, temperature, and moisture conditions.

[3] Read labels for detailed use instructions and restrictions on crop use.

DO NOT USE THIS FACT SHEET AFTER 1982

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

Preplant incorporated	Alachlor (Lasso)	Chloramben (Amiben)	Fluchloralin (Basalin)	Metolachlor (Dual)	Metribuzin (Sencor or Lexone)	Pendimethalin (Prowl)	Profluralin (Tolban)	Trifluralin (Treflan)	Vernolate (Vernam)
Soybean tolerance	G	G	F/G	G	F	F/G	F/G	F/G	F
Grasses									
Giant foxtail	G	G	G	G	F	G	G	G	G
Green foxtail	G	G	G	G	F	G	G	G	G
Yellow foxtail	G	G	G	G	F	G	G	G	G
Barnyardgrass	G	G	G	G	F	G	G	G	G
Wild proso millet	F	F	F	F	P	F	F	F	F
Nutsedge	G	P	N	G	P	N	N	N	G
Broadleafs									
Black nightshade	F	F	P	F	P	P	P	P	P
Hairy nightshade	F	F	F	F	P	P	P	P	P
Cocklebur	P	P	N	N	F	N	N	N	P
Kochia	P	G	G	P	G	G	G	G	-
Lambsquarters	F	G	G	P	G	G	G	G	G
Mustard	P	F	P	P	G	N	N	N	F
Pigweed	G	G	G	G	G	G	G	G	G
Common ragweed	P	G	N	P	G	N	N	N	P
Giant ragweed	P	F	N	P	F	N	N	N	P
Smartweed	P	G	P	P	G	F	P	P	P
Velvetleaf	P	F	N	P	F	F	N	N	F
Venice mallow	P	G	P	P	G	P	P	P	G
Wild sunflower	P	P	N	P	F	N	N	N	P

Preemergence	Alachlor (Lasso)	Bifenox (Modown)	Chloramben (Amiben)	Chlorpropham (Furloe Chloro IPC)	Linuron (Lorox)	Metolachlor (Dual)	Metribuzin (Sencor or Lexone)	Oxyfluorfen (Goal)
Soybean tolerance	G	P	G	G	F	G	F	-
Grasses								
Giant foxtail	G	P	F/G	P	F	G	F	P
Green foxtail	G	P	F/G	P	F	G	F	P
Yellow foxtail	G	P	F/G	P	F	G	F	P
Barnyardgrass	G	P	F/G	P	F	G	F	P
Wild proso millet	F	P	F	P	P	F	P	P
Nutsedge	F	P	P	N	P	F	P	P
Broadleafs								
Black nightshade	G	F	G	P	P	G	P	G
Hairy nightshade	G	-	G	P	-	G	P	-
Cocklebur	N	P	P	P	P	N	F	P
Kochia	P	-	G	P	F	P	G	P
Lambsquarters	F	G	G	P	G	P	G	F
Mustard	P	P	F	F	G	P	G	F
Pigweed	G	G	G	P	G	G	G	G
Common ragweed	P	P	G	P	G	P	G	P
Giant ragweed	P	-	F	P	F	P	F	P
Smartweed	P	G	G	G	F	P	G	F
Velvetleaf	P	P	F	P	F	P	F	-
Venice mallow	P	-	G	P	G	P	G	-
Wild sunflower	P	-	P	P	P	P	F	-

Postemergence	Acifluorfen (Blazer)	Bentazon (Basagran)	2,4-DB (Butoxone or Butyrac 200)	Diclofop (Hoelon)	Dinoseb (Premerge)	Naptalam (Alanap L)	Naptalam + dinoseb (Dyanap)
Soybean tolerance	F	G	P	G	P	G	F
Grasses							
Giant foxtail	P	N	N	G	P	P	P
Green foxtail	P	N	N	G	P	P	P
Yellow foxtail	P	N	N	F	P	P	P
Barnyardgrass	P	N	N	G	P	P	P
Wild proso millet	P	N	N	P	P	P	P
Nutsedge	P	G	N	P	P	P	P
Broadleafs							
Black nightshade	G	F	P	N	G	-	-
Hairy nightshade	P	G	-	N	-	-	-
Cocklebur	F	G	F	N	F	P	F
Kochia	-	-	-	N	-	F	F
Lambsquarters	P	F	P	N	P	-	F
Mustard	G	G	P	N	G	-	G
Pigweed	G	P	P	N	P	-	F
Common ragweed	G	G	P	N	F	-	-
Giant ragweed	G	F	F	N	-	-	-
Smartweed	G	G	P	N	G	-	F
Velvetleaf	P	G	P	N	P	-	-
Venice mallow	-	G	P	N	-	-	-
Wild sunflower	F/G	G	P	N	F	-	-

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

Table 4. Suggestions for chemical control of weeds in soybeans

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

HERBICIDE INCORPORATION

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Many herbicides which are applied before crop and weed emergence need to be incorporated to give optimum weed control. Included in this group are butylate (Sutan), cycloate (Ro-Neet), diallate (Avadex), EPTC (Eptam, Eradicane), fluchloralin (Basalin), profluralin (Tolban), triallate (Far-go), and trifluralin (Treflan). Incorporation of alachlor (Lasso), ethofumesate (Nortron), metolachlor (Dual), and pendimethalin (Prowl) generally improves weed control.

Butylate, cycloate, diallate, EPTC, and triallate should be incorporated immediately (within minutes) after application. Incorporation of profluralin may be delayed for four hours if applied to a loose, dry soil. Incorporate fluchloralin within eight hours of application. Trifluralin incorporation may be delayed up to 24 hours if applied to a cool, dry soil and if wind velocity is less than 10 mph. Pendimethalin must be used preemergence on corn but may be incorporated for soybeans. Incorporation often improves the performance of pendimethalin and may be delayed up to seven days after application. Alachlor, ethofumesate and metolachlor may be used preemergence but incorporation often improves performance especially on fine textured soils. Incorporation of alachlor, ethofumesate and metolachlor may be delayed several days.

An estimate of the efficiency of an incorporating tool can be obtained by operating the tool through flour or lime which has been spread thickly over the soil. A thorough incorporation should cover most of the flour or lime and mix it uniformly through the soil. Several tillage tools have been used successfully for the incorporation of herbicides. Some herbicides require more thorough incorporation than others and the incorporation method should be appropriate for the herbicide.

Butylate, cycloate, EPTC, fluchloralin, profluralin, and trifluralin require a thorough incorporation and should be incorporated by one of the following methods or a method which will incorporate similarly.

A. A tandem disk should be set at a depth of 3 to 4 inches for fluchloralin and a depth of 4 to 6 inches for others. Operating speed should be 4 to 6 mph. Tandem disks should have disk blades spaced 8 inches or less and disk blade diameter 20 inches or less for optimum herbicide incorporation.

B. Field cultivators of various types may be used. These should have over-lapping sweep shovels with at least three rows of gangs and the operating depth should be 3 to 4 inches for fluchloralin and 4 to 6 inches for the others. A harrow should follow the field cultivator. The operating speed necessary to achieve a satisfactory incorporation will vary somewhat depending on the type of field cultivator but the speed usually will be 6 to 8 mph.

C. Field cultivators with danish tines plus rolling crumblers behind have given excellent incorporation. These tools should be operated 4 inches deep.

D. Power driven rototiller type equipment will give adequate incorporation when set to operate at a depth of 2 to 3 inches at the manufacturer's recommended ground speed.

A single incorporation with a power driven tiller is sufficient for butylate, cycloate, EPTC, fluchloralin, profluralin, and trifluralin. However, a second tillage at right or 45 degree angles to the initial incorporation should be done if the disc, field cultivator plus harrow, or field cultivator plus crumblers is used. The second incorporation has two purposes: a) Most of the herbicide left on the surface after the first incorporation will be mixed into the soil with the second tillage, and b) the second tillage will give more uniform distribution of the herbicide in the soil, which will improve weed control and may reduce crop injury.

Trifluralin (Treflan) may be applied to wheat after planting and then incorporated above the seed. Shallow incorporation of trifluralin does not give as effective weed control as deep incorporation, but fair to good control of shallow germinating weeds such as green and yellow foxtail (pigeongrass) can be obtained.

Diallate (Avadex) and triallate (Far-go) will adequately control wild oats with a shallow incorporation. Two spike tooth harrowings at right angles will give sufficient incorporation if the soil is loose and free of trash. Experiments at North Dakota State University have shown that deeper incorporation did not reduce wild oat control from diallate or triallate and even gave better control of deep germinating wild oats. However, triallate used on wheat or durum should be incorporated less deeply than the placement of the crop seed. Crop injury may result if triallate contacts the wheat seed after incorporation. Triallate can contact barley seed without crop injury.

Alachlor (Lasso), ethofumesate (Nortron), metolachlor (Dual), and pendimethalin (Prowl) do not require deep incorporation. A tillage tool operating at a minimum depth of 2 inches will give adequate incorporation.

WEED CONTROL IN SMALL GRAIN AND FORAGE CROPS

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Weeds in "close-sown" crops like small grains and forages cannot usually be controlled effectively after seeding and emergence by cultivation or other tillage. Therefore weeds must be controlled in these crops by tillage prior to seeding or with herbicides. If small grain is sown early in the spring, it is quite competitive with "warm-season" weeds including the annual grasses: foxtail, crabgrass, wild proso millet and woolly cupgrass and the annual broadleaves: black nightshade and buffalo-bur. However, in years of late seeding, these weeds can be very competitive with the small grains and must be controlled by the timely use of herbicides where possible.

Most annual broadleaf weeds such as wild mustard, common lambsquarters, pigweed species, Kochia, wild buckwheat, and smartweed species will compete with and overtop small grain even if it is planted early, if these weed seed species are present. Therefore the use of a broadleaf herbicide to control these weeds is necessary most years.

Wild oat is a cool season plant like the small grains and unless delayed seeding with prior tillage is used to control this competitive weed, a wild oat herbicide is usually needed in areas infested with wild oat seed.

If alfalfa or other forage legumes are sown early in the spring without a companion crop, the use of an herbicide to control annual grass weeds such as foxtails and/or barnyardgrass is a must. If alfalfa is direct seeded later in the year (late summer or early fall but no later than August 15) after most of the annual grass weeds have germinated, the use of an herbicide is usually not needed. In direct seeded alfalfa or other forage legumes, most annual broadleaf weeds can usually be controlled by the first cutting unless they are thick enough to shade out the legume, in which case certain annual broadleafs can be controlled with 2,4-DB (Butyrac, Butoxone) when the crop has reached the 1 to 2 trifoliate leaf stage and before broadleaf weeds have more than 5 true leaves.

Alfalfa and other forage legumes are often seeded with a small grain companion crop to help control weeds in the young seedling legumes. This practice is usually fairly successful if the field is not too weedy, if the seeding is done early in the spring and if the companion crop is taken off early as silage. It is usually best not to attempt a mixed seeding of small grain and forage legumes later than May 15 most years, in Minnesota. In such a mixed seeding, with both a grass crop and a broadleaf crop present, the choice of an effective herbicide or herbicide combination is very limited.

HERBICIDE USE ON SMALL GRAINS IN 1982

Because most small grains were seeded early during the 1981 crop season, foxtail was not a serious problem in most fields. With less foxtail "going-to-seed" in 1981, there should be less to worry about in 1982. On the other hand, wild oat was a serious problem in many small grain fields in 1981 and likely will be again in 1982. However, the amount of snow received during the winter of 1981-82, the earliness of the crop season in 1982 and the weather and moisture conditions next spring will affect these predictions considerably.

Because two of the effective and "least-cost" annual grass herbicides for foxtail and wild oat control must be applied "postseeding", before the crop and weeds emerge, a grower must decide on his weed control program early so that he can spread his work load and minimize his costs.

Trifluralin (Treflan) applied after seeding and before emergence of spring or durum wheat or barley will effectively control foxtail and most other annual grasses except wild oat. Label precautions as to incorporation and seeding depth must be followed or crop injury is likely to occur. Triallate (Far-go, Avadex-Bw) may be applied before or after seeding barley and after seeding wheat for control of wild oat. Triallate must be incorporated into the soil. Triallate may be tank-mixed with trifluralin where both foxtail and wild oat are a problem.

The remainder of the small grain herbicides are applied postemergence after the broadleaf weeds are up and actively growing. Annual broadleafs should be controlled when they are small, less than 4 inches tall, for best results. Early season annual broadleaf weeds can be controlled effectively with MCPA or a combination of MCPA and bromoxynil in wheat or barley. MCPA alone can be used on oats and MCPA plus dicamba (Banvel) can be used on wheat or oats but not on barley. Bromoxynil and dicamba are especially effective on wild buckwheat and smartweed. Perennial broadleaf weeds such as Canada thistle or Perennial sowthistle should be sprayed later when they are 6 to 8 inches tall with 2,4-D or MCPA. Spraying with these herbicides must be done before the small grain is in the early boot stage, however.

NEW HERBICIDE CLEARANCES FOR 1982 ON SMALL GRAINS

There are very few new herbicides or herbicide combinations for use in small grains in 1982 that were not available in 1981. However there are a few changes in labels and permitted uses.

1. Diclofop (Hoelon) may be tank-mixed with bromoxynil (Brominal, Buctril) for early postemergence control of foxtail, wild oat and most annual broadleaf weeds in wheat and barley. To be effective, this mixture must be applied when wild oat and/or foxtail are in the one to three leaf stage and when annual broadleaf weeds are less than 3 inches tall.

2. Trifluralin (Treflan) alone or a mixture of triallate (Far-go, Avadex-Bw) and trifluralin (Treflan) is permitted on spring and durum wheat and barley in 1982.

3. The label is being expanded on difenzoquat (Avenge) for wild oat control to include more spring wheat varieties for 1982. New varieties to be included are: Costeau, Solar, Alex, James and Pro Brand 711. See label)

HERBICIDE USE ON FORAGE CROPS IN 1982

There are no changes in herbicide use on forage crops for 1982. EPTC (Eptam) benefin (Balan) and profluralin (Tolban) will still be available for preplant incorporation use on alfalfa. EPTC and benefin may also be used on most other forage legumes. Profluralin will no longer be manufactured by CIBA/GEIGY but will likely be available in 1982. 2,4-DB (Butoxone, Butyrac) can still be used early postemergence for broadleaf weed control in alfalfa and other forage legumes.

For weed control in established alfalfa, simazine (Princep), metribuzin (Sencor, Lexone) and terbacil (Sinbar) may still be used for late fall application in year old stands of alfalfa for the control of certain broadleaf and grass weeds.

Metribuzin and terbacil can also be used in early spring. These herbicides may injure alfalfa. If terbacil is used, no crop other than alfalfa can be planted within two years after treatment. Pronamide (Kerb) can also be used in the fall before soil freezup for grass control in alfalfa and most other forage legumes. Certain broadleaf weeds can be controlled in fall or spring with 2,4-DB amine or ester (Butoxone, Butyrac) when weeds are small and actively growing. Certain formulations of MCPA may also be used at reduced rates for the control of susceptible broadleaf weeds in alfalfa in the fall after the alfalfa is dormant.

Only three herbicides or mixtures of them may be used for broadleaf weed and brush control in grass pastures. These are 2,4-D, MCPA and dicamba (Banvel). Perennial broadleaf weeds should be sprayed when they are 6 to 10 inches tall and actively growing but before they reach bud stage. Broadleaf brush should be sprayed after it is fully leaved out in the spring.

There is still no change in the status of 2,4,5-T and Silvex. These herbicides are still suspended for use in grass pastures, along rights-of way, on home lawns and for use near water supplies (lakes, rivers, ditches carrying water, etc.). 2,4,5-T and Silvex can still be used on rangeland, on cultivated rice and on certain other non-crop areas such as airports, etc.

However, before these herbicides are used, carefully check to make sure the label covers these uses. If it does not, a supplemental label must be secured before use. Label regulations must be followed carefully for these and for all herbicides used.

For detailed weed control recommendations for small grains and forages, see Extension Folder 493, Weed Control in Small Grains; and Agricultural Chemicals Fact Sheets No's. 14, 15 and 16; Weed Control in Established Alfalfa and other Forage Legumes, Broadleaf Weed Control in Grass Pastures and Establishing Forage Legumes with Herbicides. These fact sheets or folders are available from the Bulletin Room, Agricultural Extension Service, University of Minnesota, St. Paul, or from your local County Extension Office.

CERCOSPORA LEAF SPOT OF SUGAR BEETS

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In all but eastern Minnesota, the 1981 Cercospora leaf spot epidemic on the sugar beet crop, the likes of which has not been seen since the early 1950's, has been a topic of much concern and conflicting information. If you search your memory; the occurrence of this epidemic should not have come as a surprise. The senerio was perfectly set, it mearly required time to be played out.

Without going back to the Napolanic development of the sugar beet crop, we should review some history so to better understand the nature of this disease problem on the 1981 sugar beet crop.

By the mid 1960's the sugar beet varieties being grown had relatively good resistance to Cercospora leaf spot. Although the varieties were not immune to leaf spot, the resistance was sufficient so that even under ideal disease conditions, one or two applications of fungicides would prevent crop loss and provide piece of mind. Such a situation prevailed through the early 1970's. In the mid 1970's an out-break of mildew, moderate by comparison to leaf spot in 1981, and root rot in the wet spring of 1979, were the only pathological activity of note. Cercospora leaf spot was being seen in 1978 and caused some concern by 1980.

In the early 1970's the sugar beet variety picture began to change. Growers began the switch to new varieties that would produce more tons and sugar per acre. Not an unreasonable change for the time, but maybe some-what short-sighted in view of the potential disease problems on sugar beets. As these varieties were being introduced, the major part of the crop was still being grown to leaf spot resistant varieties. By 1977 a major portion of the crop from Renville, Minnesota, to Drayton, North Dakota, was being planted to susceptible, high yielding varieties. In 1977 Cercospora leaf spot began showing up in the beet crop. At this time it was not in epidemic proportions. Some systemic fungicides were available, and growers were able to keep the small amount of disease under control for the whole season with one or two applications. With such easy control measures, there was little concern for Cercospora.

Observations in Greece, 1972, and work in Arizona in 1974 identified that the easy, persistent, systemic fungicide control practice may fail. The research in Arizona demonstrated that once the pathogen population changed from being susceptible to the systemic fungicides to being resistant, the population did not change back, even when the systemic fungicides were not used for several years. With this information and the reoccurrence of Cercospora leaf spot, recommendations for use of protectant types of fungicides were made in 1979 & 1980. The theory was that by alternating the use of the systemic with protectant materials we maybe able to prolong the life of the systemic materials.

By 1980 most of the sugar beet crop was planted to susceptible varieties. The leaf spot fungus was present throughout the beet growing area. In the 1980 crop there was some indication that the systemic fungicides were not doing the job. Dr. William Bugbee, USDA Pathologist, tested several field collections of Cercospora, but was unable to identify resistant strains of the fungus.

The 1981 crop, again almost all susceptible varieties, was planted. All that was required for a leaf spot epidemic was some favorable condition for the fungus to infect the plants. Early infections were found about July 10, (private observation) in the southern growing area. By July 15, a general disease warning was put out. However, many growers did not start their disease control practices until August. Historically, this was common practice. By using the systemic fungicides, growers were able to "catch-up" with the disease. However, this year, as growers waited to apply their 2nd application, it was observed that the systemic materials were not holding the leaf spot disease. In fact, 2nd applications of systemic materials at less than the 3 weeks scheduled did not hold the disease in the southern areas.

About mid-August, it appeared that we had resistant strains of the fungus in some areas. Subsequent tests by Dr. William Bugbee, showed that of 30 isolates collected in the southern area, all 30 were resistant to the systemic fungicides. Collections of the fungus from the Wahpeton area did not produce any isolates resistant to the systemic fungicides. This latter collection does not mean that resistant strains are not present, but rather that none we found in the limited collection. I believe that we may extrapolate from the former findings that there is a resistant population of the leaf spot fungus around, and that it will spread and/or develop in other areas of the beet production.

So what does the 1982 season have in store for the sugar beet crop? First, most of the crop will be planted to susceptible varieties, second, the leaf spot inoculum is well distributed (from Renville to Grand Forks) on infected plant debris from the 1981 crop; third, a certain part of the population of the pathogen is resistant to the systemic fungicides; fourth, equipment for crop spraying may be in short supply. The one limiting factor, weather is unknown. If we have weather conditions that permit leaves to be wet for periods of at least 8 hours, we will have the optimum disease conditions. The wet period may be the result of prolonged rain, or persistent dews.

What are the sugar beet growers choices to reduce crop loss in 1982?

1) Plan ahead - plan a disease control fungicide program.

2) Southern district may expect the disease to show-up in early July, weather permitting.

3) In all areas where the disease was present in 1981, growers should be checking their crop for: duration of foliage wetting, (8½ hrs. leaf wetting, - 62°F to 75°F minimum, optimum needed for infection to take place). Symptoms may not show up for 10 or more days after infection.

4) If a grower cannot watch his fields closely, he might choose for a protective spray program - starting before disease is seen and continue throughout the season or at least during optimum conditions.

5) The northern district might pay attention to what is happening to the south.

6) Fungicide selections:

Southern Districts - protectant types materials - e.g.

Duter	Dithane M-45	Manzate 200
Dithane M-22	Zineb	Maneb

Copper Fungicides

Use appropriate spreader sticker for chemicals selected see the label.

7) Do not cut corners!!

Aerial Application

5 gallons/acre

Applied at crop height

Ground Sprayer

Only fungicide sprayers (60 to 80 gallons of water/acre). (Check equipment recommendations). Use the required pressure 200 to 350 psi.

8) Growers in the Northern areas, Crookston, Grand Forks, etc., may still be able to use the systemic fungicides. However, they should be aware of the potential hazard of the resistant strains of Cercospora developing.

9) It may be necessary to shorten up the spray schedules, due to the potential amount of inoculum present.

10) Growers should be checking their fields continuously. Especially watch the side of the field closest to last years crop.

11) If you do not use a preventative program you should be ready to start disease control practices as soon as the disease is found in your area.

The Cercospora leaf spot epidemic of 1981 should be cause for the sugar beet growers to do some serious thinking. It is very possible that some growers are growing more beets than they can properly manage with their commitments, equipment and help. In the search for bigger yields and better quality, often we lose sight of such things as disease resistance. The loss from a disease any one year, must be accounted for by exceptional returns from other years. Often when disease resistance is incorporated into a variety some yield is lost. Will the cost of the disease control practices be covered by the return from growing a very susceptible variety? How does your crop rotation system fit into the disease pattern? As corp rotation systems are shortened, we favor the pathogen allowing it to exist on its own for shorter periods of time. Who's responsibility is it to grow resistant varieties? When a disease is easily spread by the wind, can growers economically control an epidemic disease situation?

CONTROLLED DROPLET APPLICATORS

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Controlled droplet applicators (CDA's), also called rotary spray nozzles, use centrifugal force rather than hydraulic pressure to form spray droplets. Centrifugal force is supplied by a spinning cup or disc powered by a small electric motor. Several types of CDA's are available but the type used for ground broadcast application has the trade name Micromax and the following discussion will refer to this type.

The spray solution is injected at the bottom of the CDA spinning cup and is forced up grooves inside the cup. The liquid is formed into droplets on teeth at the upper edge of the cup and flung from the teeth in a circular pattern. The rubber drive belt can be placed on one of two pulleys to select the revolutions per minute of the cup. The CDA will operate at 2000 rpm to produce droplets of about 250 microns diameter or at 5000 rpm to produce droplets of about 75 microns diameter.

Research at the Canada Agriculture Research Station in Regina established that 82 inches spacing between CDA units gave the most uniform distribution when the units were operated at 2000 rpm, a height of 13 inches above the target, and a flow rate of 1 liter/min or 0.26 gal/min. This optimum spacing was determined with a stationary sprayer and no wind. Other observations indicate that a head wind, tail wind, or even the forward speed of the sprayer can cause spray droplets to deflect as they pass through the air. This deflection will prevent proper overlap and cause non-uniform coverage. Bouncing spray booms and applying spray solutions with different viscosities also have been reported to cause non-uniform coverage. Placement of CDA units 41 inches apart rather than 82 inches apart provides additional overlap which probably would help compensate for various factors that reduce uniformity of coverage.

Experiments at North Dakota State University compared weed control from equal rates of herbicides applied at 4 mph with a CDA at 2000 rpm, a CDA at 5000 rpm, or an 8001 nozzle at 40 psi. Weed control from the CDA at 5000 rpm (75 micron droplets) was generally less than from the CDA at 2000 rpm (250 micron droplets) or from the 8001 nozzle. Weed control from the CDA at 2000 rpm was generally similar to weed control from the 8001 nozzle. However, comparisons between flat fan and CDA nozzles should be made on an individual herbicide basis. For example, glyphosate (Roundup) has generally performed better through the CDA while a few reports with other herbicides have indicated reduced weed control from CDA applications as compared to flat fan nozzles. At this time, herbicide rates should not be reduced below labelled rates when using a CDA but future research may establish that rates of a few herbicides can be reduced. Spray drift was less with the CDA at 2000 rpm than with the 8001 nozzles but spray drift from the CDA at 5000 rpm was greater than from the 8001. Greater drift from the CDA at 5000 rpm may explain the reduced weed control as compared to the 8001 nozzles.

A CDA at 2000 rpm, 4 mph and a 0.26 gal/min flow rate will apply 4.8 gal/A with an 82 inch spacing or 9.6 gal/A with a 41 inch spacing. The 8001 nozzles with a 20 inch spacing and 40 psi will apply 7.4 gal/A at 4 mph. Thus, the CDA spaced at 41 inches for optimum coverage and operated at 2000 rpm for optimum weed control and minimum drift will use more water per acre than 8001 nozzles.

The advantages of controlled droplet applicators over flat fan nozzles for herbicide application appear to be reduced spray drift at 2000 rpm and improved weed control with a few herbicides. The main disadvantages are higher cost, greater complexity of the equipment, potential non-uniform spray coverage with the wide spacing between units, and potential increased spray drift with the 5000 rpm setting.

QUACKGRASS CONTROL IN SOYBEANS

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Quackgrass [Agropyron repens (L.)] remains a serious perennial weed for Minnesota soybean producers. Historically, soybeans have been grown in rotation with corn, a crop in which several selective herbicides have been used extensively for quackgrass control. Farmers who produce corn and soybeans in rotation have relied on effective quackgrass control in corn prior to planting soybeans in the rotation. Atrazine has been used by producers for many years to provide effective quackgrass control in corn. However, when applied at rates required for effective quackgrass control, residual atrazine can remain in the soil the following year at concentrations high enough to necessitate growing a tolerant crop for two successive years to avoid crop injury. EPTC + R-25788 (Eradicane) is used widely to control annual grasses and quackgrass in corn without soil residual problems in soybeans the following year. Glyphosate (Roundup), a nonselective herbicide, can be utilized as a pretillage treatment for quackgrass control prior to planting soybeans, corn and many other crops.

Herbicides for selective quackgrass control in soybeans are very limited. Vernolate (Vernam) is the only registered herbicide that will suppress quackgrass selectively in soybeans. Quackgrass control is only fair and often erratic, especially in dense quackgrass stands, at rates recommended for annual grass control.

Recently we evaluated several experimental herbicides, such as KK-80, Ro-13-8895 and BAS 9052, as selective postemergence treatments in soybeans for quackgrass control. In limited trials, these herbicides have given excellent quackgrass control without soybean injury. In the future, these herbicides may eliminate the need for preplow treatment prior to planting soybeans by allowing selective quackgrass control in soybeans.

POTATO DEFOLIATION DEMONSTRATIONS

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Workable action levels for insecticide control of defoliating insects in potato in Minnesota have been developed by Dr. Radcliffe and his students. However, monitoring of fields in the Agricultural Extension Service has seemed to indicate either improper timing of foliar applications or treatments before defoliation estimates indicate economic benefit will accrue.

Taken together this indicates the need for demonstration of the relationship of defoliation vs. yield in our potato growing areas. Again Radcliffe's work in the metropolitan area is excellent for that area. His group has clearly indicated that yield and defoliation relationships have remained constant over several years. But there are not too many similar trials in the northwestern part of Minnesota. Also the effect of defoliation on yield in early, mid and late season cultivars needs examination.

The following two trials are the beginning of a series comparing yield and defoliation to be carried out in conjunction with the Crop Pest Management program. It is intended that these will be placed in co-operating growers' fields representative of the major potato producing areas of the state.

One trial was located on the Sherwood Peterson farm near Baker, MN. The potato cultivar was Anoka and was hand defoliated by removing complete leaves on the 11th of July 1981. Plots were three adjacent hills bordered on each end by a non-defoliated plant. Yields were collected on 10 September 1981. Weights for each of the three hills were kept separate and compared statistically. There were no positional differences in yield. Thus the yields which are tabulated in Table 1 are reported on a per hill basis but are an average of 18 hills/treatment. There were no statistical differences in yield.

Table 1. Hand defoliation of potato and yields at Baker, MN 1981. Noetzel and Holen.

Treatment in percent defoliation	Yield in pounds/hill
10	4.69
20	4.07
30	4.13
50	4.03
70	4.18
0	3.93

A second trial near Crookston was located on the Kenneth Kellar field. A portion of a field of Russet Burbank potatoes was left untreated until average defoliation for the area was 25%. Then, following treatment with Pydrin on the 6th of July, three hill plots with similar insect damage as indicated by an average of five evaluators were staked and defoliation recorded. Defoliation per plot ranged from none to 90%. Yields were collected on the 9th of September on center hills only.

Table 2. Colorado potato beetle defoliation and yields at Crookston, MN 1981. Noetzel, Holen and Radcliffe.

Range in percent defoliation	Number of plots	Yield in pounds/hill
0- 5	14	1.64
6-14	12	1.68
15-20	12	1.56
21-50	14	1.23
51-	8	1.08

There were significant reduction of yields above 21% defoliation in this field. However, there is little if any effect on yield when defoliation is at or below the crop pest management action level.

The question of Colorado potato beetle resistance to insecticides is raised each time an insecticide application fails to provide nearly complete control of that insect. Dr. Radcliffe and his students have generated information over the years which do not indicate the presence of CPB resistance in Minnesota to the presently labeled materials. Insecticide trials in 1981 near East Grand Forks and Crookston provide further observations on efficacy of many insecticides on CPB populations in the northwestern part of the state.

Table I. Control of Colorado potato beetle. 1981. J. Vanascek farm. East Grand Forks, MN. Johnston, Radcliffe and Cuperus.

Treatment	Pounds AI/a	Percent Control 24 hours	Percent Control 7 days
Check	0	0	0
Monitor	0.75	97.7*	93.2*
Lannate	0.45	81.1	69.3
Lannate	0.9	88.0	77.4
Phosphamidon	0.5	99.3	93.2
Pydrin	0.05	95.1	99.8
	0.1	97.1	98.9
	0.2	97.4	100.0
Vydate**	0.45	99.1	100.0
	0.9	99.4	100.0
Sevin XLR	1.0	99.4	99.7
Sevin 80 WP	1.0	99.7	100.0
Furadan	0.5	99.0	100.0
Azodrin	0.75	84.5	98.6
Thiodan	1.0	99.0	96.7
Imidan	1.0	98.7	99.8

* Corrected using Abbotts formula
** Not presently labeled in Minnesota

Plots were treated on 2 July 1981. The data indicate that excellent control of 2nd through 4th instar CPB was obtained with most currently labeled insecticides. In 1981 the seasonal development of CPB was such that a single properly timed application of foliar insecticide would have been sufficient for season long CPB control, if it were required at all.

A second set of plots were established near Crookston. Because insecticide performance was outstanding in the Vanascek trials rates of several compounds were reduced (Table 2). Chemicals were applied to Russet Burbank potatoes on 9 July 1981.

Table II. Control of Colorado potato beetle. 1981. R. Kellar farm. Crookston, MN. Johnston, Radcliffe and Cuperus.

Treatment	Pounds AI/a	Percent Control at 24 Hours
Check	0	0
Monitor	0.5	95.9*
Phosphamidon	0.25	99.5
Imidan	0.5	98.5
Pydrin	0.025	97.2
Pydrin	0.05	99.7
Vydate**	0.25	99.4
Sevin XLR	0.75	98.7
Sevin 80 WP	0.75	97.8
Furadan	0.25	99.4
Azodrin	0.75	99.0
Guthion	0.25	99.5
Thiodan	0.75	99.2

* Corrected using Abbotts formula
** Not presently registered in Minnesota

The control was remarkably good even with insecticide rates reduced by 25 to 50%.

These plots along with the defoliation studies provide considerable insight into judgment making in CPB control. The excellent insecticide efficacy permits us to use the thresholds Dr. Radcliffe and his group have provided because we know nearly complete control can be obtained. It appears probable that even years when CPB control is needed a single properly timed application of insecticide (and certainly no more than two) will provide maximum economic return. And finally the effectiveness of such a wide array of chemicals widens our chemical options. Both reduced number of applications and rotation in chemicals should greatly reduce the potential for development of resistance in CPB.

CUTWORM CONTROL

Cutworms continue to be an annual problem in most crops but are especially damaging to sunflower. We have attempted to have cutworm control trials every season for the past five years. To do this we have spent time seeking initial populations exceeding 5 larvae per square foot irrespective of the host plant in which they occur and irrespective of the cutworm species.

In addition a graduate student, Robert Schmidt, has been examining developmental rates, food consumption, sunflower stand reduction, and early season defoliation by two species of cutworm, the darksided and dingy cutworm in sunflower. He has also worked with us in early season simulated damage. His objective is to develop a more precise predictive "model" for cutworm damage to sunflower, hence an easier system with which to make control judgments.

Two sets of data follow. Morris data were collected in spring wheat seeded on March 23 following a 1980 crop of sunflower. The predominant cutworm was the dingy cutworm and was present in the plot area at the time of our first visit at the level of 8 per square foot. Other portions of the field contained 13 larvae per square foot.

Table I. Dingy cutworm (Feltia duscens) control in wheat. Merrill Carlson field. Morris, MN 1981. Robert Schmidt, David Noetzel and Jerrel Christensen.

Treatment	Rate ai/a in pounds	Percent Control	Corrected* Percent Control
Lorsban	1.0	93	83
Pydrin	0.1	92	81
Ambush	0.1	79	50
Toxaphene	3.0	68	24
Check	-	58	0

*Corrected using Abbotts formula

At the time this field was first observed we felt the cutworm population was consuming enough wheat to keep the field black. Bob Schmidt wanted to follow this population to measure individual larval growth, however, so control was delayed until May 11. Larval counts per square foot dropped from eight to about 2.25 over a 3 week period prior to chemical application. Pre-treatment counts taken in the morning of May 11 were 2.25 with no significant difference between plots. Insecticides were applied in about 25 gallons of total material per acre that afternoon. Post treatment counts were made at 72 hours. Percent control and corrected percent control are contained in Table I.

What is particularly striking is the high mortality in the untreated plots. This mortality was identical with that in untreated portions of the remainder of the field and so is probably not due to insecticide drift or larval migration. The second major point is that control with toxaphene at very high rates did not significantly exceed the untreated check. Lorsban, Pydrin and Ambush provided approximately equal control. There were no yield differences here so the economic thresholds were not exceeded or to say it simply, chemical control did not pay.

A second trial was carried out with Blake Peterson on the Carl Jensen farm in Roseau county. The predominant cutworm was the redbacked cutworm which were migrating and feeding as they moved from a timothy field into flax. The initial larval population was 5.8 per square foot with no significant differences between plots. Insecticides were applied the evening of the day (June 5, 1981) on which pretreatment counts were made.

Table II. Redbacked (Euxoa ochrogaster) and dingy cutworm control in flax. Carl Jensen field. Roseau, MN 1981. David Noetzel and Blake Peterson.

Treatment	Rate ai/a in pounds	Percent Control	Corrected* Percent Control
Pounce	0.1	94.6	91.0
Pydrin	0.1	89.3	82.0
Ambush	0.1	88.8	81.9
Lorsban	1.0	88.2	81.0
MV 770 (Stauffer)	1.0	75.2	60.0
Sevin XLR	1.5	43.6	9.0
Toxaphene	3.0	39.8	2.9
Check	-	38.0	0

*Corrected using Abbotts formula

Post treatment counts were taken 72 hours after insecticide application. Again the striking thing about this test is the high cutworm mortality in the check during just a three day period following treatment. And toxaphene did not outperform check. Pounch, Pydrin, Ambush, and Lorsban provided equal control at the rates used.

In five years of trials at nine locations we have not observed cutworm control with toxaphene to exceed untreated checks. These trials have included darksided, dingy and redbacked cutworm in sunflower, small grain and flax. Soil conditions at treatment time have ranged from severe drought (i.e., no measurable rainfall for 6 months prior to treatment) in 1980 to extremely moist conditions in 1981. We are speculating that what we earlier believed to be acceptable control with toxaphene was really normal mortality in cutworm populations. Hence toxaphene for cutworm control will be dropped from 1982 recommendations.

The major insect problems in sunflower in Minnesota during 1981 were sunflower midge, sunflower seed weevil and banded sunflower moth. Almost all fields also have some internal stem damage due primarily to Apion activity. The relationship of this insect injury to stalk rotting organisms (e.g., premature ripening) is not clear.

Sunflower midge

A late season swing through the west central and northwest sunflower growing areas of Minnesota provided additional observations on midge injury. Damage was present in all parts of the Red River Valley and extended outward onto lighter soils and rolling country sometimes as far as 20 to 30 miles from the valley edge. The most severe injury, however, was in the northern valley centered around Donaldson, Minnesota and south to Stephen. Moderate to severely injured fields (a few totally destroyed) were more widely spread than in 1979, the year of the last locally severe injury.

In summary, we saw a somewhat more severe midge problem than in 1979 and certainly more widespread than in any previous year. However, we do feel that our early estimate of a 10 percent reduction in yield in Minnesota, based on all July 1 acres, was a reasonably good one. This was certainly no disaster, but not a bright note either.

In some areas it was hard to find fields showing even slight midge injury. In eastern Roseau, Marshall, Pennington, and Polk we observed some of the best sunflower fields we have ever seen; many had no midge damage present. Midge populations were probably low or nil in these areas.

It is quite clear that under moderate to heavy midge pressure (and maybe under light infestations as well), none of the present insecticides appear to reduce damage. We had theorized that materials that had greater activity against the adult fly might provide hope. Direct observations of adult flies ovipositing on freshly treated plants quickly dispelled that idea.

There are some fairly positive aspects of the problem, however. Fields in every area visited, sometimes those adjacent to a field with severe midge damage, yielded the normal one ton plus of seed. Why did these fields escape the midge? There are three apparent reasons for the escape.

First, sunflower hybrids exist that are either tolerant or resistant to light to moderate midge pressure. Several hybrids appear to be superior in this respect.

Secondly, many fields escaped due to time of planting. It's very apparent that fields planted in late May and early June were generally free of midge. This was readily confirmed wherever midge was present as indicated by paired undamaged and damaged fields. It was further supported by the observation that we appeared to have had a single peak of midge adults the first week in July. (In looking back at 1980 and 1979 the adult emergence also occurred the first week in July in both years.)

Lastly, we know so little about adult midge movement that it is possible that winds may have carried these adults into some fields and away from others. We are confident that this was much less a factor than the first two observations.

Although some insect control tools appear not to function against the sunflower midge, there are others that do. Seed companies should be encouraged to discontinue midge susceptible sunflower lines. At the same time, selection of midge tolerant lines should be strongly encouraged. The value of late planting in escaping midge also needs to be examined objectively in several areas of the valley.

Sunflower seed weevil

The numbers of adults observed in the Breckenridge, Foxholm, and Wheaton areas exceeded twenty per plant in many fields. Data from plots, CPM monitored and growers' fields are still being analyzed. Tentative observations seem to indicate that control is extremely variable with some suggestion that single applications of parathion at one pound in fields with infestation levels of 20 adult weevils per plant may not be profitable. We are having great difficulty in demonstrating any effect on yield with only 10 weevils per plant.

Banded sunflower moth

This insect was much more abundant in 1981 than 1980. 1980 data indicated economic injury in about 3% of monitored fields. The adult moth must be monitored in a manner similar to sunflower moth in order to make control judgments. This has proven to be a most difficult procedure.

ROPEWICK APPLICATORS

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Ropewick applicators to selectively apply Roundup (glyphosate) have gained wide-spread acceptance since their introduction in 1978. Although these applicators do not replace conventional herbicide programs, they provide a low-cost supplement to them. Farmers have found these new tools useful for removing volunteer corn, johnsongrass, shattercane, and several broadleaf weed species from soybeans.

Several types of ropewick applicators are available commercially. These range from relatively simple units with ropes placed in PVC pipe to pressurized systems. The accompanying publication, Extension Folder 607, describes various types of selective herbicide applicators and their use. This discussion will be geared primarily toward the unit referred to as the pipewick applicator (the units constructed of PVC tubing with ropes placed into the pipe as described in the accompanying publication, Extension Folder 606).

One of the most desirable features of the pipewick applicator is the relatively low cost of materials to build a unit and the ease of construction. Since no specialized equipment is needed in construction, most farmers can construct a unit with little difficulty. Cost will vary with the method used to secure the ropes into the pipe, applicator length, number of rows of ropes used, but construction costs can be expected to run between $100 and $200. Units are available commercially in a price range of $200 to $700.

For those who desire to construct their own ropewick applicator the accompanying publication, Folder 606, describes materials and procedures in some detail. In addition to using nails to help anchor the rope, as illustrated in the above mentioned publication, other devices such as non-galvanized screws or hog rings can be used. Nails may tend to work out of the rope in which case screws or hog rings would be preferred. Once in place the ropes must be secured with glue which serves to seal around the rope, preventing leakage. Either 3-M Super Weather Strip Adhesive (a yellow glue) or 3-M Weather Strip Adhesive (a black glue) has been satisfactory. The black glue does not penetrate the rope as much as the yellow glue. Therefore, the wicking rates for ropes secured with the black glue is normally somewhat faster than when the yellow glue is used. Both glues appear to adhere to the PVC pipe satisfactorily. The black glue has more elasticity than the yellow glue and it is recommended for most applications, especially if faster wicking is desired.

One additional tip for constructing a pipewick applicator is to use 5-foot sections of PVC pipe and connect the sections together with a PVC tee with a twist-lock cap (see Extension Folder 606). This will allow the user to place sponges into the tee every 5 feet of applicator length to act as a dam to prevent the herbicide solution from flowing to one end of the applicator. The sponges can be removed when the applicator is to be drained and cleaned.

Of the factors affecting wicking rate kind of rope and location of the ropes in the pipe are very important. Since there is a tremendous variation in wicking rate of ropes, with some too fast and others too slow, care must be taken to choose a rope that has been evaluated and found to be satisfactory for this purpose. Extension Folders 606 and 607 discuss kinds of ropes. Fast wicking ropes such as Peppermint or Pistachio from the Gulf Rope and Cordage Company should not be used in units such as the 'Wedgewick' which utilizes an air pressure system or in units such as the 'Bobar' where the reservoir can be elevated to increase flow rate. Wicking will be too fast and result in excessive drippage which may lead to significant crop injury and wasted herbicide.

Recent studies done at the Southern Experiment Station further illustrate differences in wicking rates of rope (Table 1).

Table 1. Effects of type of rope and location in a pipewick applicator on the wicking rate of 33 1/3% Roundup (glyphosate).

		Location in Pipe*		
Rope manufacturer	Style	Top	Middle	Bottom
		-----ml/hour-----		
Wellington Puritan	Braided nylon G1032	8	33	46
Gulf Rope and Cordage Co.	Braided nylon Peppermint	41	98	121
Gulf Rope and Cordage Co.	Pistachio**	70	194	204
Wellington Puritan	Expt. core**	120	604	823

* Ropes located approximately as follows: Top - 3 o'clock position, Middle - 4 o'clock position, Bottom - 5 o'clock position.

** Pistachio is a diamond braid polyester over an acrylic core. Expt. core is a new rope consisting of a non-woven nylon core with a braided polyester jacket.

When ropewick applicators were first introduced, Wellington Puritan Mills solid braided nylon rope (cat. no. G1032) was recommended. In the past few months efforts have been made by rope manufacturers to develop rope with faster wicking characteristics. Two such ropes (Peppermint and Pistachio developed by the Gulf Rope and Cordage Company in Mobile, Alabama) have been manufactured. The wicking rate of the Peppermint rope is nearly three times as fast as the Wellington Puritan nylon rope. The Pistachio rope wicks nearly twice as fast as the Peppermint (Table 1 and Extension Folders 606 and 607). Although the Pistachio rope may have some advantage in dense weed stands, especially if the target species is a perennial, it probably wicks faster than is necessary for most situations. Since Roundup is relatively expensive, excessive dripping will add significantly to application cost and increase the potential for crop injury. The Peppermint rope is the preferred rope for pipe-wick units at this time.

In a study conducted near Waseca, MN in 1981 to compare the Peppermint to the Wellington Puritan nylon rope for velvetleaf control, the percentage control was 88% and 65%, respectively, for the two kinds of rope. This data indicate the desirability of a faster wicking rope for difficult to control species.

Wellington Puritan Mills has recently developed a rope with a braided polyester jacket over a non-woven nylon core. This rope wicked very rapidly in our tests and would result in excessive dripping in nearly all cases (Table 1).

The position of the rope in the pipewick applicator greatly influences the rate of wicking. Work done at the University of Nebraska (Extension Folder 607) and recent work at the Southern Experiment Station illustrate this point (Table 1). These studies were conducted using a 33 1/3% Roundup solution with the pipewick applicator one-half full at the beginning of each one hour run. The lower the rows of rope on the pipe the more hydraulic head they had and thus, the faster they wicked. The change in output for the various ropes varied from about 3 to 7 fold comparing the top to the bottom location. Because of this, placing a faster wicking rope in the top row and possibly a slower wicking rope in the bottom row may be desirable to aid in controlling wicking rate. However, this would not seem to be necessary when the Peppermint rope is used in pipewick applicators for weed control in soybeans.

Various compression fittings can be used to adjust flow rate somewhat. However, these add to construction cost and probably are not necessary. The possible exception being where Pistachio rope is used in construction.

For a discussion on herbicide concentrations for various applicators see Extension Folder 607. This publication includes a discussion of the effects of herbicide and herbicide concentration on wicking rate. Generally a 33 1/3% Roundup solution (1 part commercial Roundup formulation to 2 parts water) will provide best overall results with ropewick applicators.

There has been interest in improving escaped broadleaf weed control with selective applicators. One approach that has been tried is the addition of 2,4-D to Roundup (see discussion in Extension Folder 607). Field studies in 1980 (Nebraska) indicated that 2,4-D (amine or ester formulations) added to Roundup did not result in improved broadleaf weed control. Velvetleaf control was actually lower where 2,4-D was added to Roundup as compared to Roundup used alone. One reason for this appears to be that 2,4-D wicks at a slower rate than Roundup resulting in less material applied.

Table 2. Effects of Roundup and 2,4-D amine concentration on velvetleaf control in the greenhouse (Univ. of Nebraska).

Herbicide(s)*	% Concentration	% Velvetleaf Control
Roundup	16 2/3	95
Roundup	33 1/3	92
2,4-D Amine	16 2/3	51
2,4-D Amine	33 1/3	48
Roundup + 2,4-D Amine	16 2/3 + 8 1/3	66
Roundup + 2,4-D Amine	16 2/3 + 16 2/3	48
Roundup - 2,4-D Amine**	16 2/3 + 16 2/3	85

* Each treatment consisted of placing 2 drops (5 ul each) on each of three leaves on an individual plant. Six replications were evaluated.

** 2,4-D Amine application applied 24 hours after Roundup application. All other herbicide combinations applied at same time as a herbicide mixture.

Recent greenhouse studies on control of velvetleaf with various herbicides and combinations of herbicides shed further light on this subject (Table 2). In this research where controlled amounts of herbicide were applied to velvetleaf using a micropipet, 2,4-D amine appeared to interfere with the activity of Roundup. This is evident by the fact that addition of 2,4-D amine to Roundup resulted in reduced control of velvetleaf compared to where Roundup was applied alone. Also, delaying the 2,4-D amine application for 24 hours after the Roundup was applied improved velvetleaf control compared to applying a mixture of the two herbicides. However, delaying the application of 2,4-D after Roundup application did not result in control equal to Roundup applied alone. Because of these observations and the poor field performance when 2,4-D was added to Roundup with several selective herbicide applicators (several rope-wick applicators, a roller applicator and a recirculating sprayer), it is recommended that a 2,4-D not be used in these units with Roundup.

One of the problems with selective applicators is that the target weeds must be at least 8-10 inches taller than the crop before Roundup can be applied to weeds without injury to the crop. Therefore, the weeds compete with the crop for several weeks before they can be removed. The effects of removing simulated volunteer corn with two techniques were studied at Rosemount, Waseca and Lamberton, Minnesota.

Table 3. Effects of volunteer corn on yield of soybeans at three locations in Minnesota, 1979-1980.

Corn Density* and	Rosemount		Waseca		Lamberton	
Control Method	% Cont.	bu/A	% Cont.	bu/A	% Cont.	bu/A
None						
Hoelon spray	100	33	100	40	100	41
Roundup with pipewick	100	34	100	37	100	43
Untreated	100	34	100	39	100	42
One clump every 8 feet of soybean row						
Hoelon spray	92	32	100	37	100	40
Roundup with pipewick	96	32	98	31	87	39
Untreated	0	24	0	23	0	32
One clump every 4 feet of soybean row						
Hoelon spray	94	31	100	37	98	31
Roundup with pipewick	96	30	98	28	89	37
Untreated	0	14	0	11	0	23
One clump every 2 feet of soybean row						
Hoelon spray	93	30	98	37	98	40
Roundup with pipewick	96	26	97	20	94	31
Untreated	0	4	0	3	0	14

*Approximately 10 kernels of F_2 seed produced from a single cross hybrid planted in the soybean row at the designated spacing. Soybean planting dates for 1979 were May 23, May 25, and June 1 and in 1980 were May 12, May 12, and May 19 for Rosemount, Waseca and Lamberton, respectively. Hoelon applied at first to second trifoliolate leaf stage. Roundup applied twice--first application ranged from July 9 to July 19, 1979 and from June 23 to June 27, 1980. Second Roundup application applied July 25, 1979 at Waseca and Rosemount and not applied at Lamberton, and applied June 23 to June 27, 1980.

These studies, where approximately 10 kernels of F_2 seed were planted at various intervals in the soybean row immediately after soybean planting, illustrate the effects of early weed (volunteer corn) competition (Table 3). Either the Hoelon (diclofop) applied as a broadcast spray when corn plants were 6-8 inches tall or Roundup (glyphosate) applied twice with a ropewick applicator gave nearly complete control of volunteer corn. However, where the volunteer corn populations were high (clumps every 2 or 4 feet of soybean row), removing it with Hoelon resulted in significantly higher soybean yields than where Roundup was the method of control.

Therefore, where high populations of volunteer corn exist, early removal with a herbicide such as Hoelon would be profitable. However, where volunteer corn is not present in high populations, it can be removed at a low cost ($1-2/acre) with Roundup. This relationship would hold true for other weed species as well.

Although the ropewick applicators cannot solve all of a grower's weed control problems, they offer the farmer a relatively low-cost method of removing escaped weeds from soybeans. Some of the recent improvements have increased their effectiveness and should result in greater use of these units in the future.

Guidelines for Constructing A Pipewick Applicator*

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The use of selective applicators to control tall weeds in shorter crops is rapidly being adopted as a new weed control method. Effective use of this system requires that weeds be at least 10 inches (25 cm) taller than the crop. Roundup (glyphosate), a non-selective herbicide, is normally used and must be applied without contacting the crop. At present, the use of selective applicators allows weeds to compete with the crop for about 60 days in order to attain the required height differential. Since serious yield reductions could result if dense weed populations occur, selective applicators should be viewed as a method to supplement, rather than to replace, other chemical and cultural weed control methods.

Several types of applicators have been developed for selective herbicide applications. Among them are recirculating sprayers, roller applicators and rope-wick applicators, which involve the wicking action of ropes.

Figure 1. Completed and mounted pipewick applicator.

The simplest ropewick applicator, the pipewick, consists of a series of ropes that are placed in polyvinyl chloride (PVC) pipe. The ropes transfer the herbicide from the pipe reservoir onto the weeds by wicking action.

The pipewick, an easily constructed, low-cost and non-pressurized system with no moving parts, has performed satisfactorily. Following are instructions for constructing a pipewick applicator. For information on the use of selective applicators, including the pipewick, refer to Extension Folder 607—1981, "Guidelines for Using Pipewick and Other Selected Applicators."

The Pipe

The pipe that serves as the chemical reservoir is 3-inch (7.6 cm) diameter PVC Schedule 40 (1120) tubing commonly used in sewer and drain installations. This pipe is tan in color; black ABS pipe is not recommended because it absorbs heat from the sun and may pressurize the system.

Although the length of pipe may vary, the maximum should be 20 feet (6.1 m). On uneven terrain, a longer applicator increases the chances of dipping one end into the crop canopy, resulting in serious crop injury. Also, longer pipes may tend to sag from the weight of the solution, making it difficult to maintain uniform chemical distribution in the pipe and proper height above the crop canopy.

Pipe lengths should be approximately 12 inches (30 cm) longer than necessary to cover a prescribed number of rows. For example, a 16-foot (4.9 m) applicator should be used to cover six 30-inch rows [15 feet (4.6 m)] to account for irregularities in row spacings.

Since PVC pipe normally comes in 10-foot (3 m) lengths, it is necessary to connect the pipes together. A 3-inch (7.6 cm) tee is suggested to join the pipe sections. A tee should also be placed on each end of the pipe. Placing adapters and caps on the end tees, as illustrated in *Figure 3,* provides a convenient place to fill and drain the unit. This also allows the pipe to be cleaned easily.

Because most fields are not completely level, the solution tends to flow to one end of the pipe regardless of pipe length. To help slow this solution shift, a baffle can be made by placing a large sponge or a plastic disc in the center tee of the pipewick. The sponge is easily installed and can be removed as needed. If a removable sponge is

*Evaluation and improvment of the pipewick applicator was made possible by a grant from the Nebraska Soybean Development, Utilization and Marketing Board.

used for the baffle, a solid end cap can be used on one end of the pipe, and a tee with appropriate fitting on the other end.

A vent must be provided to prevent a partial vacuum from developing inside the pipe, which will greatly reduce the wicking rate. Drilling a 1/8- to 1/4-inch (0.3-0.6 cm) diameter hole in the fill cap will provide sufficient venting for the system. This vent must be plugged when the pipe is rotated.

The Support Frame

The pipe should be attached to a rigid frame capable of supporting it without sagging while in operation. An angle iron or wood frame with appropriate support rods or cables will help prevent sagging. The support frame should be located on the back and/or top side of the pipe so it does not contact the weeds, pushing them away from the ropes.

A front mounting on a hydraulic loader or other height adjustable framework is advisable. This allows for best visibility and prevents dust created by the tractor from collecting on the applicator.

The pipe can be mounted to the rigid framework by large band type hose clamps or similar devices. One clamp every 4 feet (1.2 m) of pipe will provide adequate support. Attachment to the framework should allow the pipe to be rotated so that the ropes can be turned up to prevent dripping when not in use, or to prevent chemical loss if a leak developes.

The Rope

Although additional research is still needed to determine the best kind of rope or combination of ropes, laboratory research at the University of Nebraska indicates that wicking rates of different kinds of rope vary greatly *(Table 1)*. Be sure to select a rope that has been evaluated for this purpose since some nylon ropes may give extremely slow wicking rates.

Table 1. A comparison of wicking rates of four kinds of ropes.

*One half-inch (1.3 cm) diameter rope**	*ml/5 hrs***
Dare Co. S.B.N.	7
Wellington Puritan Mills S.B.N.	46
Gulf Rope and Cordage S.B.N. (Peppermint)	166
Gulf Rope and Cordage Poly/AC (Pistachio)	385

*S.B.N. – Solid braid nylon; Poly/AC – Diamond braid polyester covering over acrylic core.
**Laboratory study with 8 replications.

When pipewick applicators were first developed, Wellington Puritan Mills 1/2-inch (1.3 cm) diameter solid braid nylon rope (catalog number G1032) was recommended. This rope has given relatively satisfactory results for control of volunteer corn and shattercane, and may be desirable where reduced wicking is preferred. For example, if Roundup receives approval for use with pipewick applicators in sorghum, reduced wicking may be desirable to avoid crop injury.

In our research, two ropes from the Gulf Rope and Cordage Co. (Box 5516, Mobile, Alabama, 36605) were compared to the Wellington Puritan rope. The Gulf rope, called Peppermint (style 109A), is a 1/2-inch (1.3 cm) diameter solid braid nylon that is precut and preshrunk at the factory. This rope had a wicking rate nearly three and one-half times that of the Wellington rope. The second rope from the Gulf Rope and Cordage Co., called Pistachio, is 1/2 inch (1.3 cm) in diameter, with a diamond braid polyester outer covering and an acrylic core. Wicking rate of this rope was more than twice as fast as the Peppermint rope. In many cases, the Pistachio rope may wick too rapidly and cause excessive dripping, resulting in crop injury.

Although it has not been field tested, we suggest using the Peppermint rope where dense weed populations are encountered. Using this rope may help reduce the need for two passes with the pipewick to get adequate weed control.

Most rope will shrink after wetting and drying, breaking the glue seals if ropes are installed too tightly. As much as 25 percent shrinkage may occur. Thus, the rope should be alternately soaked and dried a couple of times to shrink it before cutting it to the desired length. This is suggested even for factory preshrunk ropes like Peppermint.

To prevent unraveling of rope ends, heat the rope slightly in a flame to sear the outer fibers. After shrinking the rope, mark it to the desired length. Sear, but do not melt, a 1-inch (2.5 cm) segment near the mark by rotating the rope in a flame. Then cut in the center of the seared area. This procedure is not necessary with the Peppermint rope as it is seared and cut to length at the factory.

Sufficient length should be used to allow approximately 4 inches (10 cm) of each end of the rope to be placed inside the pipe. If the holes for the rope are 8 inches (20 cm) apart, a preshrunk length of approximately 18 inches (46 cm) is required. This allows the rope to be installed with approximately 1 1/2 inches (3.8 cm) of slack in the rope, measured from the pipe to the center of the tightly pulled rope.

Rope Installation

Holes in the pipe for rope installation should be 6 to 8 inches (15 to 20 cm) apart, with 1 1/2 to 2 inches (4 to 5 cm) between adjacent ropes *(Figure 3)*. Although two rows of ropes along a pipe may be sufficient, three rows are suggested to improve coverage. Rows of ropes should be approximately 1 inch (2.5 cm) apart. When in operation, orient the lowest row of ropes on the pipe about 30 degrees forward from a vertical position so it is not at the lowest point of the pipe. This reduces dripping and gives good rope-to-weed contact.

Grommets and compression fittings have been used to secure ropes into the PVC pipe. However, these reduce the wicking rate and increase construction cost.

The recommended method for rope installation is to insert the rope directly into the pipe without grommets or compression fittings. Clean the pipe thoroughly and then glue the rope into place, using several layers of glue to form a good seal.

The best type of glue for rope installation still needs considerable research. At present, 3M 'Super Weather Strip Adhesive' appears to give satisfactory results. A limited number of other glues have been evaluated but have not been found to be superior to this 3M product.

The hole size is very important when ropes are installed without fittings. Use a high speed wood bit to drill the holes. Since the actual diameters of "1/2-inch" (1.3 cm) diameter ropes have been observed to vary, several experimental hole sizes should be tried to find the one that gives a snug fit. Do not install ropes too tightly as this reduces the wicking rate. For example, our research with the Wellington Puritan 1/2-inch (1.3 cm) nylon rope installed into a 7/16-inch (1.1 cm) diameter hole reduced wicking rates to about two thirds that of the same rope placed in 1/2-inch (1.3 cm) diameter holes.

Although direct gluing of the ropes into the pipe has advantages, the potential for ropes to pull out and break the glue seal can be a disadvantage with this method. To prevent this, a small, nongalvanized, finishing nail (or screw) about 1 1/4 inches (3.2 cm) long can be inserted perpendicularly through the rope approximately 1/4 inch (0.6 cm) behind the point where the rope will emerge from the pipe. This will be about 4 inches (10 cm) from the rope ends. Place the nail inside the pipe by tipping the nail parallel to the rope and pushing it and the rope through the hole in the pipe simultaneously. Once inside the pipe, pull the rope out slightly so the nail is perpendicular through the rope and tight against the inside wall of the pipe *(Figure 2)*. Seal the rope with several layers of glue. This technique anchors the rope.

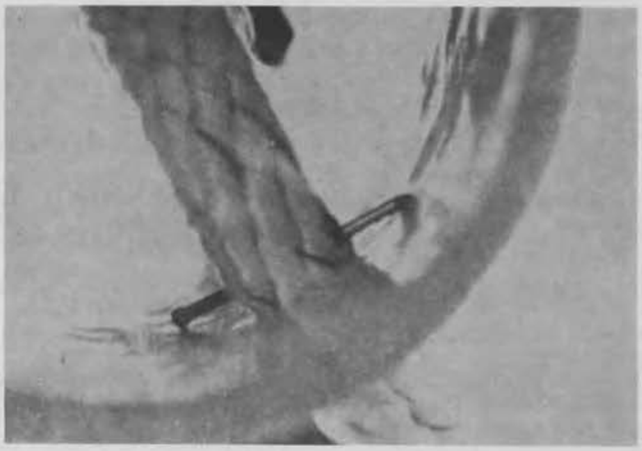
Since the wicking rate of the lowest row of ropes will be faster than the other rows because of differences in the amount of fluid pressure on them, it may be necessary to make some modification on this row to prevent excessive dripping. Drilling smaller holes [7/16-inch (1.1 cm) rather than 1/2-inch (1.3 cm) diameter for Peppermint rope installation], the use of a slower wicking rope (Wellington Puritan solid braid nylon), or the use of compression fittings can reduce dripping from the bottom row of ropes if necessary. It should be noted that a 4 mph (6 km/hr) ground speed is nearly 6 feet (1.8 m) per second and an occasional drip will not result in excessive crop injury.

Use of Pipewick Applicators

A 33 1/3 percent Roundup solution is normally used in pipewick applicators, and has given satisfactory results. This concentration is obtained by mixing one part Roundup with two parts water. Wicking rates can

Figure 2. Technique for inserting nail into rope.
A. Nail perpendicular through rope.

B. Nail tipped parallel to rope and inserted into hole.



C. Nail tight against inside pipe wall.

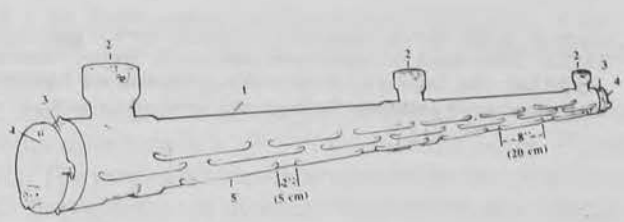


Figure 3. A diagram showing component parts of a pipewick applicator. Numbers on diagram correspond to the numbers in *Table 2*.

be increased by reducing the Roundup concentration or decreased by increasing it.

The pipe should be filled one half full of solution. This reduces both the amount of chemical needed for operation and the amount of dripping, especially from the bottom row of ropes. However, if faster wicking is desired, filling the pipe increases the wicking rate. When preparing the herbicide solution for the applicator, keep in mind that one gallon (3.8 l) of Roundup in two gallons (7.6 l) of water will treat 10 to 100 acres (4 to 40 ha) depending on the weed density.

Table 2. Materials needed to construct a 16-foot (4.9 m) pipewick applicator.

	Item	*Supplier*[1]	*Function*	*Quantity Required*	*Estimated Unit Cost*	*Total*[2] *Cost*
1.	Pipe; PVC-1120, SCH 40, 3" (7.6 cm) SDR, 260 PSI	Plumbing dealer.	Reservoir-boom.	15 feet (4.6 m)	$1.00/ft. (30 cm)	$15.00
2.	Sanitary Tee with twist lock cap, PVC SCH 40	Plumbing dealer; Genova part numbers Tee #71130; Twist Cap #71873.	Pipe end fitting, fill spout, center access.	3	5.50 ea.	16.50
3.	3" (7.6 cm) Anonda Hub Adapter	Camping and trailer supplies outlet. Part #V29-3B3S.	End cap adapter.	2	2.15	4.30
4.	3" (7.6 cm) Anonda Hub with garden hose attachment	Camping and trailer supplies outlet. Part #V29-3B3S.	End cap and drain.	2	2.90	5.80
5.	Rope; ½" (1.3 cm) diameter, solid braid nylon	a. Peppermint[3] Gulf Rope & Cordage Co. P.O. Box 5516 Mobile, AL 36605 b. Cat. No. G1032 Wellington Puritan Ind. Box 521 Madison, GA 30659	Wick.	100 feet (30 m)	0.47/ft. (30 cm)	47.00
6.	1-1¼" (2.5-3.2 cm) nongalvanized finishing nails (or screws)	Hardware store.	To secure ropes.	50	--	1.00
7.	Rubber-vinyl cement	3M Company, super weather strip adhesive (automotive) Part No. 051135-08001.	To cement ropes into PVC reservoir-boom.	2 tubes	3.00/tube	6.00
8.	Glue, PVC	Local dealer.	To seal PVC pipe joints.	1	2.50/can	2.50
						$98.10 TOTAL COST

[1] Reference to commercial products or trade names is made with the understanding that no discrimination is intended and no endorsement by the Cooperative Extension Service is implied.

[2] Price as of 3/81.

[3] This rope has a faster wicking rate than Wellington Puritan ½ inch (1.3 cm) solid braid nylon rope, and should give improved performance in dense weed stands. Other ropes may be used, but wicking rates vary greatly among nylon ropes. Only ropes evaluated for use in wicking units should be used. Gulf 'Peppermint' and Wellington Puritan G1032 are available from local suppliers.

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AGRICULTURAL EXTENSION SERVICE
UNIVERSITY OF MINNESOTA

EXTENSION FOLDER 607–1981

Guidelines for Using Pipewick and Other Selective Applicators*

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The use of selective applicators is being rapidly adopted by farmers to supplement their weed control programs. A low-cost method of removing tall, escaped weeds from short stature crops, selective application is also environmentally appealing since the herbicide is applied only to the target weeds and thus only small amounts of herbicides are used.

The concept of selective herbicide application was discovered several years ago but found little practical use until the development of Roundup (glyphosate). Short-lived in the environment, this herbicide is very active and kills most plants it contacts. Since it is rapidly translocated, it is useful for controlling both annual and perennial weeds.

Selective applicators place the herbicide on tall weeds growing in short crops without contacting the crop itself. Although registration for use of Roundup in selective applicators is currently restricted to soybeans and cotton (April 1981), excellent potential exists for its use in grain sorghum, dry beans, potatoes and range and pastureland.

Annual weed species that can be controlled with this type of application include volunteer corn, shattercane, common sunflower and velvetleaf. Perennial weeds, such as common milkweed, hemp dogbane, Jerusalem artichoke and several species of thistle, can also be suppressed or controlled with selective applications of Roundup.

Weeds must be at least 10 inches (25 cm) taller than the crop before adequate herbicide coverage can be obtained with selective applicators without injurying the crop. Because of this, weeds compete with crop plants for four to eight weeks before the adequate height differential is obtained. Substantial yield losses may result if dense weed populations are allowed to develop before they can be controlled with selective applicators. Therefore, selective applicators should be used to supplement, rather than replace, other weed control practices.

*Evaluation and improvement of these applicators was made possible by a grant from the Nebraska Soybean Development, Utilization and Marketing Board.

Types of Applicators

Three basic types of applicators are available — ropewicks, recirculating sprayers (RCS) and carpeted rollers.

Ropewick applicators are available in several designs *(Figure 1)*. The herbicide solution is transferred from a reservoir to the weeds via ropes. As weeds come into contact with the ropes, the herbicide solution is wiped onto them. Most ropewick units are relatively simple in design, have few or no moving parts and have no nozzles to plug.

The simplest ropewick unit is the pipewick *(Figure 1a)*. For most uses it provides adequate results with minimal investment in equipment. The major advantages of a pipewick as compared to other ropewick applicators are its ease of construction with inexpensive, readily available materials and its ease of operation. The pipewick also requires the least amount of herbicide of any ropewick to wet the ropes. For information on constructing a pipewick applicator, see Extension Folder 606-1981, "Guidelines for Constructing a Pipewick Applicator."

Disadvantages of pipewicks include: the wicking action of the ropes may dispense the herbicide too slowly to give good coverage in dense stands; there is limited control of the wicking rate; two passes may be necessary in dense stands or for hard-to-control weeds; and the glue that secures the ropes into the pipe may break loose, causing dripping, loss of chemical and crop injury.

The Bobar applicator has a series of ropes positioned at a 14 degree angle inside a metal framework *(Figure 1b)*. The reservoir tank can be raised or lowered to help control the wicking rate.

The Wedgewick unit is a pressurized ropewick with ropes extending in a "V" in front of the frame *(Figure 1c)*. The framework serves as a reservoir for compressed air to pressurize the chemical reservoir which is attached to the frame. A pressure regulator can be adjusted to help control the flow of herbicide. The ability to control wicking and improve coverage with a pressurized system may offer some advantages over the pipewick. The "V" shaped design may also give more rope contact with the weeds.

The major disadvantages of the Wedgewick and Bobar are the initial cost of the equipment and the herbicide solution may drip from the ropes and fittings. Also, large weeds may catch on the ropes and pull them off, resulting in the loss of the costly herbicide solution. This is particularly true of Wedgewick.

Recirculating sprayers (RCS) were the first selective applicators to be developed. With this system, solid spray streams are directed horizontally from each nozzle above the crop onto a collection mat. As weeds pass through the spray streams, herbicide is deposited on them. Material not intercepted by the weeds strikes the mat, drains into a collection basin and is then recirculated through the system *(Figure 2)*.

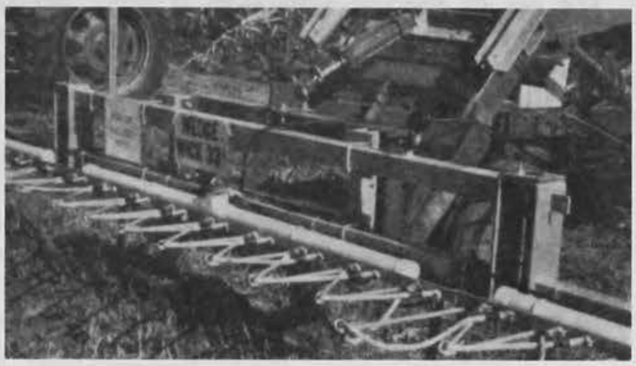
An antifoaming agent is needed when using Roundup in RCS units. A drift control agent also helps reduce fine spray particles that may drift and cause crop injury.

The major advantage of the RCS is that the solution is sprayed onto the weeds. This normally results in good herbicide coverage even in dense weed stands. Disadvantages associated with the RCS are high initial investment costs, contamination of spray solution with dust and debris, nozzle plugging, and a relatively high probability of crop injury due to splashing and drift of the herbicide.

Roller applicators consist of a steel drum covered with nylon carpet *(Figure 3)*. Herbicide solution is pumped from the supply tank and sprayed onto the carpet as the drum rotates at 20-60 rpm. Electronic sensors are available on some models to aid in automatically controlling the carpet wetness.

The carpet is normally operated at approximately 50 percent saturation. The degree of saturation can be assessed by pressing an object lightly against the carpet as the drum is turning. When solution drips from the object, the carpet is at approximately 50 percent saturation and ready to use. The roller must rotate continuously after wetting since the herbicide solution will drain off the carpet if rotation stops. As weeds pass under the roller, herbicide solution is wiped onto them.

b) Bobar



c) Wedgewick

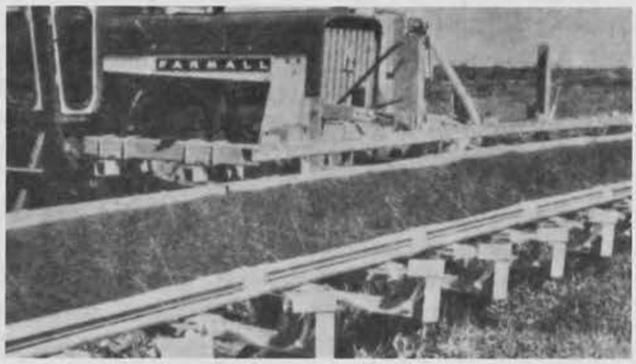


Figure 2. A recirculating sprayer.

Figure 1. Three types of ropewick applicators.

a) Pipewick

Figure 3. A roller applicator.

Even in dense weed stands, good herbicide coverage can normally be achieved with this system if proper saturation is maintained. Other advantages include no contamination of herbicide solution in the supply tank, no herbicide drift and minimal crop injury.

The major disadvantages of roller applicators are high initial cost and the large quantity of herbicide wasted when the unit is shut down. Before each use, the carpet must be saturated with about 5 gallons (19 l) of herbicide solution. When the drum stops rotating, this solution drains off the carpet.

Herbicide Concentration

The concentration of herbicide used varies with the application equipment *(Table 1)*. The RCS units are normally operated with 2 1/2 to 5 percent Roundup solution. The lesser concentration is adequate for volunteer corn or shattercane, but the higher concentration should be used for perennial or annual broadleaf weeds.

Table 1. Concentrations of Roundup for different selective applicators.

Applicator	*Roundup: Water**	*Percent Concentration*
RCS	1:39	2 1/2
	1:19	5
Roller	1:19	5
	1:9	10
Ropewicks	1:5	16 2/3
	1:2	33 1/3

* Units of Roundup and units of water used to give the herbicide concentration listed.

The roller applicator is operated with 5 to 10 percent Roundup solution. As with the RCS unit, the higher concentration should be used for perennial or annual broadleaf weeds.

Ropewick applicators are normally operated with 33 1/3 percent Roundup solution. In laboratory tests at the University of Nebraska on the effects of herbicide concentration on wicking rate of 1/2-inch (1.3 cm) diameter solid braid nylon rope, the wicking rate of the 16 2/3 percent solution was nearly twice as fast as the 33 1/3 percent solution *(Table 2)*. Thus, both concentrations results in nearly the same amount of herbicide wicked per time unit. Concentrations greater than 33 1/3 percent wicked very slowly and are not recommended. Concentrations less than 16 2/3 percent are also not recommended because they may reduce the amount of Roundup applied, and cause rapid wicking and excessive dripping *(Table 2)*.

Farmers can take advantage of these differences in wicking rates to help control flow rate. If a particular concentration wicks too rapidly, the concentration can be increased. Conversely, if faster wicking is desired, the concentration of herbicide can be reduced.

Table 2. Effects of Roundup concentration on wicking rate of solid braid nylon rope.

Percent Concentration	*Relative Wicking Rate**
66 2/3	11
50	12
33 1/3	33
16 2/3	63
8 1/3	73

* Relative Wicking Rate equals the wicking rate of the herbicide solution divided by the wicking rate of water. The larger the number, the faster the wicking action.

Field studies with various selective applicators using Roundup on broadleaf weeds have resulted in less than ideal control. Because of this, interest has developed in using 2,4-D in combination with Roundup to attempt to improve control of broadleaf weeds, especially common sunflower and velvetleaf. Research has generally indicated that the addition of either the amine or the ester formulation of 2,4-D to Roundup did not improve control. In some cases, less control of velvetleaf and shattercane resulted from the combination as compared to 33 1/3 percent Roundup used alone.

Laboratory studies indicate that the wicking rates of 33 1/3 percent 2,4-D amine (alkanolamine) or 2,4-D ester (propylene glycol butyl ether ester) solutions were about 65 and 15 percent, respectively, of the rate for a 33 1/3 percent Roundup solution. Therefore, 2,4-D does not appear to be beneficial and *is not recommended.*

Reusing Roundup Solutions

It is difficult to predict the amount of solution needed to treat an area, and some herbicide solution may be left in the unit after completing the job. Although Roundup can be degraded rapidly by microorganisms and inactivated by organic material and soil, the Roundup solution used in pipewick applicators can be saved for reuse. The material should be stored in properly labeled original containers. *Do not use galvanized containers* as Roundup reacts with the zinc in galvanizing and produces highly explosive hydrogen gas.

Some loss in activity may occur if Roundup is stored for several days, but this loss will usually not greatly affect performance. The best policy is to mix up no more than will be used in a few days. If reasonable care is taken to keep the Roundup solution clean while filling and draining the applicator, its reuse should not be a problem with pipewick applicators.

Water quality has also been shown to affect Roundup performance. However, since Roundup concentration used in ropewick applicators is relatively high (33 1/3 percent), water quality should not be a major factor. It would be more of a factor with RCS or roller applicators, which use lower Roundup concentrations.

Factors to Consider

The solution level in the pipewick and the location of the ropes in the pipe affect the wicking rate. Studies were conducted to determine the differences in wicking rate of three kinds of ropes at two levels in a pipewick applicator. The fluid level was maintained approximately midway between the two rows of ropes (pipe approximately half full), and the rows of ropes were approximately one inch (2.5 cm) apart.

The ropes in the bottom row of the pipe wicked two and a half to three times faster than those in the upper row *(Table 3)*. This difference was caused by the fluid pressure on the bottom row of ropes. The top row had no pressure on it; movement through the rope was completely by wicking. Therefore, if increased wicking is necessary, raising the level of the solution in the applicator will give faster wicking. Conversely, if wicking is too fast, the fluid level can be lowered. It is suggested that the pipe be filled about half full to start with—more solution can be added if needed to increase wicking. If satisfactory wicking can be obtained with the pipe half full, chemical cost can be reduced. One gallon (3.8 l) will normally treat 10 to 100 acres (4 to 40 ha).

Table 3. Effects of type of rope and location in a pipewick applicator on wicking rate of 33 1/3% Roundup.

	Location in Pipe	
*Rope**	*Top*	*Bottom*
	ml/hr	
Wellington Puritan	9	28
Gulf-Peppermint	50	128
Gulf-Pistachio	127	297

* Wellington Puritan 1/2" (1.3 cm) solid braid nylon, Cat. No. G-1032. Gulf Rope and Cordage Company Peppermint is 1/2" (1.3 cm) solid braid nylon; Pistachio is 1/2" (1.3 cm) diamond braid polyester covering over an acrylic core.

The type of rope also affects wicking rates *(Table 3)*. The Peppermint rope wicked nearly five times faster than the Wellington rope, and the Pistachio rope wicked nearly two and a half times faster than Peppermint. Although it has not been field tested in our trials, we feel the Peppermint rope offers some advantages where improved wicking is desirable. This rope may help reduce the need for two passes with the pipewick and may also improve broadleaf weed control. The Pistachio rope will probably wick too rapidly and cause excessive dripping in most cases.

The Wellington Puritan solid braid nylon rope has given relatively satisfactory results, especially for control of shattercane and volunteer corn. This rope may be preferred where reduced wicking is desirable, such as in grain sorghum should Roundup be registered in this crop.

Attaching the applicator to a height adjustable framework is necessary to prevent crop injury and to allow the maximum number of weeds to be treated. As the applicator moves across the field, the operator can keep the unit as close as possible to the crop canopy without contacting it. A front mounting gives the operator maximum visibility and helps to prevent dust created by implement tires from collecting on the applicator.

Groundspeed of the applicators can vary depending upon weed density, height differential between crop and weeds, the uniformities of the crop and of the terrain, and the rate of wicking in the case of ropewick units. However, a groundspeed of 4 to 5 mph (6.4 to 8.1 km) is a practical speed since this allows the operator to make necessary height adjustments with minimal crop injury. With ropewick applicators, groundspeed should be reduced in heavy weed patches to allow the ropes time to recharge with herbicide.

With annual broadleaf weeds, perennial weeds or where weed populations are heavy, a second pass with the pipewick applicator may be necessary for good control. This may also be true of other applicators as it is nearly impossible to contact all weeds with one application. Some weeds may be too small to treat with the first pass and a second pass 10 to 14 days later may be necessary. Weeds in clumps, such as volunteer corn, may require a second pass in the opposite direction as the plants first contacted in the clump may protect those on the back side of the clump.

Care of Ropewick and Other Applicators

To maintain the pipewick unit, it is advisable to rinse the ropes and fill the unit with water after each use, allowing the water to wick through the ropes. This will help keep the ropes clean. The RCS and roller units should be flushed out after use, and any unused solution properly stored in labeled containers.

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STATUS OF GYPSY MOTH AND JAPANESE BEETLE IN MINNESOTA

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THE GYPSY MOTH PROGRAM

The gypsy moth is now established in 17 states - Maine, New Hampshire, Vermont, Massachusetts, Connecticut, Rhode Island, New Jersey, Delaware, Maryland, Pennsylvania, New York, North Carolina, Virginia, West Virginia, Ohio, Michigan and Illinois. Only male moths had been trapped in Indiana, Wisconsin and Minnesota. First incidence of a male gypsy moth in Minnesota was in 1976 in a trap at Minnetonka, Hennepin county.

Table 1. Male gypsy moth trap catches in Minnesota

Year	No. traps	Trap density	No. Male Moths	Counties
1976	3,954	1 per 9 sq. miles	1	Hennepin
1977	8,898	1 per 3 sq. miles	0	
1978	10,616	1 per 3 sq. miles	1	Dodge
1979	3,536	1 per 3 sq. miles	2	Dakota, Hennepin
1980	3,590	1 per 3 sq. miles	27	Hennepin, Ramsey
1981	4,393	(1 per 3 sq. miles (16-9-4/1 sq. miles	110	(Anoka, Hennepin, (Olmsted, Ramsey, (Scott, Washington

In 1981, a total of 110 male moths were trapped at 65 locations, most of them in the Twin City Metropolitan area. This compares to 27 male moths trapped in 17 locations in 1980. Six traps had multiple moth catches ranging from 2 to 4 in 1980 while sixteen traps had multiple moth catches ranging from 2 to 12 in 1981. Four of these trap locations had multiple moth catches for two consecutive years. To date, Gypsy moth has been confirmed in 8 Minnesota counties.

Minnesota Department of Agriculture in cooperation with USDA-APHIS, University of Minnesota, USDA-FS, Minnesota Department of Natural Resources, City of Minneapolis and City of St. Paul, is monitoring for this serious pest of shade trees. An advisory council has been formed with representatives from the above agencies to formulate courses of action should this pest become established in Minnesota.

Currently, survey for the gypsy moth egg masses is in progress with emphasis in areas where multiple moth catches occurred. In 1980, nursery stock from eastern U.S. carried some viable egg masses, most of which were detected and destroyed. However, the chances of some escapees are likely. All new tree plantings in 1980 spring and fall were checked with negative results. Trees planted in 1981, both in spring and fall, will be checked the rest of this year and early next spring. At least one quarter mile section around each of the 65 trap sites will be checked intensively for egg masses. This will be followed by increased trap placement for moths again next season.

CONTROL STRATEGY - It is premature at this time for any chemical control. However, biological control of releasing gypsy moth parasites is expected to continue. The Division of Plant Industry in cooperation with USDA-APHIS had released 1900 tachinid parasites (*Compsilura concinnata*) in 1977 for establishment in cankerworms.

The Japanese Beetle Program

The Minnesota Department of Agriculture conducts the Japanese beetle detection program each year. This destructive pest has caused extensive damage in the eastern United States and is currently found from central Maine, southward into South Carolina and Georgia, and westward into Illinois, Michigan, and Missouri. Adults were trapped in Wisconsin and Minnesota but as yet not reported as established.

The Japanese beetle traps are yellow or green in color and are hung on steel rods about 17 inches high from the ground. The traps were baited with a mixture of phenethyl propionate (PEP) and eugenol (4-allyl-2-methoxphenol) until 1979. In 1980 and 1981 a combination of synthetic sex attractant (R,Z)-5-(1-decenyl) dihydro-2 (3H)-furanone in strips with a 3:7 mixture of PEP and eugenol were used.

Table 2. Japanese beetles trapped in Minnesota

	Traps set in Twin City area	Traps set in Duluth port	Bait used	No. of beetles	Counties
1976	152	52	PEP +Eugenol	0	
1977	303	84	" "	0	
1978	300	83	" "	0	
1979	300	84	" "	0	
1980	321	81	PEP +Eugenol+ Syn. Sex attractant	3	Hennepin, Ramsey
1981	329	72	" "	4	"

Of the 4 beetles trapped in 1981, one was about 200 feet away from the previous year's find. Also, for the first time two of the four beetles were found alive. All positive trap sites will be intensively surveyed next season.