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MINNESOTA SCIENCE

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In this issue—Soybeans, a Spectacular Minnesota Crop

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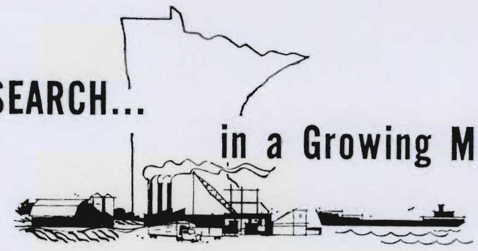
RESEARCH... in a Growing Minnesota



THE DRAMATIC CHANGES in agriculture during the past two decades have presented the University of Minnesota's Agricultural Experiment Station with new challenges and new opportunities.

Minnesota Science is one of the ways in which we try to keep you up-to-date on the results of our research. This issue, for example, tells about a wide variety of research. You can read about the dramatic story of soybeans, soil and water losses, the probabilities of wet and dry days, reproduction research, and many other important topics affecting the entire state. In all there are 364 research projects conducted by the Experiment Station.

The results of this research are brought to you in many ways. Here are a few:

County Extension Agents, your local University representatives, base their educational efforts on research. Thus the meetings and workshops they conduct or arrange, the calls you make to their offices, the counsel they give to many individuals and groups, and the publications they issue or distribute are important ways of bringing research results to you.

Bulletins of the Agricultural Experiment Station report in more detail the results of our investigations. You can be placed on a list to receive announcements of these by writing directly to *Minnesota Science.*

Field Days at our agricultural experiment stations throughout the state feature specific information and results for the area. Again, watch your local paper and listen to your local radio station for announcements. Several are scheduled this fall.

Research Report, a weekly radio program carried by 40 local stations in Minnesota, brings the latest information from the University to you.

Special science stories appear regularly in the press of the state.

We could add many other ways we try to bring you information about our research. We welcome, too, your suggestions and ideas.

SOYBEAN PRODUCTION in Minnesota has multiplied more than 26 times since the end of World War II, passed the 3-million-acre mark in 1965. A background report on Minnesota's soybean industry begins on page 3; information on a special problem, seed coat mottling in soybeans, is found on page 31. The cover photo shows a scene that will be repeated in thousands of Minnesota soybean fields this fall.

Soybeans -- A Spectacular Minnesota Crop

EVEN IN THE MOST DRAMATIC ACCOUNTS of agricultural innovation and change after World War II, the soybean stands out as spectacular.

Research interest already bestowed upon this humble little seed stands to pale alongside future scientific energy directed toward this crop. Little wonder that a major Midwestern newspaper, in jocular cartoon humor, once referred to the increasing soybean acreage as a "hill of beans that amounts to something." What soybeans amount to may be shown by some hard figures:

- Nationally, annual soybean production more than tripled since the end of World War II, reaching 840 million bushels in 1965 and around 900 million in 1966. Soybeans made up 5 percent of all cash farm receipts in 1964, compared with 1.7 percent in 1947.
- In Minnesota (fourth largest soybean grower in the nation) production multiplied more than 26 times in the same period, passing the 3-million-acre mark in 1965.
- World markets are taking an increasing share of soybean production. They accounted for roughly half of the $2.1 billion worth of soybeans and products (value at farm level) in 1965, compared with about 14 percent of the farm value in 1947-49.

Thus it isn't surprising to find the soybean such a popular object for research. It has diverse uses and its diversity is in some ways a key to its abundance. Increased demand and research in soybean production and processing made the abundance possible and feasible. Research in economic aspects has highlighted both the diversity and limitations of the bean. Research on new uses, and varieties adaptable to new uses, may extend its potential even further.

Yes, soybean versatility is deceptive, often obscuring the fact—well established by economics research—that the soybean market is overwhelmingly dominated by a few outlets. A list of soybean products is impressive: animal feeds, food products for human consumption, industrial uses for meal and whole beans, margarine and salad dressing, and a variety of industrial uses for the oil. But for the bulk of soybean utilization you can look to animal feed and human food uses for beans, meal, and oil. Industrial uses account for under 5 percent of the total value of the crop.

As with many rapidly expanding industries, the growth of soybean production and processing has been uneven. Agricultural Economist James P. Houck has compared the utilization patterns of soybeans and products in two periods, 1962-64 and 1947-49. The data, providing a snapshot of the industry at two times, show a number of specific trends.

Bean Utilization

Houck looked at three major forms of soybean utilization—on-farm feed and seed, bean exports, and crushing. The first of these forms is a small proportion of the total, accounting for under 8 percent. The value of bean exports boomed during the 15-year period between Houck's analysis, however, surging ahead at an annual rate of 19 percent. Exports of whole beans accounted for 27 percent of farm value in 1962-64, compared with only 6 percent during 1947-49.

Yet the domestic crushing industry was the most important user of U. S. soybeans through all of these years. Although it dropped from 83 to 66 percent of the total farm value between the two periods, domestic crushing actually increased 6 percent annually in actual value of beans used. The average crushing and handling margin—difference between what processors pay for beans and wholesale prices they get for meal and oil—dropped from 79 cents per bushel in 1947-49 to 20 cents in 1962-64. This reduction stemmed from a more efficient chemical extraction method adopted in the early 1950's and from other improvements in handling and processing in more recent years.

Meal vs. Oil Markets

The most solid growth in the soybean industry, Houck found, was in meal markets. Value of meal has grown at about 7.6 percent annually, nearly tripling in the 15-year period he studied. The outlets were both foreign and domestic. Farmers in the United States and other nations contributed to this increase by raising larger numbers of hogs, chickens, and other livestock. These are the major uses for meal; edible and industrial uses provided only a fraction of 1 percent of farm level values in 1962-64.

In general, soybean oil has not enjoyed as much increase in market demand, compared with meal. Oil prices show it; they drifted down from 1947-49 levels as supplies grew faster than demand. They would have fallen more had there been no Public Law 480 shipments. Oil made up half of the value of crushed beans in 1947-49, compared with only a third in 1962-64.

Some increase in oil value resulted from expanded use in food products such as margarine and exports. Nonfood uses of soybean oil, mostly in paint and soap products, actually shrunk in value in the period Houck studied. Even in exports, there was little increase in commercial value of oil. However, large government-sponsored Public Law 480 oil shipments under the Food for Peace program more than doubled total oil export values between 1947-49 and 1962-64. These "nondollar" exports accounted for over half of the 1962-64 export value and an eighth of the total value of oil production.

Soybean "Exports" Out-of-State and Out-of-Country

Since markets outside the state are so important to the Minnesota soybean grower and processor, the bean consumer must be kept in mind. One Minnesota plant crushes 180 million tons or more of beans in a year and both the oil and the meal then leave the area for further processing and distribution.

Economist Reynold P. Dahl points out that two of our big customers for soybeans outside the North American continent are West Germany and Japan. Their uses of soybeans are quite different, but together they point up a challenge for research in economics and production technology.

West Germany's booming livestock and poultry industries have been a boon for U. S. soybean exporters. European farmers import most of their high-protein feeds, and have recently bought more U. S. soybeans. Even with the uncertainties of the European Economic Community (Common Market), Dahl says prospects are good for a continued rise of exports of beans and meal to Western Europe in general.

The ultimate factor, of course, is the European citizen who is eating more meat than ever. Between 1956 and 1961 meat consumption in EEC countries went up sharply. Increases were 20 percent for beef and veal, 18 percent for pork, and a whopping 78 percent for poultry. Assuming a continued rise in consumer income, economists expect increase in meat consumption in Europe during the currrent decade.

But in Germany as in other European nations, the outlook for oil is not as bright. Income elasticities for fats and oils in Europe are lower than those for meat. This simply means that change in personal income in these countries is not accompanied by as much of change in demand for oils as for meat. Thus, demand for vegetable oil is likely to increase at a much slower rate than demand for oilseed cakes and meal, since the latter is tied to meat consumption. Furthermore, other oils—such as from olives, peanuts, coconuts, and animal fat—compete with soybean oil for international consumer markets.

Japan presents a quite different kind of situation—a kind of marketing challenge which the soybean industry so far is accepting with enthusiasm. Japan is now the biggest single export customer for soybeans, having gone from 20 million bushels of U. S. soybeans annually to more than 60 million over the past decade. The Japanese use soybeans partly for human food and partly for livestock production. They also grow beans themselves and import beans from Red China, the world's only other major exporter.

During the past decade, U. S. soybean producers have been working with the USDA Foreign Agricultural Service on a market development project in Japan. The potential for such a project is apparent enough; the problem lies in the fact that every bushel of soybeans crushed to produce meal also produces oil. Here is the rub! The average Japanese citizen consumes about 15 pounds of edible oils per year, less than a third of the consumption of the average U. S. citizen. Although Japanese nutritionists hope to increase their domestic oil consumption, Japanese soybean oil is showing up in world markets in competition with United States soybean oil. Little wonder then that the industry seeks new uses to boost consumption for soybean oil.

In another respect, however, U. S. research technology may be moving toward opening up one segment of the Japanese food market. Japanese use soybeans for a variety of foods, but prefer for these foods soybeans with a uniform yellow color, in addition to other less well-defined quality characteristics.

Many U. S. soybeans in the past have had colored hila, or seed scars, which the Japanese find objectionable. Minnesota researchers recently developed a new variety of soybeans, adapted to local growing conditions, which has a yellow hilum and other special quality attributes desired in the market. The variety is Traverse, released in 1965 and adapted to west-central and southern Minnesota. Other states have also been active in development of such varieties. Iowa last year introduced the yellow-hilum variety Amsoy. Another Iowa variety, Hark, is likely to be important in southern Minnesota and was increased in 1966.

Will these yellow-hilum varieties break into the Japanese food market? Time and market development efforts in that nation will tell. Efforts are now underway to build use of these varieties among Japanese food processors. There also must be a premium to U. S. producers and exporters for expenses involved in shipping these new varieties "identity preserved" (free of varietal mixture) to Japan.

In summary, then, the soybean industry can look forward to general expansion. The best prospects for the industry are in beans and meal, with substantial growth in exports. New and perhaps exotic uses for soybeans may develop and may provide nominal additions to overall growth. The less optimistic picture is on the oil side, although there should be moderate growth in dollar markets for oil and oil-using products. Food for Peace shipments will probably continue to be a factor in price strength for oil.

Expansion in the soybean industry would seem to call for expanded research. As Dahl puts it, success in the export market requires a dependable source of the product you're selling. At least two kinds of research needs are apparent. One is for study of ways to produce at lower costs per unit. Another is for study of trends in industrial and consumer demand, not just at home but around the world.

A curious fact about soybeans is that expansion in production has occurred in spectacular fashion with only modest increases in average yields. In Minnesota, soybeans averaged under 14.2 bushels per acre in 1941-45, 16.7 per acre in 1946-50, and slightly over 21 bushels per acre during 1961-65.

This modest increase is parallel with the increase in national yield averages over the same span of years. Thus, even with higher bean prices, it is becoming more difficult for soybeans to compete with corn for acreage in the Corn Belt. This apparent "yield barrier" in soybean production raises a special problem for research today and in the future.

The Pocket Gopher in Minnesota

James R. Beer

THE pocket gopher, a destructive and troublesome wild mammal, affects Minnesota's agriculture. His tunneling damages many crops by cutting or exposing the root systems; death or reduced vigor of the plants occurs. In hilly areas, these tunnels are often the starting points of damaging soil erosion. The mounds of dirt which are pushed up cover small plants and make the mowing of alfalfa and harvesting of other crops difficult.

The extent of the problem is indicated by results of a questionnaire sent to the several Minnesota county agents. Pocket gophers were noted and recognized in 81 counties; they were abundant enough to be considered a problem in 64 counties. In about 40 counties, the county and/or the township paid bounties on pocket gophers.

Trapping and distributing poisoned bait by hand have given mediocre control results. A burrow builder, a machine that makes an artificial burrow and automatically dispenses poisoned bait, gives the best control results when the area is large enough for its use.

To properly evaluate the problems involved in controlling the pocket gopher, we must understand its habits. This animal spends almost its entire life underground in a system of burrows which it digs. These tunnels, usually about 2½ inches in diameter, may be barely under the surface of the soil or 6 feet deep. Most burrows are about 8 inches deep with occasional dips to 18 inches. The shallow burrows are feeding tunnels; deeper burrows usually lead to their nests.

The pocket gopher feeds entirely on vegetation, primarily the fleshy roots of plants such as bluegrass and alfalfa. Although the quantity of tree roots taken annually is not great, gophers may extensively damage young orchard trees and Christmas tree plantations. They find the roots by random digging. While burrowing, they push the dirt up to the surface, forming the characteristic mounds. Sometimes they push the dirt into unused tunnels.

During the spring and early summer, pocket gophers dig only enough to satisfy their daily food requirements. At this time they may plug old burrows and go several weeks without putting up a mound. But during the late summer they start gathering and storing roots for winter. You generally can see a sharp increase in the number of new mounds about the first of September. This activity continues until the soil freezes, but at a decreased rate after the middle of October.

The pocket gopher stores roots in chambers near the soil surface. Individual storage chambers usually contain from 2 to 4 quarts of roots. When chambers are filled, they are sealed off from the tunnels by an earth plug.

The pocket gopher remains active throughout the winter in his burrows and does some digging below the frost line. He packs the dirt into shallow tunnels.

When about 1 year of age, the pocket gopher breeds. The breeding season starts during the latter part of March, but some females do not breed until several weeks later. An average of four young are produced per litter. About 95 percent of the females breed; about 71 percent produce two litters. Normally, there are about twice as many females in the breeding population. In stable populations, about half of the young survive until they are independent of the maternal burrow system. But if the population is at a low level and there is not great compitition for a suitable place to live, about three-fourths of the young survive.

Not being a social animal, the pocket gopher tends to live alone. Occasionally, several gophers may be found in a single burrow system. This social intolerance probably forces the young to leave the home burrow and travel above ground in quest of a new home. They are known to travel over a quarter of a mile in this manner.

This movement of young starts in late summer but is most prevalent in fall. After finding a suitable area, the young animal establishes a burrow system in which it spends the rest of its life. These burrow systems or home areas usually are not more than 200 feet across. Once a pocket gopher is established, his chances of survival are good. The survival rate runs from about 50 to 80 percent per year for females and from about 25 to 45 percent for males. Some females live at least 4 or or 5 years.

Unless large areas are systematically worked, control methods give short-lived results. Since it is often not practical to cover large areas completely, you have to think in terms of a continuing program. Control methods usually are most effective in the late fall when: (1) the presence of pocket gophers is most easily determined, (2) soil conditions are often suitable for use of the burrow builder, and (3) animals are gathering food.

By eliminating pocket gophers in the fall, no reproduction will occur in the area the following spring. But the area will be reinvaded the next fall. During the second spring, some moderate reproduction will occur. With further invasion of outside animals, a nearly normal breeding population will be established by the second fall. At this time control methods are again necessary.

James R. Beer is an associate professor, Department of Entomology, Fisheries, and Wildlife.

Wet-Dry Day Probabilities in Minnesota

Donald A. Haines and Donald G. Baker

HAVE you ever wondered how long good weather would last as you mowed hay, poured concrete, or hung out the Monday wash? The daily weather forecasts of the Environmental Science Services Administration (Weather Bureau) are valuable for planning almost all short-term outdoor activity. However, the meteorologist still does not have sufficient knowledge of the atmosphere to give meteorological forecasts for long periods. For such predictions, one must turn to climatological records which can be expressed in terms of probabilities. For example, the chances for wet and dry days in Minnesota on a year-round basis can now be determined due to recent climatological research.

Last year, more than 50 years of Weather Bureau precipitation records were summarized in a publication, *Probabilities of Sequence of Wet and Dry Days in Minnesota*, North Central Regional Research Publication 161, by A. M. Feyerherm, L. Dean Bark, and W. C. Burrows. The study provides wet and dry day probabilities for 10 locations in Minnesota (figure 1) under four "wet and dry day" definitions.

Depending upon the job involved, a dry day need not necessarily be without any precipitation. For some operations precipitation totaling 0.10 inch might not be critical; but if more than 0.10 inch of rain falls, the day is, in effect, wet. Thus, various levels of precipitation can be established, and a day when these levels are not exceeded can be termed a "dry" day. By the same token, a "wet" day occurs only when certain precipitation levels are reached. In this study, the critical precipitation levels selected to define a wet day are totals of at least 0.01, 0.10, 0.20 or 0.50 inch within 24 hours.

In this publication, the probability of a wet or dry day not only is given for specific dates but is also computed for any calendar day, given that the previous day was wet or dry. The table is an example of the many tables contained in the bulletin. This table furnishes the basic information for calculating the probability of any specific combination of wet and dry days needed in management decision-making.

A similar table is available for each of the 10 Minnesota locations shown in figure 1 and for each wet and dry day definition. The most appropriate table can be selected for a specific operation. For example, concrete finishing may be affected by as little as 0.01 inch of rain. Hay drying may be adversely affected by 0.10 inch on any of the 3 days normally required for mowing, curing, and baling or chopping.

Donald A. Haines is state climatologist, Environmental Science Services Administration, U.S. Department of Commerce. Donald G. Baker is an associate professor, Department of Soil Science.

Probability that a given day will be wet or dry at Minneapolis (a wet day has at least 0.10 inch of precipitation within 24 hours)

	INITIAL		TRANSITION			
PERIOD OF	DRY	WET	DRY/DRY	WET/DRY	DRY/WET	WET/WET
MAR 1-MAR 7	.886	.114	.897	.103	.801	.199
MAR 8-MAR 14	.886	.114	.890	.110	.855	.145
MAR 15-MAR 21	.868	.132	.883	.117	.769	.231
MAR 22-MAR 28	.851	.149	.876	.124	.708	.292
MAR 29-APR 4	.852	.148	.868	.132	.760	.240
APR 5-APR 11	.853	.147	.861	.139	.807	.193
APR 12-APR 18	.833	.167	.853	.147	.733	.267
APR 19-APR 25	.811	.189	.846	.154	.661	.339
APR 26-MAY 2	.809	.191	.839	.161	.682	.318
MAY 3-MAY 9	.805	.195	.832	.168	.694	.306
MAY 10-MAY 16	.783	.217	.826	.174	.628	.372
MAY 17-MAY 23	.763	.237	.821	.179	.576	.424
MAY 24-MAY 30	.765	.235	.816	.184	.599	.401
MAY 31-JUN 6	.770	.230	.813	.187	.626	.374
JUN 7-JUN 13	.762	.238	.809	.191	.612	.388
JUN 14-JUN 20	.758	.242	.807	.193	.605	.395
JUN 21-JUN 27	.776	.224	.806	.194	.672	.328
JUN 28-JUL 4	.797	.203	.805	.195	.766	.234
JUL 5-JUL 11	.800	.200	.806	.194	.776	.224
JUL 12-JUL 18	.801	.199	.807	.193	.777	.223
JUL 19-JUL 25	.820	.180	.820	.180	.820	.180
JUL 26-AUG 1	.835	.165	.835	.165	.835	.165
AUG 2-AUG 8	.827	.173	.827	.173	.827	.173
AUG 9-AUG 15	.815	.185	.821	.179	.789	.211
AUG 16-AUG 22	.822	.178	.827	.173	.799	.201
AUG 23-AUG 29	.828	.172	.832	.168	.809	.191
AUG 30-SEP 5	.816	.184	.839	.161	.714	.286
SEP 6-SEP 12	.805	.195	.846	.154	.636	.364
SEP 13-SEP 19	.818	.182	.853	.147	.661	.339
SEP 20-SEP 26	.835	.165	.861	.139	.703	.297
SEP 27-OCT 3	.835	.165	.868	.132	.668	.332
OCT 4-OCT 10	.836	.164	.876	.124	.632	.368
OCT 11-OCT 17	.857	.143	.883	.117	.701	.299
OCT 18-OCT 24	.878	.122	.891	.109	.784	.216
OCT 25-OCT 31	.880	.120	.897	.103	.755	.245
NOV 1-NOV 7	.877	.123	.904	.096	.684	.316
NOV 8-NOV 14	.892	.108	.910	.090	.743	.257
NOV 15-NOV 21	.906	.094	.915	.085	.819	.181
NOV 22-NOV 28	.901	.099	.920	.080	.728	.272
NOV 29-DEC 5	.892	.108	.924	.076	.628	.372
DEC 6-DEC 12	.904	.096	.927	.073	.687	.313
DEC 13-DEC 19	.918	.082	.930	.070	.784	.216
DEC 20-DEC 26	.914	.086	.931	.069	.733	.267
DEC 27-JAN 2	.908	.092	.932	.068	.671	.329
JAN 3-JAN 9	.921	.079	.931	.069	.804	.196
JAN 10-JAN 16	.935	.065	.935	.065	.935	.065
JAN 17-JAN 23	.928	.072	.928	.072	.928	.072
JAN 24-JAN 30	.916	.084	.925	.075	.818	.182
JAN 31-FEB 6	.920	.080	.921	.079	.909	.091
FEB 7-FEB 13	.924	.076	.924	.076	.924	.076
FEB 14-FEB 20	.908	.092	.911	.089	.878	.122
FEB 21-FEB 27	.887	.113	.905	.095	.746	.254

To demonstrate the use of the probabilities, let us consider a haymaking operational example. The "initial" probability for a dry day on the day the hay is cut is 1 or 100 percent; it is assumed the hay will not be cut unless the day is dry. In the table, which provides probabilities for wet days of at least 0.10 inch in Minneapolis, only "transition" probability data are used. So the probability of a dry day immediately following the dry day when the hay was cut is entered for each week under the "dry day" column.

The chance of a dry day following a dry day in the week of June 7-13 is 80.9 percent—about 8 times in 10. If the 2nd day is dry, then the chance for a 3rd dry day is the same as for the 2nd day.

Since the 1st day is assumed to be dry or no cutting would be done, the probability of 3 consecutive dry days with rainfall less than 0.10 inch per day is 100 percent x 80.9 percent x 80.9 percent = 65.4 percent. Thus, in east-central Minnesota, a farmer cutting hay on a dry day in early June can expect no rain interference in about 2 of 3 years.

If a farmer reduces his haying to a 2-day period by using hay conditioning equipment (crimper or crusher) or a hay dryer, the probability of 2 dry days is 80.9 percent; that is, 100 x 80.9 percent. Therefore, the chance of getting wet hay can be reduced to about 1 year in 5 if the haying period is 2 days.

In the same manner, successful haying probabilities were derived from the publication for other Minnesota locations for the period, June 7-13. (See figures 2, 3, 4, and 5). As shown in figure 3, the probabilities of "favor-

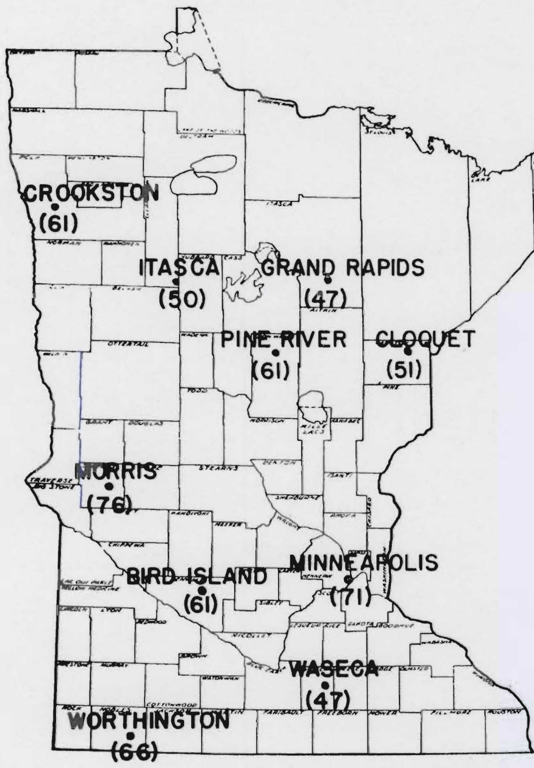


Figure 1. Location of stations in Minnesota (number indicates years of record used in determining probabilities).

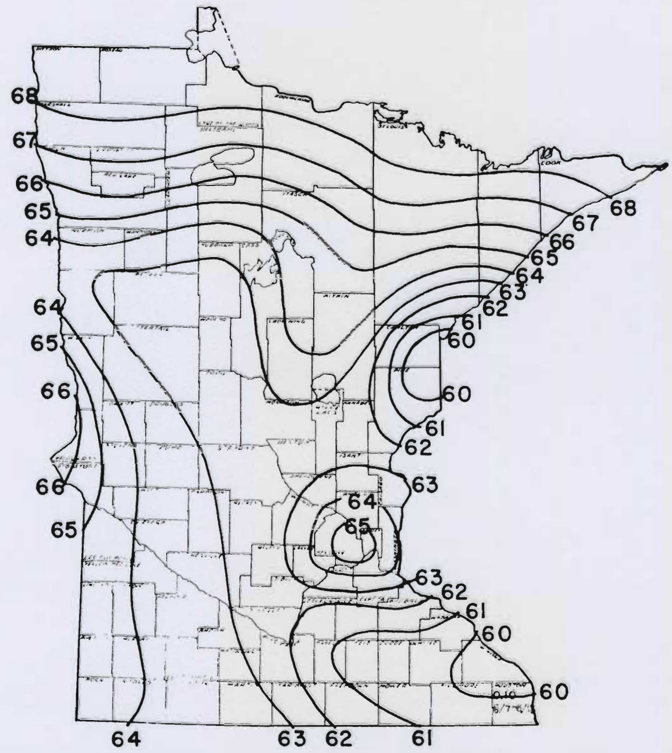


Figure 3. Probability of 2 dry days following an initial dry day, precipitation less than 0.10 inch, during June 7-13.

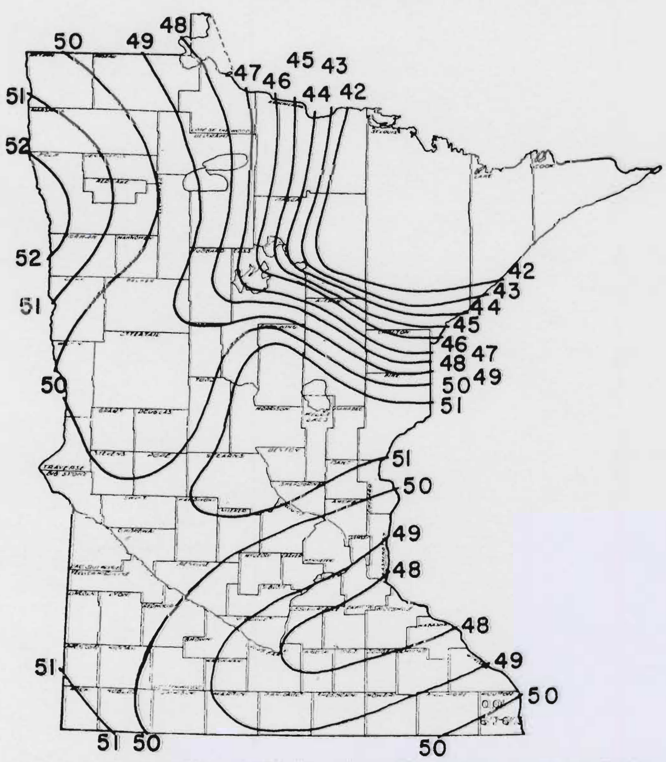


Figure 2. Probability of 2 dry days following an initial dry day, precipitation less than 0.01 inch, during June 7-13.

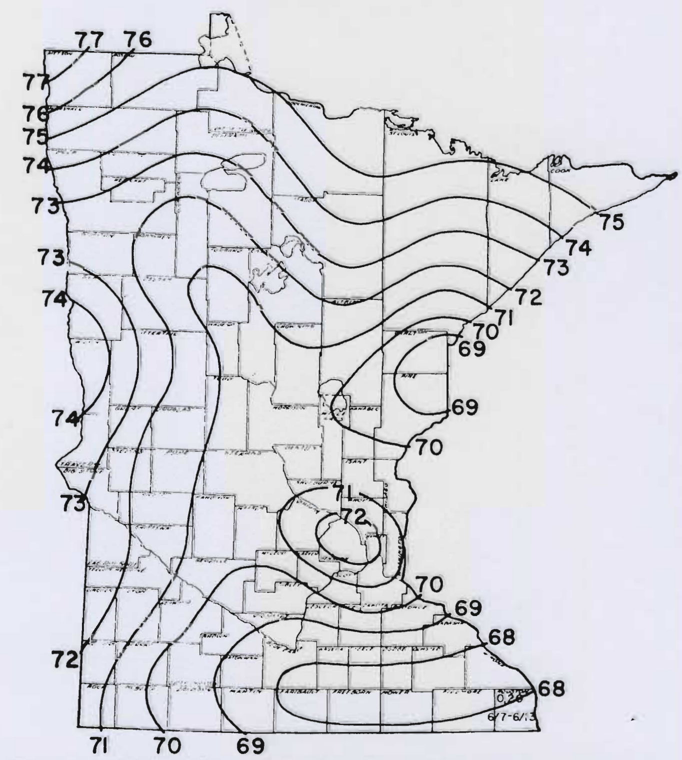


Figure 4. Probability of 2 dry days following an initial dry day, precipitation less than 0.20 inch, during June 7-13.

able haying weather" in this week are highest in northern Minnesota and lowest in southeast Minnesota.

If the 0.01 inch definition is used to identify haying weather, the probability of 2 dry days following the dry hay cutting day drops to 48 percent in east-central Minnesota during July 7-13. About once in 2 years a farmer will have wet hay in that week.

June 7-13 is one of the rainier weeks of the year over Minnesota. For Minneapolis, the probability for 3 consecutive dry days (precipitation less than 0.10 inch per day) increases in mid-July and August and reaches a maximum in January (see figure 6). Between January

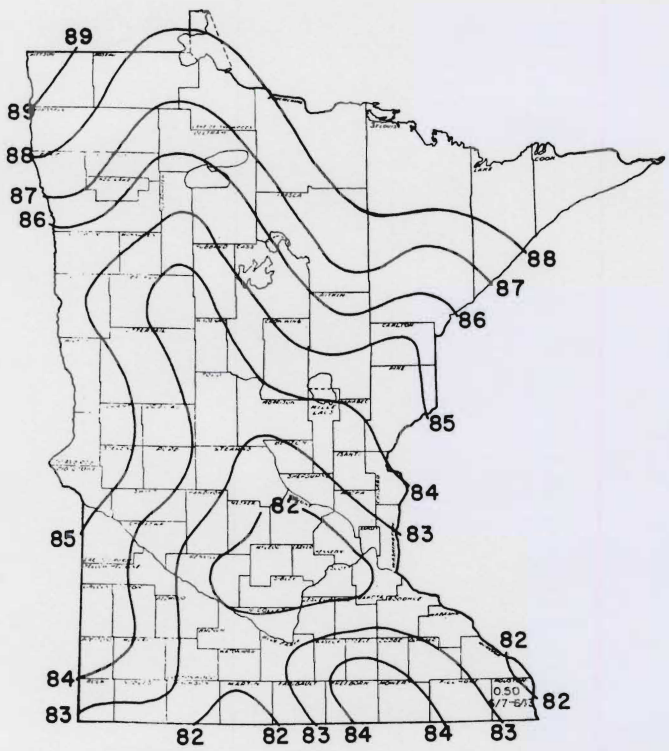


Figure 5. Probability of 2 dry days following an initial dry day, precipitation less than 0.50 inch, during June 7-13.

10-23, there is nearly a 100-percent chance that precipitation of 0.50 inch or more will not occur during any day.

If one does not assume that the 1st day is dry, the "initial" day probability in the week of June 7-13 is 76.2 percent ("dry" column under "initial" in the table). The probability of 3 consecutive dry days (less than 0.10 inch rain) is then 76.2 percent x 80.9 percent x 80.9 percent = 50 percent. Therefore, there is a 50-50 chance of rain in any specific 3-day period in the week of June 7-13.

With this publication, you could assign loss values of wet hay and extra labor costs for such operations as turning the hay. You can even derive an average seasonal hay value loss from the expected number of wet days. And you can plan the most profitable haying methods and choose equipment accordingly.

For your copy of NCR Res. Pub. 161, write the Bulletin Room, 3 Coffey Hall, University of Minnesota, St. Paul, Minnesota 55101.

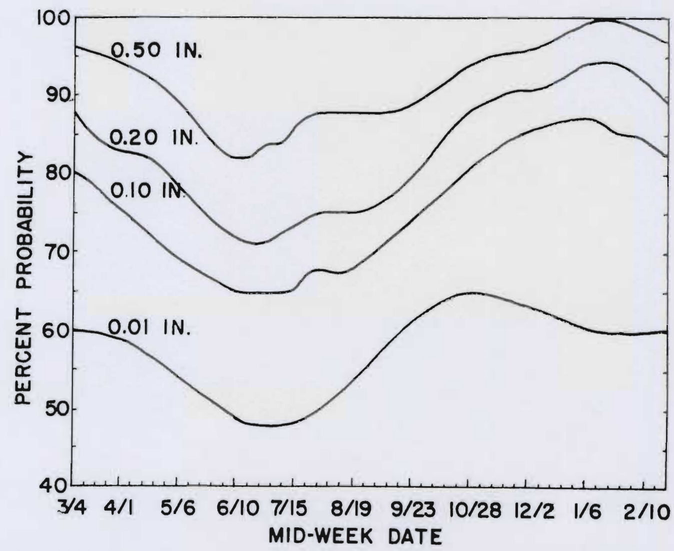


Figure 6. Probability of 2 dry days following an initial dry day at Mineapolis for four precipitation definitions. A daily total of at least 0.01, 0.10, 0.20, or 0.50 inch of precipitation in 24 hours constitutes a wet day.

How Climate Affects Foliar Diseases of Forage Legumes

Roy D. Wilcoxson

THE principal forage legumes grown in Minnesota are alfalfa with about 3 million acres and red clover with 90,000 acres. Severity of diseases on these crops varies greatly with season and location of fields. Apparently this variation is due mostly to local weather, because the fungi, bacteria, and viruses which cause the diseases occur throughout the state. Our field surveys and experiments, as well as experiments with controlled environment facilities, all indicate that temperature and moisture are the most important weather factors influencing diseases of forage legumes.

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Virus diseases—mosaic on alfalfa and vein mosaic and bean yellows on red clover—are not directly influenced by moisture. Temperature is most important. Many infected plants usually are found in spring and fall when temperatures are relatively cool. But during the hot summer months the few symptoms on the plants are very mild and easily overlooked. So many farmers are surprised when we show them that 25 to 50 percent of their plants are infected.

By use of serological techniques and indicator plants, it is possible to demonstrate that apparently healthy plants may be infected with a virus. When many plants in a field are infected, seed and forage yields may be reduced. In addition, virus-infected plants may be readily killed by root rot or weakened so much that they die during cold or hot weather.

In addition to its direct effects, weather may indirectly affect virus diseases by influencing the insect vector. Viruses in forage legumes are transmitted mostly by the pea aphid. The movement, distribution, abundance, and feeding of these aphids are greatly affected by weather; thus, virus diseases may be accordingly increased or decreased.

Many fungi and several bacteria cause leaf and stem diseases of forage legumes. Since most of these pathogens and diseases have similar moisture requirements, let us discuss a common disease in detail. Remember, however, that a particular disease and pathogen may have their special requirements. One example, spring black stem and leaf spot of alfalfa and red clover, is caused by *Phoma herbarum* var. *medicaginis*.

Spring black stem is found mostly in the spring and fall when conditions are relatively cool and wet. Warm dry weather retards the pathogen and prevents the disease from developing. Plenty of free water is essential; atmospheric relative humidities of 99 to 100 percent are not enough for the pathogen. When plant growth is lush and there is some lodging, the lower leaves and stems may remain wet for several days. Thus, ideal conditions are created for the pathogen and disease is usually severe. Timely clipping helps prevent these conditions and reduces losses.

Phoma herbarum var. *medicaginis* overwinters on crop debris. During the spring when this debris is thoroughly wet, thousands of spores are formed in pycnidia, tiny flask-shaped bodies, embedded in the bits of debris. The spores are released from the pycnidia only when they are wet. And they are disseminated only when rain splashes them about or when insects or other animals contact them. When the spores finally are deposited on a leaf or stem, they germinate after absorbing a large quantity of water. They will not germinate until they have swollen to about three times their original size; about 8 hours in water is required.

The swollen spore puts forth an extremely delicate germ tube which dies readily if it becomes dry. When germ tubes are 3 or more hours old, they begin to form appressoria, the organs which aid the fungus in penetrating plant tissues. Penetration is completed by most germ tubes 20 hours after they are formed, provided the leaves remain wet all that time.

From the production of spores until the host is penetrated, water is essential throughout the pathogen's development. And the need for water is not ended with penetration; if the disease is to develop normally, the plant must be kept wet another 10-12 hours. Even after several days, when plants are obviously infected, the disease can become more severe if plants are wet for additional periods of 12-24 hours. How moisture influences disease development after infection occurs is not known.

The diseases are most prevalent in regions of relatively high rainfall such as the eastern half of the United States and Canada. In Minnesota, the severity and prevalence of the diseases are usually correlated with local rain.

The water requirements of all foliage diseases of alfalfa and red clover, except powdery mildew of red clover, are similar to those of *Phoma herbarum* var. *medicaginis* and spring black stem. Powdery mildew is a dry weather disease. The spores of the pathogen germinate and the fungus infects the plant when no apparent free water is on leaves. In fact, the spores can germinate in the laboratory when relative humidity is zero. Rain may actually reduce the severity of powdery mildew.

Temperature also greatly influences pathogen development and disease severity. Most forage legume pathogens are favored by temperatures between 65° and 75° F. At these temperatures spore production is greatest, germination is best, growth of the germ tubes and penetration are most rapid, and the disease is most severe. Since these temperatures generally prevail in Minnesota, the water factor is of greater importance in disease development in this area. Nevertheless, temperature can be the determining factor. In 1965, plenty of water generally was available, but diseases were not unusually severe. Because temperatures were below normal, the pathogens could not develop properly.

A few diseases are warm weather diseases. Summer black stem, caused by *Cercospora zebrina*, and *Stemphylium* spp., are common in Minnesota. These diseases do not become widespread until after July when the weather is generally warm. Another warm weather disease, southern anthraconose of red clover, is caused by *Collectotrichum trifolii*. Not common in Minnesota, it is confined to the southern clover growing areas of the United States. But, in some seasons, it has been reported as far north as Canada.

Control of diseases of forage legumes is not easy. Although timely cutting may reduce losses, the use of resistant varieties is the only feasible approach. Unfortunately, varieties resistant to all diseases are not available. No alfalfa variety is resistant to mosaic or stem and leaf diseases. Vernal and Ranger, the two varieties recommended for Minnesota, are highly resistant to bacterial wilt.

The two recommended red clover varieites, Lakeland and Dollard, are the best sources of disease resistance available to farmers. Lakeland is highly resistant to powdery mildew; Dollard has some resistance. Both have field resistance to common virus diseases and are more resistant than other varieties to several other foliage diseases.

RECENT EXPERIMENT STATION PUBLICATIONS

Climate of Minnesota, Part V. Precipitation Facts, Normals, and Extremes. Technical Bulletin 254. Donald A. Haines, and Joseph H. Strub, Jr. Describes types, sources, measurement, and the process of precipitation; gives information on precipitation falling within Minnesota. 44 pages. Available from your county agent.

Soil and Water Losses From Barnes Soil in West-Central Minnesota

R. E. Burwell and R. F. Holt

SOIL and water, two of our most valuable food-producing resources, are being lost in considerable quantities through runoff and erosion. If agriculture is to meet the future food demands for the rapidly growing population, these valuable resources must be conserved to permit expansion of present production levels.

The complex soil and topographic conditions that exist on farm lands in west-central Minnesota, as well as in many other areas, complicate the application of tested soil and water conservation practices on many farms. To develop effective conservation practices for a given location, information is needed on the interrelations of rainfall characteristics, soil erodibility, topographic features, present cropping and soil management practices, and the adaptability of proven conservation practices at that location.

Most of the runoff and erosion research data on which presently used criteria for planning conservation practices are based, were obtained in the humid areas of the United States. To provide information needed for planning effective soil and water conservation at the western edge of the Corn Belt, researchers are presently measuring the magnitude and severity of natural rainfall, runoff, and erosion at the Barnes-Aastad Soil and Water Conservation Research Association Farm near Morris, Minn. This report briefly sumarizes the first 5 years' results from this study and discusses the field application of the research findings.

Research Installations and Procedure

The erosion plot studies were started on a Barnes loam soil in 1961. Runoff, erosion, and crop yield measurements were made for five soil-cover conditions which were replicated (repeated) three times. The plots were 13.3 feet wide and 72.6 feet long. Standard runoff- and erosion-measuring equipment and procedures were used to determine soil and water losses. The measuring equipment on five plots of one replication was automatically heated to permit measurement during periods of snowmelt and surface thaw (figure 1). Accurate weather records were maintained at the plot site to aid in interpreting the data.

The five soil-cover conditions studied included (1) continuous corn; (2) continuous, clean-cultivated fallow; (3) corn in rotation; (4) oats in rotation; and (5) hay in rotation. Although not recommended for soil and water conservation, crops were planted in the up- and down-slope direction to study the effects of cover conditions without the added effect of perfect contouring attainable in small plot row lengths. Tillage and cropping management practices prevailing in the area were used. Fertilizer was applied in sufficient amounts to maintain a high level of crop production.

Data reported herein were systematically grouped according to relative seasonal crop-cover intervals respective to seedling establishment, reproductive-maturity, residue, and rough plow periods to permit a logical application of research plot results to field situations.

Data and Observations

The cropping season monthly preciptation for the 5 years of the study and the long-term (79-year) averages at Morris, Minn., are shown in table 1. Cropping season rainfall was below normal in 1961, above normal in 1962 and 1965, and near normal in 1963 and 1964.

Average annual precipitation, soil loss, and water loss data for the 5-year study are tabulated by crop-cover condition periods in table 2. The total 5-year soil loss of 60.6 tons per acre measured from the continuous corn plots was equivalent to slightly over one-third of an inch of topsoil uniformly distributed over the surface. Should this rate of erosion continue, the 6-inch layer of productive topsoil that was on the plots at the beginning of the experiment would be lost in about 70 years.

A major portion of the runoff and soil losses resulted from 10 storms during 1962 and 1964 (see table 3). These 10 storms accounted for 42 per-

Water Conservation Research Association Farm near Morris, Minnesota. The tanks are insulated and equipped with heat cables and tank heaters to allow snowmelt runoff measurements.

This summary of 5 years of measurement of soil and water losses caused by natural rainfall is a contribution from the U.S. Department of Agriculture, Agricultural Research Service (ARS), Soil and Water Conservation Research Division, Corn Belt Branch, in cooperation with the Minnesota Agricultural Experiment Station and the Barnes-Aastad Soil and Water Conservation Research Association, Inc. Appreciation is expressed to Soil Conservation Service personnel for their assistance in locating the plot site.

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Table 1. Monthly precipitation at the Soil and Water Conservation Research Farm for the 1961-65 cropping seasons

Month	Normal*	Year 1961	1962	1963	1964	1965
		inches of precipitation				
April	2.25	1.82	1.25	2.28	4.20	3.09
May	3.02	1.38	7.90	3.37	.41	5.18
June	3.90	1.58	5.39	3.46	3.55	3.88
July	3.61	1.82	9.42	3.78	3.54	5.63
August	2.91	2.80	1.98	2.37	5.95	2.55
September	2.27	3.91	3.47	2.65	2.71	5.07
October	1.45	.86	.54	1.14	.08	1.07
Total	19.41	14.17	29.95	19.05	20.44	26.47

* Long-term (79-year) average at the University of Minnesota, West Central Agricultural Experiment Station, Morris.

Table 2. Five-year average (1961-66) annual precipitation, runoff, and soil loss from natural rainfall erosion plots on a 6-percent slope

Cropping treatment	Crop	Crop-cover condition period* 1	2	3	4	Season total	5	6	Season total	Annual total
		Inches of precipitation								
Fallow	None	3.95	4.39	8.25	.16	16.75	4.88	4.06	8.94	25.69
Continuous corn	Corn	3.95	4.39	8.25	.16	16.75	4.88	4.06	8.94	25.69
C-O-H	Corn	3.95	4.39	8.25	.16	16.75	2.85	4.06	6.91	23.66
C-O-H	Oats	4.39	4.97	2.30	7.70	19.36	5.04	4.06	8.94	28.30
C-O-H	Hay	4.46	5.03	8.40	....	17.89	5.04	4.06	8.94	28.30
		Inches of runoff								
Fallow	None	.30	.89	.52	0	1.71	.52	1.73	2.25	3.96
Continuous corn	Corn	.33	.79	.41	0	1.53	.39	1.16	1.54	3.07
C-O-H	Corn	.28	.62	.31	0	1.21	.05	1.40	1.45	2.66
C-O-H	Oats	.81	.53	.14	.08	1.56	.28	3.73	4.01	5.57
C-O-H	Hay	.12	.19	.04	....	.35	.08	.63	.71	1.06
		Tons per acre of soil loss								
Fallow	None	5.40	11.06	4.66	.02	21.14	3.76	1.19	4.95	26.09
Continuous corn	Corn	3.46	5.64	.89	0	9.99	1.68	.44	2.12	12.11
C-O-H	Corn	1.94	2.78	.43	0	5.15	0	.20	.20	5.35
C-O-H	Oats	3.18	.17	.02	.01	3.38	0	0	0	3.38
C-O-H	Hay	0	0	0	0	0	.12	0	.12	.12

***1.** Seedling—planting to 1 month thereafter; **2.** Establishment—between 1 and 2 months after planting; **3.** Reproduction maturity—2 months after planting to harvest; **4.** Residue—harvest to turn-plow; **5.** Rough plow—turn-plow date to planting date; **6.** Losses resulting from thaw of snow and ice.

cent of the total runoff and 83 percent of the total soil loss in the 5-year period, but only 13 percent of the total rainfall.

The total snowmelt runoff during the 5-year period ranged from 1.5 inches on the fall-plowed sod plots to 16.6 inches on those in oat stubble. Soil loses in snowmelt runoff were low for all cropping treatments.

Discussion

The erosion studies on the Barnes soil were made under variable rainfall conditions above, below, and near normal. The studies were conducted on plot slope lengths of 72.6 feet. Studies at other locations have shown that doubling the slope length usually increases per-acre soil loss by about 40 percent. A 300-foot slope loses about twice as much soil as a 75-foot slope. These slope-erosion relationships indicate that a 6-percent, 300-foot slope in the vicinity of Morris that was conventionally planted and continually cropped to corn probably would have averaged about 25 tons of soil loss per acre per year during the 5-year period. Projecting the research plot data for the 3-year rotation to field situations would indicate an average annual soil loss of about 3 tons per acre for the rotation.

An average of 3 to 5 tons per acre is considered the maximum erosion loss that can be safely tolerated on most soils of the area if a high level of productivity is to be maintained. Thus, the rotation maintained soil losses within the safe limit, but the continuous row cropping system with straight-row farming exceeded this limit by five times.

Use of the 3-year rotational system is limited because it often does not fit into the production pattern that would be economically optimum for a given farm unit. Therefore, in the search for practical solutions to the problems of soil and water conservation, the more intensive cropping systems used in combination with conservation practices that will restrict annual erosion within tolerable limits and still provide high levels of productivity must be considered.

The 5 years of record at Morris indicate that 75 percent of the total soil loss from continuous corn occurred during the 2-month period following corn planting, when the bare soil surfaces were frequently exposed to high intensity and prolonged periods of rain (figure 2). Nine of the 10 most erosive storms listed in table 3 occurred during this 2-month period. Use of cultural practices such as con-

Table 3. Rainfall, runoff, and soil loss from continuous corn for the 10 most erosive storms during the 1961-66 period

Year	Date	Rainfall inches	Runoff inches	Soil loss tons/acre
1962	5-18	1.06	0.34	1.46
	5-21	1.22	.71	3.05
	5-22	1.58	.49	3.15
	6-16	.96	.15	2.41
	6-28	2.22	.78	13.50
	7-4	1.74	.54	1.75
	7-7	1.65	.83	5.71
	7-18	2.61	.93	10.35
1964	7-10	1.45	.70	6.99
	8-29	2.10	.97	2.06
	Total	16.59	6.44	50.43
% of 5-year total		13	42	83

touring, minimum tillage, and mulch tillage to provide the most effective erosion control during the 2 months after corn planting would contribute appreciably toward holding soil erosion within safe limits.

Runoff data shown in table 2 suggest that 1 inch greater average annual infiltration during this critical period would have held the average annual soil loss within the allowable limit. However, runoff data in table 3 indicate that a 4.8-inch increase in infiltration would have been needed to completely eliminate erosion from the conventional continuous corn during the critical 2-month period in 1962.

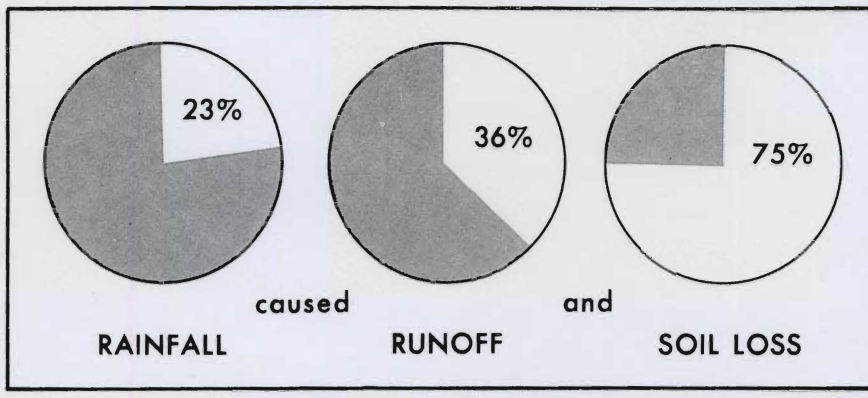

Figure 2. Results of storms during 2-month period following corn planting. For the 5-year period (1961-66), 23 percent of the annual rainfall caused 36 percent of the annual runoff and 75 percent of the annual soil loss from continuous corn farmed up and down a 6-percent slope.

The data in table 2 indicate that the crop-stage periods of major runoff from continuous corn do not coincide with those of major erosion. As shown in figure 2, the 2-month period following corn planting accounted for 75 percent of the average annual soil loss but for only 36 percent of the average annual runoff. Runoff from continuous corn for the period from corn planting to harvest was one-half of the annual total (see table 2). The cropping-season rainfall is vital for crop production because the soil water reservoir often is only partially filled at the beginning of the season.

Snowmelt runoff from fall-plowed continuous corn plots accounted for 38 percent of the annual water loss. Observations on these plots and on areas with similar slopes reveal that considerable snow is blown from fall-plowed slopes and, thus, does not melt where it falls. Snowmelt runoff from hay plots with grain stubble, which retained more snow than did fall-plowed surfaces, was 92 percent of the water equivalent of measured snow fall. This suggests that only a small part of the moisture supplied by snow actually contributes to the replenishment of soil moisture, even when snow is retained in oat stubble. Limited infiltration of melted snow is probably the result of frozen soil. Thus, the problem of soil moisture replenishment from winter precipitation appears to be twofold. First, soils in this climatic area are usually frozen and impermeable to water movement during the snowmelt period. Second, snow is frequently blown off the fields before melting occurs.

Differences in corn yields for the two cropping systems shown in table 4 were not consistently accounted for by differences in runoff.

Conclusions

The first 5 years of the plot study have shown that without conservation practices, the Barnes soil is susceptible to serious erosion from natural rainfall. The average annual soil loss from continuous corn conventionally farmed up and down the 6-percent, 72.6-foot-long slope was 12.1 tons per acre. This annual soil loss, which represents a total of one-third of an inch of topsoil, was caused by 3.1 inches of average annual runoff. On longer field slopes the per-acre losses probably would have been greater. The 3-year rotation of corn-oats-hay, with all residues left on the field, maintained soil losses within safe limits for continued high production.

The major soil and water losses resulted from a relatively small number of storms with high erosive potential. The 10 most erosive storms accounted for 13 percent of the total rainfall, 42 percent of the total runoff, and 83 percent of the total soil loss from continuous corn. Nine of these 10 storms occurred during the 2-month period following corn planting when bare soils were unprotected from erosive forces of falling rain. Measured soil losses during this critical period accounted for 75 percent of the annual losses. Elimination of much of this "75 percent" by use of improved soil, crop, and residue management practices would contribute appreciably toward alleviating the erosion problem under intensive cropping systems.

Water losses from runoff were distributed more uniformly throughout the year than were soil losses. Only 36 percent of the annual water losses from 5 years of continuous corn occurred during the 2-month critical period following corn planting. Thirty-eight percent of annual water loss resulted from snowmelt runoff. Four years of snowmelt runoff measurements indicate that little, if any, of the snowfall moisture contributes to the replenishment of soil moisture, even when snow is retained in oat stubble.

Table 4. Crop yields on the natural rainfall erosion plots

Cropping treatment	Crop	Year 1961	1962	1963	1964	1965	Total	Average
				Bushels per acre				
Continuous corn	Corn	72.5	90.2	89.4	53.8	62.8	368.70	73.74
C-O-H	Corn	69.8	89.0	100.1	42.9	70.5	372.30	74.46
C-O-H	Oats	64.2	55.4	83.3	67.7	137.8	408.40	81.68
				Tons per acre*				
C-O-H	Hay	....	2.6	1.9	2.7	2.1	9.30	2.32

* Removed as hay from two cuttings; values computed on an oven-dry weight basis.

Evaluating Soil and Crop Management Systems

R. L. Thompson and S. D. Evans

RECENT advances in agricultural production have caused everyone to look more closely at some of the production practices long considered "standard." Practices such as crop rotation, row spacing, plowing and other tillage operations, and cultivation for weed control have tended to follow fairly uniform patterns in areas where soil and climatic conditions are similar. With the ready availability of cheaper fertilizers, selective herbicides, more effective insecticides, and versatile power equipment and machinery, some of the old "standard" practices are being questioned and often changed.

In view of some of these changing conditions, an experiment was set up in 1960 at the West Central Experiment Station at Morris to evaluate yield and economic advantage of combinations of several crop management practices.

Two management systems, "base" and "test," were used in the experiment. The base system included practices currently used in the Morris area; the test system included practices thought to have potential for increasing crop productivity. These management systems were applied to continuous corn, soybeans, and alfalfa (table 1) and to a rotation of oats, hay, soybeans, and corn (table 2).

Table 1. Management practices followed for continuous soybeans, corn, or alfalfa

Crop and cultural practice	Base level	Test level
Continuous Soybeans:		
Seeding rate	60 lb./acre	90 lb./acre
Weed control	3 cultivations	Broadcast amiben* and cultivation
Fertilizer	None	0-45-0, 100 lb./acre broadcast
Row width	38 or 40 inches	20 inches
Variety	Merit	Merit
Continuous Corn:		
Population, plants/acre	14,000-16,000	18,000-20,000
Row width	38 or 40 inches	20 inches
Soil insecticide	None	Aldrin
Fertilizer, starter or	8-32-16, 80 lb./acre	8-32-16, 160 lb./acre
broadcast	Nitrogen, 40 lb./acre	Nitrogen, 100 lb./acre
Weed control	3 cultivations	Broadcast atrazine and cultivation
Variety	Various Minhybrids	Various Minhybrids
Continuous Alfalfa:*		
Variety and seeding rate	Vernal, 10 lb./acre	Vernal, 10 lb./acre
Fertilizer	0-45-0, 100 lb./acre	0-45-0, 200 lb./acre
Cuttings	2 or 3	2 or 3

* (The crop was initially established without a companion crop using 2,4-DB and dalapon for weed control.)

* Use of trade names does not imply endorsement.

Table 2. Management practices followed for oats, hay, soybeans, corn rotation

Crop and cultural practice	Base level	Test level
Oats (1960)		
Variety and seeding rate	Minton, 2½ bu./acre Vernal alfalfa, 8 lb./acre Lincoln brome grass, 3 lb./acre	Minton, 4 bu./acre Vernal alfalfa, 8 lb./acre Lincoln brome grass, 3 lb./acre 9-36-0, 280 lb./acre
Fertilizer	None	Nitrogen, 50 lb./acre
Harvest—Silage and grain yields		
Hay (1961)		
Fertilizer	0-45-0, 100 lb./acre	0-45-0, 100 lb./acre
Harvest—Yields were measured separately for plots where oats were harvested as silage and grain.		
Soybeans (1962)—Same treatment as continuous soybeans.		
Corn (1963)—Same treatment as continuous corn except weeds were hand hoed in test plots to eliminate possible carryover effect of atrazine.		
Oats (1964)—The 1960 treatments were repeated except: (1) Garland substituted for Minton. (2) No fertilizer was used on test plots.		
Hay (1965)—The 1961 treatments were repeated except that 0-45-0 at 200 lb./acre was applied to test plots.		

Soybean Yields

The 6-year average shows a highly significant 7.1-bushel-per-acre increase for soybeans grown under the test management system as compared to the base management system. The yield advantage for the test management system has been quite consistent each year. This increased yield probably results from the use of phosphate fertilizer, narrower rows, and weed control.

Soybeans in a different rotation experiment on the station have shown an average response of 2.3 bushels per acre from 17.5 pounds of phosphorus (40 pounds P_2O_5) over an 8-year period.

Weed control in the test plots has been somewhat better than in the base plots. Chemicals have helped in controlling weeds but cultivation has been needed to supplement the chemicals when weather conditions were not favorable for a chemical or when resistant weeds were a problem.

Corn Yields

Continuous corn grown under the test management system has yielded

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Table 3. Six-year yields from continuous cropping systems

Year	Continuous soybeans Base	Continuous soybeans Test	Continuous corn Base	Continuous corn Test	Continuous alfalfa Base	Continuous alfalfa Test
	Bu./acre		Bu./acre @ 15.5% moisture		Tons/acre (air dry basis)	
1960	16.8	23.1	61.2	70.3	1.4	1.8
1961	20.7	28.4	62.0	65.5	2.2	2.0
1962	21.2	26.4	67.0	87.4	4.8	5.1
1963	23.4	36.7	72.7	73.1	4.9	4.9
1964	15.6	22.1	36.7	34.2	3.0	3.1
1965	24.7	28.1	69.5	101.0	6.0	5.4
Average	20.4	27.5	61.6	71.9	3.7	3.7

Table 4. Six-year yields from rotation cropping systems

Rotation	Yield per acre Base	Yield per acre Test
1960 (Oats) Grain:	86.7 bu.	90.0 bu.
Silage:	7.9 tons (green wt.)	8.2 tons (green wt.)
1961 (Alfalfa) From grain plots:	1.87 tons	1.79 tons
From silage plots:	2.44 tons	2.19 tons
1962 (Soybeans)	25.6 bu.	24.1 bu.
1963 (Corn)	86.4 bu.	113.0 bu.
1964 (Oats) Grain:	65.1 bu.	94.2 bu.
Silage:	1.14 tons (dry wt.)	1.76 tons (dry wt.)
1965 (Alfalfa) From grain plots:	5.1 tons	5.3 tons
From silage plots:	4.8 tons	5.4 tons

10.3 bushels per acre more than under the base management system. This yield difference is statistically significant, but the advantage has not been as consistent each year as for soybeans. The yield increase paid for the additional seed, fertilizer, and herbicide only 2 of the 6 years. But this does not mean that one or more of these treatments would not prove profitable when used alone.

Atrazine has controlled the weeds fairly well in the 20-inch rows, but cultural practices must also be used.

Fertilizer rates which are considerably in excess of recommendations based on soil test may give increased yields, but the cost of these increases usually exceeds their value.

Alfalfa Yields

Continuous alfalfa has shown no yield increase from the higher fertilizer rates included. It appeared that 20 pounds of phosphorus (45 pounds P_2O_5) was adequate to obtain maximum yields under the conditions of this experiment. No additional potash was supplied since soil tests indicated very high levels.

The slightly lower yields from the test management alfalfa plots in 1961 may be accounted for by a difference in harvest dates. The first crop was removed from the test plots 6 days before the base management system. The yield of protein and TDN probably would have been about equal from both plots because of a higher percent of protein and TDN from earlier harvest.

Precautions for Continuous Cropping

Certain precautions must be followed in a continuous cropping system. Since insects and diseases are likely to be a problem, one must watch these fields more closely than under a rotation system and be prepared to correct the problem or change the cropping program at the earliest indication of trouble. For example, no difficulty was encountered in 6 years of continuous corn where no insecticides were used, but the 7th year many adult corn rootworm beetles were found and now the insects must be controlled. Serious infestations probably would have occurred sooner in areas of the state where rootworms have been more of a problem.

Soybeans may be more likely to develop root and stem rots and other diseases where grown continuously. No difficulties have been encountered in 6 years of continuous soybeans, but these are relatively small plots and difficulties may develop more quickly in large fields than in the plots.

Crop Rotations

The most common rotation in western Minnesota is alfalfa-corn-soybeans-small grain. This sequence permits corn to utilize nitrogen from the legume but presents some problems. Moisture is often limited in fields where alfalfa is fall-plowed late in the season and this may reduce corn yields the following year. Also, there is often a problem with volunteer corn in the soybeans. The sequence of crops in this experiment is hay, soybeans, corn, and oats; this sequence overcomes the problem of volunteer corn in the soybeans. Yield comparisons between the continuous cropping system and the rotation system should be made for a specific year rather than using the 6-year average data for the continuous cropping system (tables 3 and 4).

Alfalfa grown in the rotation in 1961 and 1965 yielded approximately the same as when grown continuously. In 1961 the same early cutting dates were used for the rotation and continuous alfalfa, which may account for the slightly reduced yield under the test system.

Removal of the oats as silage 1 week before grain harvest in 1960 resulted in considerably increased hay yields in 1961. The earlier harvest of oats in 1964 apparently did not affect yields in 1965.

Weather conditions following removal of the companion crop will often affect survival of the new alfalfa seeding. These alfalfa seedlings are usually lacking in vigor due to the competitive effect of the companion crop, and relatively small differences in harvest dates may make an important difference in stand survival. Results of other experiments have shown the advantage of the early removal of a companion crop where moisture is limited.

When soybeans were grown in the rotation in 1962, a yield comparison showed no significant difference between the continuous cropping system and the rotation. In continuous soybean plots the test management produced higher yields than base management, but in rotation plots yields from the two management systems were essentially equal.

Although it is difficult to draw conclusions from a single year's comparison, it appears that there are some advantages to growing soybeans in a rotation. But this advantage can be eliminated through more intensive management practices where soybeans are grown continuously.

In 1963, when corn was grown in the rotation plots, yields for the different treatments were quite variable. Corn grown in the rotation yielded significantly more than continuous corn, with the highest yield from the test management level.

Test and base management yields of continuous corn were about equal, but significantly lower than the base management rotation yield. It is difficult to explain the large yield advantage for corn grown in the rotation; the advantage is probably related in some way to conditions that occurred during the favorable growing season in 1963. Another fertilizer and cropping system experiment at Morris shows an average 4.4-bushel-per-acre advantage for continuous corn over a 10-year period.

Oats was grown in the rotation in 1960 and 1964. The only comparison that can be made for the oats is between the different management levels, since there was no continuous cropping of oats. In 1960 there was no significant difference between the base and test management level oat yields whether the crop was harvested for grain or silage. In 1964, oats produced 54 percent more silage and 45 percent more grain under test than base level of management. This increase was probably due to the increased fertilizer. It is doubtful that the higher seeding rate had much effect on the yields; adaquate stands were obtained at either rate.

Crop rotations remain a desirable management practice in crop production where the overall farm operation will permit. Crop diversification spreads some of the risk of changing weather and price conditions in addition to soil and crop benefits which have been considered important. Changes in soil structure that affect tilth, drainage, water infiltration, and many other factors are probably affected by the cropping system. These factors are extremely difficult to measure and change slowly, so it is hard to tell what the long-time effects of continuous cropping systems will be. Continuous cropping experiments carried out for prolonged periods at other places have shown that crop production is not necessarily reduced.

Where soil erosion is a problem, crop rotations with limited cultivated crops are an effective means of control. However, it may be possible to grow continuous cultivated crops on parts of a farm while leaving the areas most subject to erosion in sod or a rotation with a fairly high level of sod crops.

Regardless of whether a rotation or continuous cropping system is followed, careful management of crop residues, erosion control measures, and disease and insect precautions are needed. Some of these problems may be more critical under a continuous cropping system than where a rotation is followed.

These trials were conducted on a Barnes clay loam. Soil tests were taken initially and at the end of the 6-year cropping period. The tests showed little change in pH, percent organic matter, and exchangeable potassium. Little change would be expected in pH and organic matter content over this short period.

The initial level of exchangeable potassium was very high and the rates of potassium used were not high enough to increase this level. As shown in table 5, the level of extractable phosphorus was increased by the application of fertilizer in the various cropping systems. The phosphorus-supplying power of this soil is indicated by the base soybean plot where no phosphorus was applied. On this plot an average yield of 20.4 bushels per acre has been maintained with essentially no change in phosphorus level. On all other plots, the extractable phosphorus level has been increased where phosphorus applications ranged from 50 to 236 pounds per acre over the 6-year period.

Table 5. Extractable phosphorus and rates of phosphorus applications on crop management plots

Treatment	Extractable P*	Total P applied (lb./acre)†
Initial soil level	11	....
Soybeans (base)	10	0
Soybeans (test)	27	118
Corn (base)	22	65
Corn (test)	34	134
Alfalfa (base)	16	118
Alfalfa (test)	28	236
Rotation (base)	13	50
Rotation (test)	32	144

* Level of soil phosphorus as determined by the University of Minnesota Soil Testing Laboratory.
† To convert to P_2O_5 multiply by 2.29.

Summary:

1. Soybeans responded to management practices such as narrower rows, fertilizer and good weed control.

2. Response of corn to more intensive management practices was not as consistent as response of soybeans.

3. Fertilizer rates exceeding present soil test recommendations did not increase alfalfa yields.

4. Oats grown in a rotation following fertilized corn yielded more under the more intensive system.

5. Corn and soybeans were grown continuously for 6 years without major difficulties; however, there are advantages from rotations and a rotation cropping system should be considered where land conditions and crop utilization will permit.

6. Soil phosphorus levels were increased, even with moderate levels of phosphorus fertilizer.

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Cropland Quality and Land Use Changes in Southern Minnesota

by Lowell D. Hanson

CHANGES in land use are obvious around our rapidly-growing cities where in a few months the landscape can change from open land to streets and houses. In contrast, the rural scene appears unchanging to most observers. On a drive through southern Minnesota, the countryside appears about the same now as it did 20 years ago. But is it the same?

A closer look at cropland and where it is located reveals that substantial changes are continually taking place. Most of these shifts are gradual and go unnoticed; a slough is drained and planted to soybeans, while on the other side of the section a 15-acre field, because of a droughty soil, goes uncropped for a few years and finally is planted to trees.

Thousands of these rather small changes add up to a sizable change over a few years. For example, 10 townships representing a large area in western Minnesota show an increase of 32,500 acres of cropland from 1945 to 1959, an increase of 22.6 percent. At the same time, cropland in 10 townships in central Minnesota decreased by 24.7 percent. Although statewide figures show practically no change in cropland, the location of an estimated million acres of cropland actually has changed.

In order to better understand the magnitude of these land-use shifts and the reasons for the changes, a study has been made of land use as related to soil geography. The quality of land for agriculture is best determined by the kinds of soil types which occur in a given area. Soils in central and southern Minnesota vary widely from low-fertility sands to fertile medium- and fine-textured soils which are well adapted to intensive corn and soybean production.

MEASURING LAND QUALITY

One of the first questions involved in the study was to develop a way of measuring this range of land quality. This was done by calculating a corn yield index for each township in the study, based on the distribution of soil types. Table 1 illustrates the close agreement between predicted corn yields based on soil resources and the actual yields reported by agricultural census.

Table 1. Predicted and actual corn yields in 55 townships from selected soil associations, bushels per acre

Soil groups	Predicted yields from soil maps	Actual yields, 1954-59 average
Flak-Brainerd-Nokay	38	37
Estherville-Wadena-Hubbard	43	34
Clarion-Nicollet-Webster	58	57
Lester-LeSueur-Glencoe	56	57
Barnes-Aastad-Flom	39	41
Kasson-Skyberg-Kenyon-Floyd	59	58
Fayette-Tama	67	66

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The ranking of the soil areas is more important than the level of corn yields. Individual farm reports and experimental plots indicate that present yield potentials under good management are approximately double the figures listed in table 1. One exception would be the Estherville-Wadena-Hubbard soils where drought usually limits yields unless irrigation is used.

Yields are only one factor concerning cropland quality or suitability of land for modern crop production methods. Large fields suitable for cultivation with today's six- and eight-row farm implements are increasingly important. Other factors such as distance from markets and transportation facilities enter into determining whether or not land is used for crop production.

SOIL AREAS AND LAND USE TRENDS

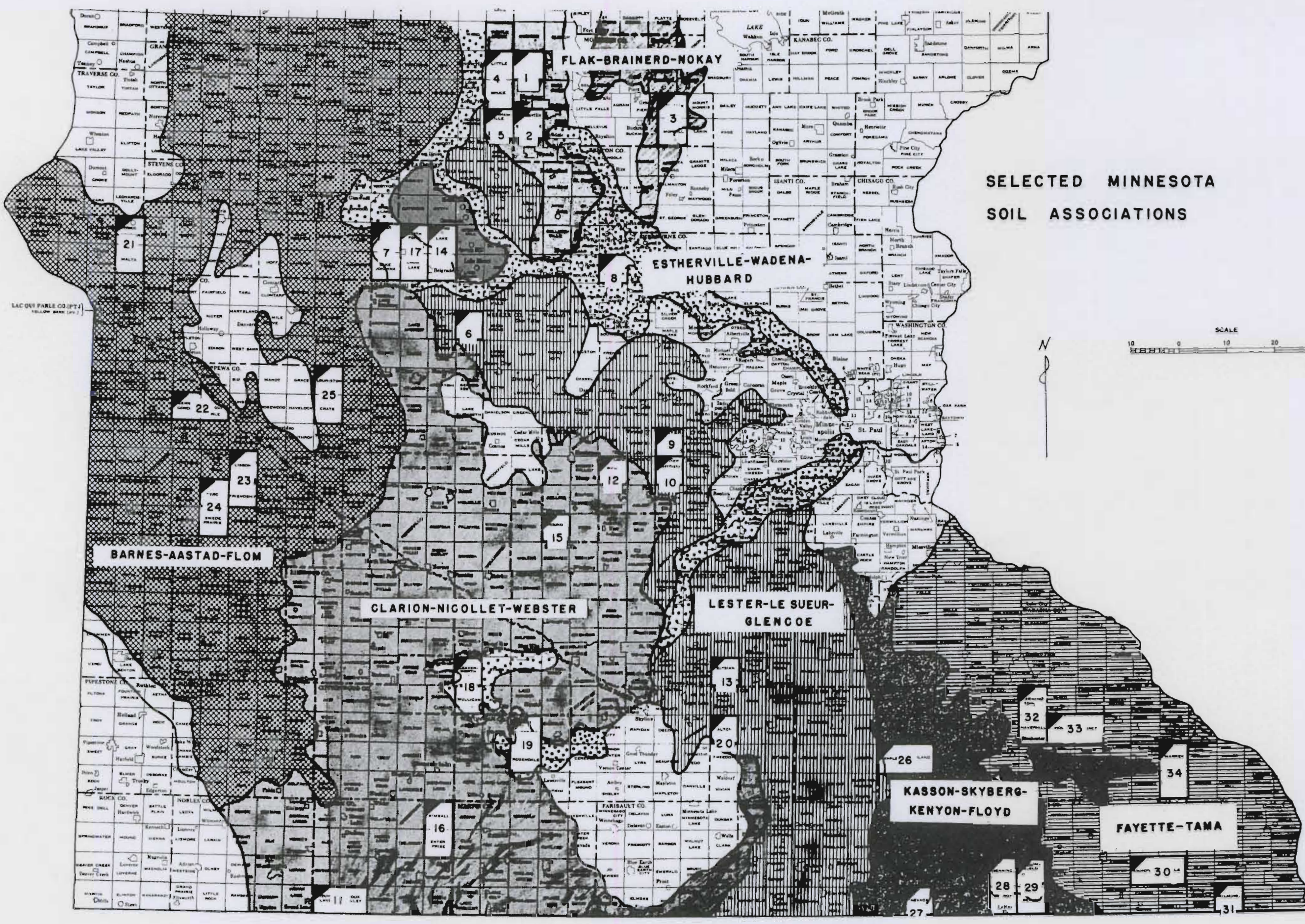
A general description of the nature of the land and soils of the seven soil areas shown in figure 1 follows. Some of the trends in land use are given as indicated from sample townships in each area.

Fayette-Tama Area

This is a 2-million-acre southeastern Minnesota region of rolling hills covered with wind-blown silty material from which the silt loam soils are developed. The combination of fertile, easily worked soils along with a long growing season and the highest rainfall of the state make this one of the highest yielding corn areas of Minnesota. Both Fayette and Tama soils are gently to moderately rolling, and erosion is a constant problem. Only 3 percent of the soils need drainage, as this older landscape has naturally developed surface drainage through thousands of years of geologic erosion.

Cropland has remained quite constant since 1945. The nine sample townships show a cropland decrease of only

This landscape in Amherst Township, Fillmore County is typical of the Fayette-Tama soil association.



Location of selected Minnesota soil associations.

1.5 percent up to 1959. 1964 census figures indicate that acres of harvested cropland have decreased more rapidly the last 5 years. USDA feed grain diversion programs have contributed to this decline recently.

About one-third of the land is steep, wooded terrain unsuited for crops. Therefore, as other land uses compete for level land, agricultural cropland will continue to decrease in the future.

Kasson-Skyberg Area

Occupying about 300,000 acres in Dodge, Fillmore, and Mower Counties, these soils are developed from mixed prairie and forest vegetation on compact glacial till. In contrast to the rolling Fayette-Tama soils with permeable subsoils, crop yields on these soils are often limited by slow water movement in the subsoil. Low fertility of both phosphorus and potassium has been a problem for farmers in this area, but poor drainage has been more serious in restricting development of these soils.

The effect of a large acreage of poor natural drainage and recent rapid increases in artificial drainage by tile and ditch is reflected in the increase in cropland from 1945 to 1959. The seven sample townships from this soil area recorded a cropland increase from 89,000 to 119,000 acres, 33 percent, in this period.

The impact of this added cropland on the community is substantial. While most of the farm areas of the state have been decreasing in total population, this area has not been losing population as rapidly as most areas. In 1959 the population was 87 percent of the 1930 figure while the whole study area declined to 82 percent. One township, Nevada in Mower County, actually had 10 more people living on farms in 1959 than in 1930.

Drainage has had the effect of enlarging the effective farm size without adding total farm acres. Thus, the size of the farm business could be increased without a corresponding decline in farm numbers by adding productive cropland through drainage.

Table 2. Percent of cropland soils with restricted drainage

Soil group	Percent of cropland soils
Flak-Brainerd-Nokay	29
Estherville-Wadena-Hubbard	16
Lester-LeSueur-Glencoe	26
Clarion-Nicollet-Webster	53
Barnes-Aastad-Flom	64
Kasson-Skyberg-Kenyon-Floyd	59
Fayette-Tama	3

Lester-LeSuer-Glencoe Area

This soil area represents about 2.5 million acres west and southwest of the Twin Cities (see map). Glacial moraines deposited at the margins of ice sheets account for the rolling topography and numerous lakes, potholes, and sloughs. Land suitable for crops has been used for crop production for some time. There is less opportunity for adding cropland through drainage in this area than in the Skyberg-Kasson area. Here 26 percent of the soils have restricted drainage compared to 58 in the Skyberg-Kasson soils (table 2).

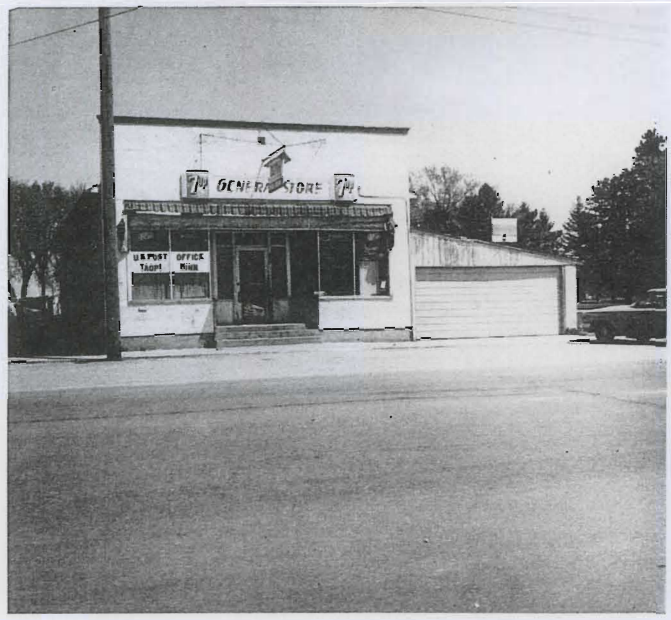
Farm numbers have declined substantially, reflecting the consolidation of the relatively small dairy farms common to this region. The five sample townships from this area lost an average of 16 farms per township from 1945 to 1959. Despite a total cropland increase of 8 percent during this period, the average farm had only 105 acres of cropland in 1959. Full-time commercial farm operations are almost impossible with this size crop base, so further large decreases in farm numbers are likely.

The decrease in farm numbers is necessary because the soil geography is such that only a few acres of additonal cropland can be added per farm by operations such as drainage or clearing.

Clarion-Nicollet-Webster Area

Directly west of the Lester-LeSueur soils is the large soil association of Clarion-Nicollet-Webster. Representing about 4.5 million acres of gently rolling prairie soils, this is a highly productive area of Minnesota's agricultural land. Although parent materials of these soils are similar to those of the Lester-LeSueur area, the more level topography and original prairie vegetation make the land more valuable for modern commercial agriculture. A high percentage of the land—85 to 90 percent—is cropland, and crop yields are high. This combination makes possible a high crop productivity per square mile. The somewhat poorly drained Webster and Glencoe soils occupy over half of all the cultivated land in the area.

Obsolete farmsteads are often abandoned in favor of a completely new set of buildings. Fewer farmsteads are phased out in soil areas where cropland is increasing.



Hamlets decline in areas of farm consolidation.

Land use trends of more intensive cropping and increases in cropland are similar to those occurring in the Skyberg-Kasson area. The 10.4 percent increase in cropland since 1945 has not been as large. Drainage is also important here in increasing cropland but, compared to other wet soil areas of the state, a higher proportion of this land was drained in the 20's and 30's.

Population has declined by about 15 percent and the proportion of families who farm from 95 to 85 percent in rural townships since 1930. The adjustments necessary to larger farm units are perhaps not as difficult on a community basis as in the dairy farming area to the east because the population density, 12.3 per square mile, is not high. In the Carver, Wright, and Scott County areas, Lester-LeSuer soils rural townships had a population of 19.6 per square mile in 1960.

Barnes-Aastad-Flom Area

Barnes-Aastad-Flom is a large soil area, 4.5 million acres, in western Minnesota. A 23- to 26-inch annual rainfall coupled with warm summers favored short prairie grass vegetation during past glacial time and the soils developed reflect these conditions in moderate topsoil depth and a subsoil rich in the plant nutrients of calcium, magnesium, and potassium. Despite fertile soils, corn yields are the lowest—39 bushels per acre—of the southern Minnesota soil areas (table 1).

In general, this land is level to gently rolling, favoring large fields and farms. Except for drainage ditches and roads, there are few restrictions to field size. In spite of the low rainfall, sizable amounts of land need artificial drainage. This drainage has been installed rapidly since World War II and is reflected in the increasing acreage of cropland in the census. The 10 sample townships recorded a 22-percent cropland increase from 1945 to 1959. Part of this increase is land that was farmed without drainage during the drought of the 1930's and went out of production during wet years in the 1940's.

Numbers of farms declined by 13 percent from 1945 to 1959. This decline, together with the additional cropland, has resulted in an average increase in crop acres per farm from 162 to 224 during this period. Total acres per farm are continuing to increase. Lac Qui Parle County farms, for example, average 284 acres in 1964, a 33-acre increase over 1959. Farmers in this soil area are the most efficient of all of the areas studied in terms of acres farmed per man. In 1945, cropland per man was 100 acres and this increased to 160 acres per man in 1959. Part of this high acre per man figure can be explained by the low numbers of high labor requirement dairy herds, but a large share is due to extensive use of large farm implements.

So, despite rather modest average yields, this is an area of expanding crop production, both in terms of efficiency and size. These changes have been accompanied by a population decline in rural townships; 1959 population was only 71 percent of 1930 numbers in the study area.

Flak-Brainerd-Nokay Area

The Brainerd-Nokay area soils were developed from reddish-brown sandy loam glacial till under forest vegetation. Several factors, including cool and short season climate, soils low in lime and potash, "cut-up" nature of the topography, and numerous surface stones and boulders combine to make these somewhat marginal agricultural soils.

Traditionally, this area has had livestock farms with emphasis on dairy. In 1959, 97 percent of the cash sales from the sample township farms were from livestock; only 2.8 percent were from direct sale of crops. This is in contrast to the Aastad-Flom area where 32 percent of income came directly from crops.

Agriculture is declining in terms of farm numbers, about 12 percent from 1945 to 1959. Soil bank land and cropland shifting to pasture or trees has caused a corresponding decline in cropland, so average acres of crops per farm have remained constant at about 72 acres.

Although a high proportion of the land is too wet for crop production, few acres have been drained or are likely to be drained in the future. This is because of the heavy concentration of boulders in the low swales. Also, the land value per acre makes it difficult to justify expensive drainage.

The physical deficiencies of the land and soils in this region appear to be making it increasingly difficult for these farmers to compete with those from southern Minnesota and Corn Belt states.

Estherville-Wadena-Hubbard Area

Sandy soils are the rule in areas of the state represented by this category. Glacial meltwater sorted out the small particles of silt and clay, leaving sands for soil formation. Low water-holding capacity is the chief problem with these soils. Natural soil fertility is also usually low, but this can be corrected with nitrogen and potassium fertilizers. While most southern Minnesota farmers are troubled by poor drainage, too rapid drainage is the case on these sandy soils.

Townships representing this soil area in the study showed a sharp decline in cropland from 1945 to 1959. The average decrease was 24.7 percent. One census unit, Bangor and Lake Johanna Townships in Pope County, recorded only half as much cropland in 1959 as 15 years earlier. Another area in Todd County, Little Elk and Bruce Townships, had a 21-percent decrease. Apparently the soil bank program was partially responsible for this decline, as most of the acreage loss occurred from 1954 to 1959 when this program was most active.

The people also left; there was a 36-percent decline in numbers of farms in this area from 1945 to 1959. Change in farm size was small, only 3 percent decrease in crop acres per farm, since both farm numbers and acres decreased.

Recently irrigation has been used on individual farms in this area. The total acreage irrigated is still small, but offers a way to utilize these soils in the future. Therefore, past trends of decreasing land value may not hold true in the future.

Summary

Of the seven soil groups studied, there appear to be three patterns of land use change. Both numbers of farms and acreage farmed have been decreasing over the past two decades on the Flak-Brainerd-Nokay and Estherville-Wadena-Hubbard soil groups. Under traditional technology and management, farms on these soils have not been able to compete with those in southern Minnesota.

An intermediate pattern of farm size change is illustrated by the Lester-LeSueur, Nicollet-Webster, and Fayette-Tama soil areas. These groups have had a 10- to 15-percent decrease in numbers of farms and a 16- to 24-percent increase in cropland per farm. The cropland increase per farm is partially from farm consolidation and partially from absolute increase in cropland over the 15-year period.

A third pattern is exhibited by the Aastad-Flom and Skyberg-Kasson soil areas where decrease in farm numbers has been a modest 11 and 7 percent, but averaged 38 and 44 percent increase in cropland per farm.

The extent to which there has been an opportunity to add new productive land through drainage has apparently been a big factor in these changes.

There are substantial geographic differences in the rate of adjustments of farm sizes and numbers caused by economic and technological forces. Among the factors affecting these changes, physical geography as expressed by soils is important.

Cameras, Burning, and Freezing—Tools for Forestry Research

IN SOME WOODED BOGS and uplands of northern Minnesota, high wispy columns of smoke on certain days are a signal, not of uncontrolled destruction, but of science at work—on prescribed burning as a tool of forest management.

In the University's forest products laboratories, research men put green boards in a freezer before kiln drying, seeking an answer to a vexing old problem of the lumber industry.

In the skies over the Twin Cities area, small planes carrying specially designed equipment and highly-trained cameramen are using infrared film in camouflage detection—not as a military exercise but in detection of oak wilt, Dutch elm disease, and other diseases.

These activities are part of the modern look in forestry and forest products research at the University of Minnesota. This research has two main thrusts:

1. Educating professional foresters for research careers in public and private positions, and
2. Direct involvement in basic and problem-oriented research.

About a third of Minnesota's land is in forests, and about half of this forest acreage is public land. Processing and distributing forest products in Minnesota annually create about $500 million in the state economy. Nearly 60 percent of this value is from harvesting and processing of Minnesota timber; the rest is advanced processing and distribution of wood brought in from other states. So although we don't have the towering redwoods and Douglas firs growing here, they figure in our forest industry in a major way.

The forest products processing industries directly employ between 15,000 and 20,000 Minnesotans. At least half of this employment is in the pulp and paper industry, which has promising opportunities for still further growth. Past research has shown how to utilize tree species formerly unacceptable for high quality market products. Silviculture (forest management) research has shown how to increase forest yields. Along with new knowledge about protection from insects, fire, and disease, silviculture is contributing to restoration of vast areas of Minnesota's forests.

Yet, with many northern communities relying on forest industries for economic well-being, there are major problems in utilization of forest resources. Leisure time interests of citizens have led to multiple demands on forested land. Although the pulp market has helped utilize low-quality trees, the aspen and other species pose major research problems. The challenge to research in Minnesota has several aspects:

- Utilization and marketing research for ways to use low-grade species in the short run and for ways to maintain cost competitiveness in the long run.
- Management and biological research on ways to convert these areas, when harvested, to more desirable species.
- Studies of problems facing institutions and managers in adapting to such trends as the growing labor shortage for woods work and the resultant shift to mechanical harvesting.
- Resolution of conflicts between uses of forest areas. Too often, decisions on forest use must be made without thorough understanding of costs and benefits of various courses of action.

Among the various University research projects directed toward these problems, we shall describe three—prescribed burning, study of a new technique for drying green lumber, and use of aerial photography in forest study.

Prescribed Burning

An elder citizen who recalls the great Hinckley fire of 1894 or the Cloquet–Moose Lake–Sandstone fire of 1918 might be hard to convince, but fire under control is proving its worth as a forest management tool. Foresters have ample proof that without fires down through the ages we wouldn't have the majestic stands of red pines like those along trailways of Itasca Park. To re-create an 18th century forest, we may need an 18th century kind of environment, and that would include periodic fires to wipe out competing vegetation and give red pine seedlings a better chance. In older stands of red pine at Itasca Park, the trees often date back to the times of major fires—1714, 1803, 1807, and 1820, for example.

Prescribed burns conducted under carefully selected fuel and weather conditions are showing merit in studies at the Cloquet Forest Research Center, at the Cedar Creek Natural History Area, and in other locations. Frank Irving and his associates conducting the studies say the technique promises to have other applications. In cooperation with plant pathologists, University foresters are attempting to control certain forest diseases and undesirable plants, such as dwarf mistletoe in black spruce. This presents an especially ticklish problem, since spruce swamps are hard to burn except in dry periods when surrounding areas are tinder dry. One experimental approach is to spray these diseased areas in swamps first with liquid fuel, to create a hot continuous fire that does the job under safe conditions.

Fire under careful control is being studied as a way of improving wildlife habitat at Carlos Avery Game Refuge near the Twin Cities, in cooperation with the Minnesota Department of Conservation. The problem at Carlos Avery is not to learn whether fire can be used this way, but how to do it efficiently with available men and equipment. Current efforts are intended to make the procedure safer, easier, and cheaper.

Drying Prefrozen Lumber

Science history is sprinkled with anecdotes dramatizing the eventual significance to the everyday world arising from fundamental findings that first seemed without practical value. Such an illustration is emerging from Minnesota research on an old problem in the forest products industry—drying lumber. Many types of green lumber, if dried too fast in a kiln at too high a temperature, will collapse, shrink, and "honeycomb" in ways that virtually ruin the boards or at least require expensive and wasteful trimming. To cope with this problem, the redwood lumber industry must allow a part of its green lumber of some species to air-dry in large outside yards for 3 months to a year before kiln-drying. The space and time add up to big expenses for the lumber industry.

Are there ways to dry green lumber of these problem species immediately after sawing, without damage to the boards? Forest products researchers Robert Erickson, John Haygreen, and Ralph Hossfeld have suggested a technique that may provide some long-sought answers—prefreeze the green lumber before kiln drying. Repeated tests show that prefrozen green redwood lumber dried at extremely high kiln temperatures (175° F. or more) has negligible collapse and shrinkage, compared with green unfrozen lumber dried the same way.

After these striking laboratory results, the University applied for a process patent and the discovery is being tested on a semicommercial scale to test its feasibility for large-scale operations.

The story behind this discovery starts at another time and with another problem. Hossfeld and W. C. Kelso in 1962 sought to explain some problems complicating the wood treatment process. They found that air bubbles, so small they are invisible with a microscope, can actually block capillaries in wood. This finding helped explain why wood being treated with preservatives tends to stop absorbing the liquid preservative long before the wood is saturated.

How did that finding relate to the drying problem? It gave the wood scientists a better understanding of the general role of bubbles and hydrostatic tension. While these bubbles cause difficulty in some cases, they might be helpful in others, such as the wood collapse problem.

A classical theory in wood technology holds that liquid tension can be responsible for wood collapse. During evaporation of water from saturated wood cells, water leaves through capillary action, passing through pit pores in a cell membrane. Tensile strength of the evaporating water puts pressure on cell walls to collapse. The overall effect may be compared to pulling water from a plastic bag with a large syringe. As you pull the handle back, the water comes out and the bag collapses.

How could this tensile strength of water be broken? Here is where the bubble comes back into the picture. Water contains dissolved air which, under a shock of some kind, may form a small bubble. If it is larger in diameter than the cell pores, the bubble tends to grow as water vapor moves into it, and tensile force on the cell wall is lessened. If you think of water with its tensile strength as a chain between the cell wall and the pit pores, the bubble is a weakened link.

The researchers then sought a way to start bubble formation in wood cells. Kelso and Hossfeld had found that ultrasonic waves (as well as various forms of mechanical shock) could produce bubbles in wood. But ultrasonics in lumber piles? Hardly feasible even in a space age. Then Erickson had an idea. He recalled that dissolved air is always forced out of water during freezing. Ice in a cube tray takes on its white, milky appearance from air bubbles that come out of the water. If freezing can cause bubbles to form in an ice cube, why not in a wood cell? From research literature, Erickson learned that scientists had interrupted capillary action in the New Zealand rattan vine by freezing. The effect might be through bubble formation. At any rate the idea was worth a try in green lumber.

The test was simple. Erickson cut a green redwood board in two and put half of it in a freezer for two days. After it was thawed out, the prefrozen half and the unfrozen half of the board went into a kiln at 220° F. (high by industrial standards) and dried for a day. Results were clear. The unfrozen board came out of the kiln with the depression, collapse, and shrinkage so familiar to lumbermen. The prefrozen board still had a good, almost perfect rectangular shape across the cut end.

Tests on larger amounts of redwood brought similar results. Erickson tried several other species, finding that prefreezing makes a difference in some (such as walnut and incense cedar) and not in others (such as aspen).

It is a rare theory that is accepted once and for all as proven, and the hypotheses about hydrostatic tension and bubbles are far from sacred. Freezing produces a variety of effects, not all of which fit into this theoretical scheme. Yet, to date it provides the best known solution for the collapse problem. And the fact that it led to a potentially rich practical finding attests to its worth.

Aerial Photography

An old idea from military reconnaissance is being borrowed by forester Merle Meyer and plant pathologist David French for detecting diseased trees in forested areas. Infrared color photography from spotter planes is old stuff to experienced air photo interpreters, who know that infrared light waves are reflected by healthy, growing summer foliage, which therefore shows on infrared color transparencies as bright, raspberry red. If the foliage is sick, diseased, or cut (as with some military camouflage) it absorbs infrared rays and appears blue to green on the film. The technique therefore spots unhealthy foliage which the naked eye might fail to distinguish from surrounding vegetation.

Cameramen have flown several areas over the Twin Cities and out-state regions, and the research men are finding telltale results. In black spruce stands, trees infected with dwarf mistletoe stand out as bright green on the infrared transparencies, amid the reddish-colored healthy trees around them. Trees infected with Dutch elm disease and oak wilt have been spotted, including several that had not been found previously by ground detection. A disease such as oak wilt ordinarily affects the uppermost portions of the tree crown first, and who —or what—can see it better than a camera looking down from above?

The infrared technique has other value. Studies in cooperation with USDA pathologists show that it can detect infected plants in crops such as sugar beets and potato fields. It even identified relative moisture in selected areas at Carlos Avery wildlife refuge this summer, suggesting its possible worth as a tool in wildlife management.

There are many questions about the process. Best altitudes need to be worked out; so far, about a mile up seems best. Timing is critical. The technique doesn't work for disease detection in the autumn. Laboratory processing and handling need more study. But the promise of the technique is clear.

These projects provide a partial glimpse of University research dealing with the problems and potential of the forest economy. Apart from research on prescribed burning, aerial photo interpretation, and wood drying, the School conducts projects in broad areas of wood technology and utilization, forest ecology, silviculture, forest physiology, forest recreation, forest hydrology, forest economics and marketing, and forest measurements and sampling.

These research efforts, in all their comprehensive details, add up to better education for the modern forestry profession and to more assurance that Minnesota's forests will contribute to society's needs tomorrow, next year, and in the distant future.

Reproduction Research—Key to the Future

RESEARCH on how creatures reproduce is emerging from the Dark Ages none too soon to help confront some major population problems of the future.

With the disappearance of Victorian-age taboos against reproduction studies, new discoveries are rapidly providing insights into potential population crises limited neither to humans nor to overpopulation alone.

Population control is an idea reaching far beyond the question of whether human numbers should be limited in some or all nations. It applies to all kinds of creatures and to population increase and decrease as well.

India might seek ways to limit the birth of cattle that are protected from slaughter by religious codes. Tanzania, on the other hand, might want more animals that thrive on East Africa grasslands and might therefore wish to accelerate population growth among native animals that can be domesticated for food and profit. Right here at home the problem of increasing numbers of more efficient milk and meat producing animals is far from solved.

These are some of the problems to which research in the University's Department of Animal Science is being addressed. Among the recent findings from reproduction research in that department are these:

- Successful transplantation of a fertilized egg from one cow to another.
- Refinement of methods for storing semen.
- Identification of plasma proteins that coat the sperm cell during ejaculation and which must be removed or altered before the sperm can fertilize an egg. Identification of this mechanism suggests another approach to birth control; anything that interferes with removal of this coating might inhibit fertilization and thereby serve as a population control measure.
- Investigation of ways to predict high and low fertility in a species.

The research behind these developments is another illustration of the need for fundamental knowledge, in this case basic knowledge of the biological and chemical factors involved.

Predicting fertility

To approach population control sensibly, you must know the extent to which certain kinds of creatures will reproduce, even if everything outside of the animal favors reproduction. Then you might be able to analyze a sample of semen, blood, or uterine fluid and predict high or low fertility for specific matings.

University scientists have analyzed semen from about 1,000 different bulls, measuring volume, percent motility, cell concentration, concentration of chlorides, phosphate, calcium, sugars, sodium, potassium, alkaline and acid phosphatase, and about 25 different nitrogenous compounds, including all the amino acids.

They correlated these measurements with fertilizing capacity and found some definite trends. Higher phosphatase and potassium and lower calcium content tended to be related to higher fertility in bull semen. One particular amino acid is highly correlated with fertility among turkeys.

This, then, is solid evidence that semen chemistry may help predict fertility, recognizing that the related characteristics may vary with different animals. The same characteristics are now being studied in uterine fluids from females. Thus, scientists are trying to learn about the environment of newly fertilized eggs and perhaps designate factors that influence the egg's life between conception and birth.

These studies are invaluable to the ova transplant experiments. Scientists must know precisely the environment in the uterine tract, so they know what the egg came from and what it must go back into in a transplantation situation.

Coating on the Sperm Cell

Necessary to reproduction, of course, is union of sperm and egg to form a zygote, or fertilized egg. Under the microscope, sperm cells are readily seen swimming around. This activity, or mobility, is one index of potency. But closer inspection showed something else. As Professor Alan G. Hunter explains it, each sperm cell has some strange chemicals on it, one of the most interesting being a glycoprotein that coats the sperm cell like a gelatinous glove.

Before the sperm cell can join with the female gamete, this coating on the sperm cell must be altered in some way. Stop or inhibit that alteration and you have a potential mechanism for birth control.

Is this coating universal among different species? Professor Hunter has found that it occurs among rabbits, bovines, human beings, sheep, and bats.

Normally, this glycoprotein is altered within the uterus, which digests the carbohydrate part of this coating and thereby changes its chemical form so that fertilization can take place. Studies are now under way to learn how this alteration can be interfered with by some practical means.

Refined knowledge of this coating is leading to some scientific speculation about its possible role in other reproduction problems. Take the problem of female sterility, for example. Females of many species can become literally immune to male sperm; under some conditions female egg and sperm simply will not join. Is the glycoprotein coating somehow involved in such immunity? Are there physiological conditions in the female reproductive tract that may somehow interfere with alteration of that coating? Such questions do not have immediate answers but they are promising leads to an age-old problem of reproductive capacity.

Reproduction Research in Cattle

Although artificial insemination may be one of the major breakthroughs of our time in animal reproduction, the methods and accompanying technology have needed improvement in recent years. Technicians in artificial breeding vary widely in nonreturn rates achieved among cattle, or success in conception at first service.

Professor E. F. Graham has worked out a variety of techniques for training technicians to deposit semen at a specific site in the uterus. The training involved using a dye instead of semen in practice sessions with organs removed from slaughtered cattle. The dye location could be checked and the technician's methods could then be modified if necessary. Training by the dye technique led to marked improvement in nonreturn rates among technicians.

Any extensive research leads to development of new procedures that may accelerate the progress of study itself and perhaps have practical implications later on. These studies are no exception. In studying the chemical environment of the uterus in cattle it was originally necessary to remove the organ from a slaughtered animal and then take out the fluids for study.

Could fluids be removed from a live animal without injury? M. L. Fahning, R. H. Schultz, and E. F. Graham worked out such a procedure. They developed a series of pipettes and related equipment that make it possible to withdraw samples of uterine fluid at various stages of estrus without harming the donor cow. This technique made possible a quick and much less expensive way to study the intrauterine environment—where the fertilized egg grows into a full-term fetus.

Ovum Transplant Studies

Nearly a decade ago the University of Minnesota was one of the first places where scientists successfully transferred a fertilized egg from a donor cow to another, an "incubator" cow. The procedure is far from ready for everyday use, but is becoming better understood. If the day of practical ovum transplantation should arrive, many calves from a good donor cow could be raised a year. Farmers could better maintain good cow families in their herds.

Problems in ovum transplantation were formidable. Donor cows must be superovulated, or induced to shed more than one egg. This hurdle was solved with hormones. Donor and recipient cow must be synchronized in their estrus, or heat periods. If the transplanted ovum is to survive, it must go into a uterus environment that as nearly as possible approximates the one from which it came. Here another hormone (progesterone) was the answer; progesterone treatments will prevent estrus in both donor and recipient cow. Remove the treatment, and within a predictable period of time each cow comes in heat. Next was the problem of recovery of the ovum. In the early studies, it was necessary to slaughter the donor cow and flush the reproductive tract to recover the fertilized egg. Transfer to the incubator cow was done by surgery. The first success was a normal pregnancy, following transplantation, that resulted in the full term birth of a 98-pound bull calf.

Sperm Preservation

One of the great advances in the practical aspects of reproduction, on the male side, is in sperm cell preservation. Before the use of frozen semen, about 80 percent of the sperm cells produced by a sire were thrown away. They couldn't be preserved long enough to be used in the field.

Again, Dr. Graham and his colleagues studied the semen environment to improve methods of preservation. They found that for one thing, amino acids are important. The higher the amino acid content, the higher the fertility. These studies led to development of extenders for semen, one of which is now used in Minnesota, other states, and around the world to increase cattle breeding efficiency.

A later advance was the development of techniques for freezing semen without use of glycerol, an essential part of earlier freezing processes. Semen placed in a special buffer can now be frozen in drop form on dry ice. Frozen droplets are then put in liquid nitrogen and stored until used.

With the new developments in reproduction physiology, even a science fiction writer might have trouble out-imagining possibilities for the future. If semen can be frozen, why not a whole zygote—a fertilized egg ready for incubation in a donor female when needed? Temperatures in outer space may be some 400 degrees below zero Fahrenheit. Might frozen zygotes be spun into outer orbit and recalled when earthly populations require them? The mind boggles in fantasy, perhaps, but the ideas should not be discounted. With scientists now writing 21,000 journal articles per year in reproduction physiology, the sheer volume of new findings may be without limits.

Bacteria and Experimental Animals Aid Nutrition Research

HUMBLE LITTLE BACTERIA and experimental animals are helping research specialists at the University of Minnesota deal with two important nutritional questions of our time.

One question: Is protein makeup linked to development of body fat—and if so, how and to what extent?

Another: How are birth deformities traceable to nutritional deficiences, particularly vitamins?

Both are open questions, lacking in specific answers but surrounded by a rapidly growing body of background information. Both are subjected to research by a diverse group of scientists, among them research specialists in the University's School of Home Economics.

The questions are national and international in their scope. Protein deficiency is a problem in many underdeveloped nations. Science has established that poor quality protein in a person's diet may cause him to lose body fat and may, in fact, lead to starvation. He may suffer not from a low amount of food but from a lack of enough of the right kind.

Birth deformities are not restricted by national boundaries. They occur around the world and in tragic numbers. In the United States during the past year, about 250,000 live human births involved some type of physical deformity.

Amino Acids and Lipids

As part of a regional project, nutritionists Robert Sirny, Lura Morse, and Margaret Doyle are conducting studies with bacteria and laboratory animals, gathering new information about the way amino acids fit together in body nutrition. They are using bacteria that need the same amino acids as man. For their experimental work bacteria provide more easily observed results for preliminary studies on amino acid balance.

The idea of amino acid balance is something like this: An animal or other organism may need, say, 8-10 amino acids (of the 20 found in proteins) in certain proportions for normal growth and development. There may be a need for a certain proportion of one amino acid, such as leucine, relative to proportions of two others closely related, such as isoleucine and valine. What has intrigued nutritionists for years is that too much of two of these amino acids may lead to poor use—and therefore, what amounts to a deficiency—of the third. The first two in excess amounts act as metabolic antagonists of the other.

These functional deficiencies in amino acids are not restricted to the laboratory; they might contribute to major nutritional catastrophies among growing populations. The world has had, and still has, a scarcity of protein, and people in many lands consume proteins with amino acids imbalanced to various degrees. Although the primary imbalance is outright deficiency (as with lysine among persons depending heavily upon corn in diets) deficiencies traceable to other kinds of imbalances are also quite likely.

Furthermore, there is the question of whether imbalances lead to simple starvation, or whether they may trigger other problems such as unhealthy deposit of body fat. Although the research has a long way to go, Sirny and his co-workers have found that differences in amino acid balances in laboratory rats lead to differences in lipids or fat components in the blood serum and tissues of the animals. It is possible, he says, that rats eat less of the imbalanced than the balanced diet, but more factors are probably involved and need to be identified.

Nutrition and Birth Defects

Although deformity at birth is no longer blamed on evil spiritual powers or fright during pregnancy, the causes of birth defects still are not completely known.

One strong possibility is vitamin shortage in the mother's diet, and this possibility is being studied carefully with experimental animals at the University of Minnesota.

Of all babies born in Minnesota this year, at least 1 in 100 will have some physical deformity at birth. There may be several causes; the possible effect of drugs was highlighted by the disastrous use of the tranquilizer thalidomide a few years ago. Deformed children were born to thousands of European mothers who had used this tranquilizer during pregnancy.

Another major factor may be the mother's diet during pregnancy. Ever since a dramatic nutritional discovery in experimental animals more than three decades ago, scientists have known that a shortage of vitamins can lead to severe congenital abnormalities. The discovery was by a scientist named Hale, who found deformed piglets in litters from dams whose diets were short in vitamin A.

In following years scientists studied a variety of vitamin deficiencies, finding that some led to birth defects in experimental animals and some didn't. But unanswered in the research world, so far, is the *way* such a deficiency can lead to deformed limbs and other body defects.

Professor Lura M. Morse and her colleagues in the School of Home Economics are conducting a series of experiments on folic acid deficiency in laboratory animals, to help identify this mechanism of vitamin deficiency.

What might this mechanism involve? Professor Morse and her colleagues are studying whether folic acid deficiency may result in a failure of replication of DNA and RNA and, therefore, the process by which proteins are put together. Perhaps, they are reasoning, failure of a limb to grow properly might result from a failure of normal protein synthesis, which might trace back to a defect in DNA or RNA synthesis, arising from a vitamin deficiency.

Past research has shown that coenzymes of folic acid catalyze, or bring about, the synthesis of the purine and pyrimidine bases which are necessary for construction of DNA and RNA. DNA (for deoxyribonucleic acid) is the carrier of genetic information in chromosomes and is often likened to an alphabet, or template, for protein synthesis.

Professor Morse's work is with experimental animals, principally laboratory rats, and, necessarily, one of the main concerns is the technique for experimentally creating folic acid deficiency.

On the surface, it might seem best to simply feed the animals a diet void of folic acid throughout pregnancy. But this procedure wouldn't tell at what point in pregnancy the problem develops, and it would take a great amount of research time.

An easier technique, and used in the Minnesota studies, is to inject the pregnant animal with a vitamin antagonist—a substance that inhibits the utilization of the vitamin and thus creates deficiency.

It has been clear to scientists for some time that deformity effects are most pronounced when the deficiency occurs during critical periods of pregnancy. In the laboratory rat having a total gestation period of 22 days the critical period is between the 9th and 15th day after conception. This critical period is when the organ systems, including the limbs of the fetus, are forming. The specific time during this period when folic acid deficiency is created can determine the extent and nature of the deformity at birth later on.

The initial studies seem to support Professor Morse's hypothesis. When female rats were injected with the antagonist on the 10th day of pregnancy, the young rats showed evidence of deformity. Furthermore, important to the theory, there was a depression in DNA synthesis in the fetal tissues.

The precise nature of the effects varies somewhat with the type of chemical antagonist used, and thus much of the research is based upon refining the experimental technique. One antagonist used is a substance known as Daraprim, otherwise used as a drug for prevention and treatment of malaria. This drug, although it has these obvious experimental advantages in laboratory research, is not known to cause birth defects in human beings.

The next step in the research is systematic study of the early embryos. To date, the studies have involved injections during the critical period and examination of fetuses near the time of normal birth. There is a hint from early studies that a folic acid deficiency created by a single Daraprim injection lasts only about 72 hours. If this is the case, it would mean that improper protein synthesis when limb buds are forming might be critical. Even if proteins are built normally by the body later on in pregnancy, it may be too late: the damage will have been done.

Major Floods and Agriculture

Philip W. Manson

RECORDBREAKING FLOODS on the Mississippi River in 1965 caused much discussion as to why floods occur. Some of the more irrational flood remarks imply that the farmer is solely responsible for all major floods because he does not use adequate or proper water conservation practices. Yet flow records from Minnesota rivers indicate that recent floods are of no greater magnitude or frequency on outlet rivers from large watersheds than they were in the past.

As more streamflow data is accumulated new extreme flow records will become available. Floodflow on the Upper Mississippi River in 1965 had an estimated frequency of occurence of about 1 in 100 or more years.

Losses from floods are much greater today than they were in the past. Pressures from industry, homeowners, and agriculture, have increased to the extent that flood plains earlier shunned as unsuitable for development are occupied. *One of the main problems is not that there has been a change in the flood pattern, but that there has been a development of these hazardous natural flood plains.* More adequate zoning regulations are needed to minimize future flood damages.

Former Dean Athelstan Spilhaus of the University's Institute of Technology contends it isn't a matter of the waters encroaching on the cities, but of the cities spreading into the natural flood plains faster than engineers can plan and build dikes and levees.[1] Dean Spilhaus, like many others, also proposed "that the natural flood plains be reserved for purposes other than industrial sites and residential areas from which people and property have to be removed when rivers overflow from the spring snow melt and rains." He suggested ". . . that these natural flood plains be used as parks or for other development that would not suffer unduly from occasional flooding, or for such building as would not be damaged or lost in floods."

Frequency and magnitude of flooding on Minnesota rivers

Period	Mississippi River at St. Paul, floodflow exceeded 56,200 cu. ft./second		Minnesota River at Mankato, floodflow exceeded 19,500 cu. ft./second		Red River at Grand Forks, floodflow exceeded 26,600 cu. ft./second	
	Time period	No. of floods	Time period	No. of floods	Time period	No. of floods
Number of years when floodflow exceeded amounts above						
First half period	1867-1915	12*	1881-1922	12*	1882-1923	15*
Second half period	1916-1965	8	1923-1965	11	1924-1965	11
Number of years when floodflow exceeded amounts above 50 percent						
First half period	1867-1915	4*	1881-1922	2	1882-1923	3*
Second half period	1916-1965	3	1923-1965	3*	1924-1965	2
Average yearly floodflow in cu. ft./second as calculated for the two periods						
First half period	1867-1915	74,800	1881-1922	35,200	1882-1923	34,700*
Second half period	1916-1965	90,700*	1923-1965	38,000*	1924-1965	33,300

* Indicates periods with the greatest flood frequency, greatest magnitude floods, or the largest average yearly floodflow. Data from U.S. Geological Survey records.

The farmer can control to a large degree the damage that results from soil erosion by following the recommended practices of the U.S. Soil Conservation Service and the agricultural experiment stations. In the past quarter century tremendous strides have been made in the science to better manage water in agricultural areas through the "watershed approach." Well-planned watershed projects in Minnesota have provided excellent flood protection to small local areas through the installation of detention reservoirs and through the soil and water conservation practices usually recommended.

Many examples could be cited to show that the occurrence of floods on outlet streams from large watersheds has not changed through the years. The table provides a close-to-home illustration.

For comparison, data showing the frequency and the magnitude of flooding for the Mississippi River, the Minnesota River, and the Red River of the North is summarized separately for the first half and the second half of the period.

Data in the table show that the Mississippi River, the Minnesota River, and the Red River all had a greater flood frequency during the first half of the period.

The Mississippi River and the Red River had more "great" floods during the first half of the period. The Minnesota River showed more "great" floods during the second half of the period. The average yearly floodflow for the Mississippi and Minnesota was greatest during the second half of the period. For the Red River the average yearly floodflow was greatest for the first half of the period.

None of the data indicate significant trends. Long-time records would tend to equalize all values.

It can be quite definitely stated that floods as occurred in the spring of 1965 on the major rivers in Minnesota are not the result of man's making. They are a result of nature's work as culminating from an unusual combination of many weather conditions, such as wet fall, a soil of high moisture content, a deep soil freeze, continuous cold weather with limited winter thaw, an ice-sheet cover over much of the ground surface, a high accumulation of snow, or a late spring thaw accompanied by heavy rains. Maximum floodflows are realized at specific points when the peak flows from many small streams collect at one location in the main stream at the same time.

It can be concluded that the frequency and the size of floods as occur on large outlet streams from large watersheds have not been materially altered by modern farming practices.

Philip W. Manson is a professor in the Department of Agricultural Engineering.

[1] St. Paul Dispatch, April 19, 1965.

RARE NATIVE TREES OF MINNESOTA

Albert G. Johnson and Scott S. Pauley

MINNESOTA has long since lost its role as a frontier state in terms of settlement by human immigrants. But in a botanical sense, it remains a western frontier for many eastern plant species and the southern or southwestern outpost for several species predominantly Canadian.

Minnesota's frontier role in the migration of plant species probably is due chiefly to its mid-latitude and mid-longitude location in the north temperate zone, coupled with the post-glacial climatic changes in east-central North America. The important ecological result in Minnesota was the development of two principal plant formations: the tall grass prairie and the forest. These diverse plant formations interlock in a roughly diagonal course from the northwest boundaries with North Dakota and Manitoba to the southeast boundary with Iowa (figure 1).

Consequently, Minnesota represents both the western or northwestern outpost in the native range of many tree species of the eastern United States and the southern or southwestern limit in the native range of several northern species. Of the 46 major North American tree species native in Minnesota no less than 38 (83 percent) have a portion of their natural range boundary in the state (3).

But as you might expect, some of Minnesota's claimed native tree species are extremely rare, some may even be extinct. Still others occupy a native range restricted to southeastern Minnesota.

Of related botanical interest is the presence of relic populations of certain northern conifers in the southern part of the state and the sporadic occurrence of certain native hybrids between native species or with related exotics that have been introduced. This article summarizes what is presently known of the local distribution of these rare native tree species and natural hybrids.

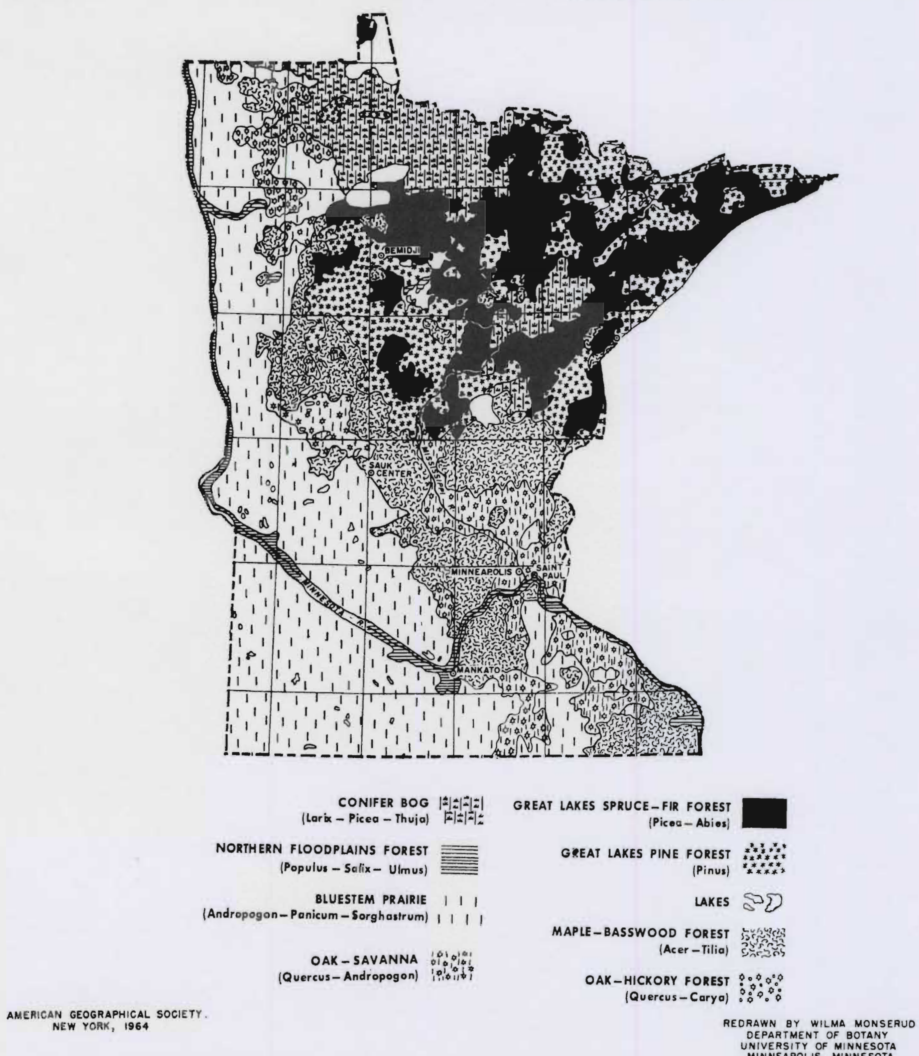


Figure 1. Vegetational map of Minnesota showing forest-prairie border. Map was originally prepared by A. W. Küchler, University of Kansas, Lawrence, Kansas.

RARE OR EXTINCT SPECIES*

Red Mulberry

Red mulberry (*Morus rubra* L.) is a small tree now of doubtful natural occurrence in southeastern Minnesota. The long-acuminate (tapering) tips of the rough leaves distinguish it from the commonly planted and often escaped Tartarian mulberry (*M. alba tatarica* Ser.), which has smooth shiny leaves the tips of which are abruptly sharp pointed. In both species great variability in lobing is likely to occur. Red mulberry has been reported only from the extreme southeastern corner of Houston County where it is probably now extinct. Some cultivated varieties of this species are planted for their fruit, and spontaneous seedlings descended from such plantings are frequently reported.

Honeylocust

The status of honeylocust (*Gleditsia triacanthos* L.) as a native species in Minnesota is based upon one collection made by Professor W. A. Wheeler in Houston County in 1899. He found a single tree on an island in the Mississippi River in an area now flooded by a navigational dam. In spite of its probable extinction as a native, honeylocust is widely planted as an ornamental and is now common in towns and around residences throughout much of the state, especially the named thornless horticultural varieties.

Chinkapin Oak

One of the more unusual trees of Minnesota is the chinkapin oak (*Quercus*

Albert G. Johnson is a research fellow in the department of Horticultural Science, and Scott S. Pauley is a professor in the School of Forestry.

* Another rare or more probably extinct native tree of Minnesota is the Sassafras (*Sassafras albidum* (Nutt.) Nees). Two detached leaves were collected by Mr. Matt Saari of the Minnesota Conservation Department and are in the University Herbarium. The leaves were obtained in August 1939 from a tree growing on an eroding bank in Quincy Township, Olmsted County (Sec 2 or 11 T107N R11W) in what is now part of the Hardwood Memorial State Forest. Recent unsuccessful efforts to find this tree indicate that the site has probably been destroyed by continued bank erosion.

muehlenbergii Engelm.), sometimes called yellow or chestnut oak. This tree has been found but once within the state. Profesor W. A. Wheeler of the University of Minnesota collected specimens of the the species in July 1899 on a rocky slope in Section 19, Crooked Creek Township, Houston County. Because this oak has neither been found elsewhere in the state nor the original trees observed again, Wheeler's record of this discovery is of some historical interest. His field notes read as follows:

"July 15, 1899.
2 trees ¾ mile N.W. from Freeburg on E. side of road going N.W. up tributary of C. Cr.[1] valley:

No. 1

Height 9 feet
Circum 1 ft. from gr. 8½ in.
Circum 3 ft. from gr. 7 in.
Spread 6 feet.

No. 2

Height 10 feet
Circum 1 ft. from gr. 8½ in.
Circum 3 ft. from gr. 7½ in.
Spread 7 feet

Descrip.: Bark dark gray peeling off on branches and trunk.
Twigs small, gray, very finely branched, not coarse like Bur Oak.

Further notes taken July 17 . . .
Tree apparently shrubby as there are numerous sprouts at base which cattle have browsed off. Sprouts very much from the trunk. Trunk crooked. Acorns smaller than Bur Oak at this season. Branches spreading. Leaves somewhat shining above, pale tomentose beneath, coarsely toothed; sinuses larger toward base of leaf, 3 to 6 inches long, 1¼ to 2½ inches broad. Petioles slender but rigid, 4″ to 12″.[2]

A recent search for remnants of Wheeler's chinkapin oaks was unproductive, and the species is quite probably extinct in Minnesota.

Striped Maple

Striped maple (*Acer pensylvanicum* L.) is a species of very doubtful occurence in Minnesota. Recurrent rumors have claimed its presence in the North Shore area, but no authenticated specimens are known to exist.

[1] Crooked Creek.

[2] Wheeler here used the current inch mark (″) to indicate the unit of measure termed a "line" which equals 1/12 of an inch.

Due to differences in interpretation and confusion in the nomenclature, this single collection of Wheeler's is the basis for the reported presence of both *Quercus muehlenbergii* Engelm. and *Q prinoides* Willd. in Minnesota. Wheeler's specimens, of which three are on deposit in the University of Minnesota herbarium (U. of Minn. Nos. 98932, 98933, 225962), originally bore the name *Quercus prinoides* Willd. The determinations were made by Prof. C. S. Sargent of the Arnold Arboretum. These were redetermined by Wm. M. Keith, Jr. as "*Q. prinus* L. subspecies *acuminata* (Michx.) Keith var. *humilis* (Marshall) Keith." This name is here interpreted as synonymous with *Q. muehlenbergii* Engelm. In any event the specimens do not appear to be *Q. prinoides* Willd. as it is presently interpreted, but conform more closely to *Q. muehlenbergii* Engelm (figure 2).

RARE SPECIES—EXTANT

Eastern Hemlock

Among the conifers native to Minnesota, only the range of eastern hemlock (*Tsuga canadensis* (L.) Carr.) is highly restricted. While records indicate a wider occurrence within historic times, probably less than a dozen native trees remain. A few scattered trees are on record from St. Louis County, occuring on the bluffs above Duluth and in the Floodwood-Meadowlands area. A single tree grows along the Ogantz Trail in Jay Cooke State Park, Carlton County. Two trees of the three reported by Roe and Rudolf (4) in Mille Lacs County (figure 3) are alive at present, the third tree has been blown down since their report in 1937. Efforts to track down old reports of eastern hemlock undertaken by Dr. Roland Schoenike and the authors in recent years have been largely unrewarding, as the trees mentioned in these old reports were apparently destroyed during the fires of the early part of this century.

The failure of hemlock to reproduce and maintain itself in the northwestern peripheral areas of its range is not completely understood. In Wisconsin hemlock rarely reproduces successfully under the browsing pressure of high deer populations. There are so few hemlock trees in Minnesota that significant observations on browsing effects cannot be made; however the trees at Mille Lacs are known to produce large quantities of viable seed. Roe and Rudolf reported 2,000 seedlings grown at Badoura State Nursery, but there are no records of where the seedlings went.

More recently seedlings have been grown at the University of Minnesota Landscape Arboretum and by the School of Forestry at the North Central Experiment Station, Grand Rapids. Seed collected from the solitary tree at Jay Cooke Park has been of poor quality, largely insect infested, and of low vitality, probably due to self-pollination.

Figure 2. Specimen of chinkapin oak collected by Prof. W. A. Wheeler in Houston County, Minn., in 1899.

White Ash

White ash (*Fraxinus americana* L.) has had a controversial status as a native tree species of the state of Minnesota. While often listed in botanical and dendrological texts as ranging into eastern or southeastern Minnesota, the University of Minnesota only recently acquired specimens to support its occurence within the state. Rosendahl (5) indicated the species to be infrequent or rare within the southern border of the state. Its presence in Iowa and western Wisconsin (including St. Croix, Polk, Barron, Burnett, and Washburn counties) supported the probability of its occurence within the adjoining counties of Minnesota. On the strength of this assumption Dr. Thomas Morley of the University of Minnesota Botany Department found this ash in July 1966 near Brownsville in Houston County, and also in Winona County. Since then we have found the tree along the St. Croix River in both Chisago and Pine Counties, However, white ash remains of local and relatively infrequent occurrence and is of no commercial importance within the state.

White ash and green ash (*F. pennsylvanica* Marsh.,) are easily confused by anyone unfamiliar with the botanical distinctions between the species. This confusion has led to use of the name white ash for green ash in Minnesota. Green ash is a tree of usually moderate size (up to 60 feet) and relatively slender proportions. Its leaflets are nearly the same color on both upper and lower surfaces. The blades of the leaflets are decurrent (running down) on their stalks making them appear very short stalked.

In white ash a sharp contrast exists between the green upper surface of the leaflet and its whitish underside. The leaflets are rounded to broadly sharp pointed at the base on well-developed wingless stalks.

SPECIES RESTRICTED TO SOUTHEASTERN MINNESOTA

Black Walnut

Black walnut (*Juglans nigra L.*) is a common species in rich wooded areas in the southeastern counties of Minnesota,

Figure 3. Mille Lacs County hemlocks as they appeared when reported by Roe and Rudolph in 1937. Photo courtesy of the U. S. Forest Service.

reaching as far north as the metropolitan area in Dakota and Scott Counties. Southwestward it has been reported as far as Nobles County. Black walnut is frequently planted north of its range as an ornamental tree.

Shagbark Hickory

The Minnesota range of shagbark hickory (*Carya ovata* (Mill.) K. Koch) is limited to the extreme southeastern corner of the state, reaching only as far north as Wabasha County and westward to Freeborn County. Because of its distinctive bark and edible nuts this species is well known within its range.

River Birch

River birch (*Betula nigra* L.) is sometimes called red birch locally because of the lustrous reddish-brown bark on its upper stem and branches. It is a common bottomland tree of the Mississippi River southward from where the Chippewa River joins the Mississippi at the lower end of Lake Pepin. Upstream, to the mouth of the St. Croix River, it is less frequent. One small grove on the St. Croix (in Washington Co., Sec 27 T27N R20W), about 3 miles north of Point Douglas, was discovered by Dr. and Mrs. Knud E. Clausen in 1957. This station represents the most northerly known occurrence of river birch in Minnesota. The species is unique among the birches in that the fruits mature in early summer and germinate immediately on alluvial soils left by receding water in the manner of silver maple, the elms, willows, and cottonwood.

Oaks

Seven species of oak are native to Minnesota and are divided conveniently into two groups: the white oaks characterized by rounded leaf lobes and acorns that mature in a single growing season, and the black oaks with sharp bristle-tipped lobes, and acorns that require two seasons to mature.

The white oak group includes white oak (*Quercus alba* L.), bur oak (*Q. macrocarpa* Michx.), swamp white oak (*Q. bicolor* Willd.), and chinkapin oak (*Q. muehlenbergii* Engelm.). White and bur oak are of wide distribution in the state, bur oak reaching into the extreme northwest area along the Red River Valley. Swamp white oak is limited largely to the major river drainages of the southern part of the state. In the Minnesota River Valley it is known from as far west as Yellow Medicine County and southward from Ramsey and Hennepin Counties along the Mississippi. A sizeable population of this oak still exists in St. Paul in the vicinity of Cretin Avenue south of Summit Avenue. The special status of chinkapin oak was discussed earlier.

Only three members of the black oak group are found in the state. Two, red oak (*Q. rubra* L.), and northern pin oak (*Q. ellipsoidalis* E. J. Hill), known locally also as Hill's oak, jack oak, "scarlet oak," and "black oak," are of general distribution. *Q. velutina* Lamb., commonly called black oak, is found on dry soils in the southeastern corner of the state as far north as Goodhue County. Black oak is readily distinguished from the other two members of the black oak group by yellowish hairs on the lower leaf surfaces and hairy buds. The looser scales of the acorn cups also distinguish this species.

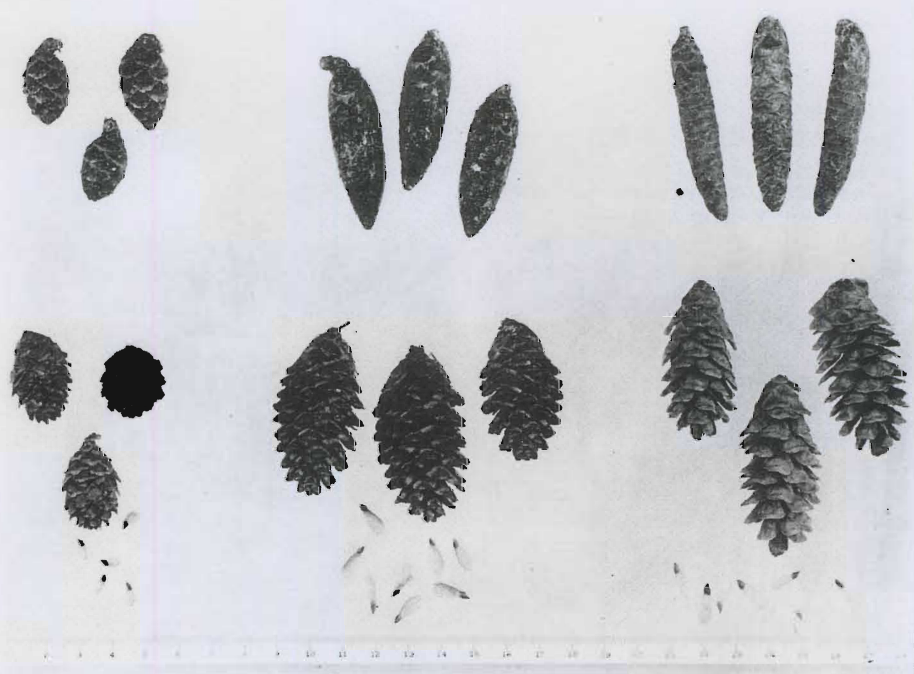


Figure 4. Unopened cones, opened cones, and seeds: Left, black spruce; center, Rosendahl spruce; and right, white spruce about natural size. Scale is in centimeters.

Scarlet oak (*Q. coccinea* Muenchh.) is an eastern and southern ranging species not present in Minnesota. Early references to this species in the state are based upon confusion with the northern pin oak which was not recognized as a separate entity until Hill described it in 1899. The two species are usually separable by the acorn characters; those of the northern pin oak are elongate and striped, while those of scarlet oak are hemispherical, broader, and usually a uniformly, light reddish brown color. Northern pin oak is often alleged to lack the red fall colors of scarlet oak, but while these colors may be somewhat subdued in northern pin oak, red, yellow and orange leaf colors are by no means lacking in the species. The color effect varies somewhat from season to season as it does in the maples, but on the whole the autumn color of our oak savannas is due largely to this species.

Kentucky Coffee Tree

The Kentucky coffee tree (*Gymnocladus dioicus* (L.) K. Koch) follows closely the lower reaches of the Minnesota and Mississippi Rivers in its distribution. It is a rare to uncommon tree found largely in the river bottoms from Brown County down to Houston County. Curtis (1) states that the distribution of this tree in Wisconsin is correlated with former Indian village sites because Indians used the large seeds in a sort of dice game. A similar pattern of distribution may be present in Minnesota.

NORTHERN CONIFERS WITH OUTLIER STANDS IN SOUTHERN MINNESOTA

Balsam Fir

Balsam fir (*Abies balsamea* (L.) Mill.) is a species of wide distribution in the coniferous area of the northeast portion of the state. A remarkable outlier consists of two small groves in Fillmore County northwest of Wykoff. The trees are on a north-facing slope of a deep ravine associated with other plants typical of the coniferous forest of the north. Other small outposts of a similar nature have been reported from Winneshiek and Allamakee Counties in northeast Iowa.

Red Pine

The most southerly natural occurrence of red pine (*Pinus resinosa* Ait.) in Minnesota is a small grove of trees in the Cedar Creek Natural History Area of the University of Minnesota near Bethel, Anoka County. The stand consists of a few trees of an old age class, probably older than 150 years, and a somewhat larger population of trees 60 to 70 years old.

Jack Pine

Jack pine (*Pinus banksiana* Lamb.) ranges throughout the northeastern conifer area coming as far south as the vicinity of Taylors Falls in its principal distribution. Schoenike (6) records three southern outlier stands located in Wabasha, Winona, and Fillmore counties.

Northern White Cedar

Northern white cedar (*Thuja occidentalis* L.) is of general distribution in our northern coniferous forest on moist sites and occasionally on rock outcrops. A southern outpost exists on the limestone rock of Queen's Bluff, Winona County.

NATURAL HYBRIDS

Hybrids resulting from the crossing of allied species are always of interest and occasionally result in plants of ornamental or economic merit. Among some groups of trees such as the oaks, hybrids occur with considerable frequency and many Latin names have been proposed in describing individuals intermediate between the presumed parental species. Considerable natural hybridization also takes place among the poplars, and the genus is also the source of numerous artificial hybrids. Hybrids often display a certain amount of hybrid vigor which is reflected in a rapid growth rate and superior adaptability to certain environmental conditions.

Rosendahl Spruce

A single natural hybrid tree of white spruce (*Picea glauca* (Moench) Voss) and black spruce (*P. mariana* (Mill.) B. S. P.) was discovered near Cromwell (Carlton Co.), Minnesota in 1955 and reported in 1958 (2). A binary Latin name was not assigned, the hybrid being designated by formula: *Picea glauca* X *mariana*. The cromwell hybrid was given the variety (cultivar) name of Rosendahl spruce in honor of Dr. Carl Otto Rosendahl, late professor emeritus, Botany Department, University of Minnesota, in recognition of his many contributions to a better knowledge of the plants of Minnesota.

Rosendahl spruce is of special botanical interest since it is the first reported hybrid between two species that have broad and almost identical ranges from Newfoundland and the northeastern United States across Canada to Alaska. Subsequently a single putative natural hybrid was found in the Tanana Valley of Alaska and two on Minnesota's North Shore.

Rosendahl spruce is readily identifiable if mature cones are available. The dark purple color of the cones resembles black spruce but their size and shape is intermediate between white and black spruce (figure 4). The gross morphological characteristics of the hybrid (branching habit, crown form, etc.) do not make it readily distinguishable from white spruce, suggesting that the hybrid may be more common than is presently suspected.

Poplar Hybrids

Trembling aspen (*Populus tremuloides* Michx.) and bigtooth aspen (*P. grandidentata* Michx.) ordinarily flower at sufficiently different times, about 2 weeks apart, so that hybridization does not readily occur. Occasionally weather conditions or other environmental factors are favorable to crossing and hybrids are produced. Such trees are usually intermediate in leaf characteristics. A large specimen of such hybrid origin growing naturally in the University of Minnesota Landscape Arboretum has bark of a light color, typical of the trembling aspen parent.

The widely cultivated white or silverleaf poplar (*P. alba* L.), native of Europe, is the parent of another hybrid that is found with some frequency. The tree is apparently readily pollinated by bigtooth aspen, and hybrid individuals are reported from many points within the range of our native tree. These hybrid individuals are handsome trees, often of very rapid growth. Occasional hybrids of the white poplar with trembling aspen are also reported.

Birch Hybrids

Two hybrid birches are known to occur in the state. Wherever yellow birch (*Betula allegheniensis* Britt.), or paper birch (*B. papyrifera* Marsh.) come within close proximity to bog birch (*B. pumila* var. glandulifera Regel), hybrids are likely to occur. The hybrid between yellow birch and bog birch has been described under the name of Purpus birch (*B.* X *purpusii* Schneid.) while that involving paper birch is known as Sandberg birch (*B.* X *sandergii* Britton). Both specific names of the hybrids commemorate their discoverers, J. A. Purpus and J. H. Sandberg. The hybrids are large shrubby plants, those involving yellow birch parentage have a marked wintergreen odor in the leaves and twigs, and unstalked fruiting catkins. Sandberg birch lacks the wintergreen odor and its fruits are stalked.

Oak Hybrids

Among the oaks in the vicinity of Cretin Avenue in St. Paul, are some trees that appear to be hybrids between swamp white oak and bur oak. The trees are more or less intermediate between the parental species in both leaf form and fruit characteristics. In the hybrid the long fruit stalk of swamp white oak is shortened and the acorn broadened. This hybrid has been given the name of *Q.* X *schuettei* Trel. after J. H. Schuette who first reported it.

A hybrid occurring occasionally between bur oak and white oak is known under the Latin name of *Q.* X *bebbiana* Schneid. in honor of M. S. Bebb. Rosendahl (5) comments that individuals of this infrequent hybrid in our area appear to be sterile.

Intergrade-individuals suggesting hybridization between red oak and northern pin oak are frequent in some areas. In the Lake Minnetonka region, for instance, it is sometimes difficult to find individuals of red oak that do not show some evidence of mixing. The evidence of such infiltration of genetic materials from northern pin oak is present in the form of unusually rounded leaf sinuses, dark rough bark, or striping of the acorn.

An unusual native oak growing in the University of Minnesota Landscape Arboretum has the stature and leaves of northern pin oak. Its acorns and their cups are characteristic in size and form of those of red oak but have the longitudinal stripes characteristic of northern pin oak.

Elm Hybrids

A not uncommon hybrid in areas where the slippery elm (*Ulmus rubra* Mühl.) occurs is the result of natural crossing with the much cultivated Siberian or Chinese elm (*U. pumila* L.). This hybrid has much the habit of Siberian elm but the leaves are larger, rough, and somewhat oblique in the manner of slippery elm.

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Seed Coat Mottling in Minnesota Soybeans

B. W. Kennedy and R. L. Cooper

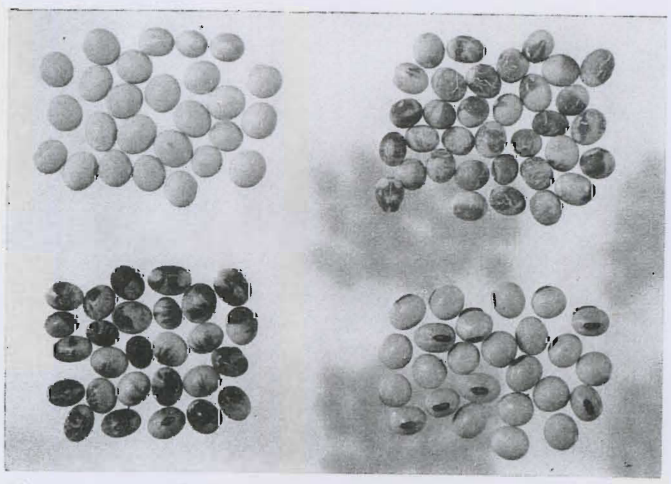
SEED coat mottling of soybeans (figure 1) is a problem to growers, processors, and researchers. If seed lots are heavily mottled (greater than 50 percent of the seed coat colored black, brown, or buff), they receive the U.S. market class of "bicolored soybeans." Such a classification represents a financial loss to growers and processors. Furthermore, our oriental customers object to the undesirable appearance of food and food products made from mottled soybeans. So the demand for such beans, as well as the price, is considerably reduced.

We observed that soybeans grown at the St. Paul Campus mottled heavily every year while seeds grown at Lamberton, some 150 miles southwest of St. Paul, seldom if ever mottled. Some varieties, such as Merit, Hawkeye, and Blackhawk, were completely free of mottling regardless of where they were grown, These facts agreed with observations of other investigators who pointed out genetic and locational influences on mottling.

Planting date apparently influenced the severity of mottling at St. Paul; early planted varieties were more free of the problem than late planted varieties. Late planted varieties also were more severely infected with soybean mosaic virus.

The suggested connection between virus infection and mottling was dampened by the fact that the mottling-resistant variety Merit appeared to be as severely infected by soybean mosaic virus, when artificially inoculated, as the mottling suceptible varieties Chippewa, Harosoy, and Acme. However, greenhouse experiments showed that Merit, although susceptible to the virus, did not transmit the virus to its seeds as did mottling-susceptible varieties. This finding indicated a possible connection between mottling susceptibility and seed transmission of soybean mosaic virus.

Our objective was to establish what relationship existed between virus and mottling. In 1964, we grew mottling-susceptible, virus-free soybean plants in an environment where mottling normally did not occur (Lamberton). We inoculated half these plants with soybean mosaic virus; the other half remained free of mosaic. The results were striking. Plants inoculated with virus gave rise to mottled seeds while the virus-free plants did not (see table 1).



Above: nonmottled and mottled Harosoy (yellow hilum); below, mottled and nonmottled Chippewa (black hilum).

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FINANCIAL STATEMENT MINNESOTA AGRICULTURAL EXPERIMENT STATION RESEARCH FUND EXPENDITURES YEAR ENDED JUNE 30, 1966

Expenditures by Source

	Percent	Amount
Federal Funds	17.1	$1,170,236
State Appropriations	60.7	4,153,037
Gifts and Grants	8.4	570,224
Fees, Sales, Miscellaneous	13.8	944,568
Total	100.0	$6,838,065

Expenditures by Object Classification

	Percent	Amount
Personal Services	63.7	$4,357,969
Travel	1.5	99,063
Equipment, Lands, Structures	8.8	601,064
Supplies and Expense	26.0	1,779,969
Total	100.0	$6,838,065

Expenditures by Location

	Percent	Amount
University Campus—St. Paul	89.3	$6,109,810
Branch Stations—Within Minnesota	10.7	728,255
Total	100.0	$6,838,065

Table 1. Effects of virus infection on seed coat mottling in two soybean varieties, Lamberton 1964

		Number of plants*	
Variety	Treatment	Nonmottled seeds	Mottled seeds
Harosoy	Inoculated	0	18
	Control	18	0
Merit	Inoculated	18	0
	Control	18	0

* Total number of plants from three replications of six plants each.

With the same objective in mind, we used a different approach in 1965 in an environment normally favoring mottling (St. Paul). Virus-free, mottling-susceptible varieties, which normally would become heavily mottled, were kept virus free by placing cages over them. These cages prevented virus-transmitting insects from feeding on the plants during the growing season. We were able to prevent mottling simply by keeping the plants virus free (see table 2).

Therefore, location apparently affects mottling only insofar as it affects virus infection. Furthermore, the amount of natural virus infection undoubtedly depends on the population of insects present and the percentage of them carrying mosaic virus. This finding explains why

Table 2. Seed coat response in mottling-susceptible soybean varieties when caged to prevent natural virus infection at St. Paul

		Number of plants with:*	
Treatment	Variety	Nonmottled seeds	Mottled seeds
Uninoculated:			
Caged	Harosoy	8	1†
	Acme	9	0
Not caged	Harosoy	1	8
	Acme	4	5
Inoculated:			
Caged	Harosoy	0	6
	Acme	0	6
Not caged	Harosoy	0	6
	Acme	0	6

* Total number of plants from three replicates, each containing three plants (uninoculated) and two replicates (inoculated).

† One cage torn, permitting possible insect entry.

plants at St. Paul mottle while those at Lamberton do not—virus-carrying insects are not present at Lamberton but are common at St. Paul.

Mottling is not to be confused with other seedcoat discoloration (see photo, page 31). Virus-induced discoloration apparently results when pigments normally found only in the hilum (seed scar) develop in an irregular pattern over the seedcoats. The color of these irregular streaks is the same as that found in the hilum, with the exception of yellow hilum varieties which have a light-brown or buff mottling. Germination is not affected.

Due to the general interest in producing soybeans free of blemishes, mottling assumes an important relationship to seed quality. The problem can be eliminated by planting resistant varieties or by keeping mottling-susceptible varieties free of mosaic virus. We do not know if other less common viruses can induce mottling. Soybean mosaic generally is found only in a few specific areas in Minnesota; spread within a field probably is due to insect feeding. The relationship of insects to epidemiology of soybean mosaic virus in Minnesota could be a fruitful and interesting study.

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