1984 CORN CONFERENCES

Agricultural Extension Service
University of Minnesota

PROCEEDINGS

CORN CONFERENCES

January 5-6, 1984 - Bloomington
January 10-11, 1984 - Owatonna
January 12-13, 1984 - Montevideo

Presented by the
University of Minnesota
Institute of Agriculture, Forestry and Home Economics
Agricultural Extension Service
Office of Special Programs

In Cooperation With
Minnesota Corn Growers Association

Office of Special Programs Education Series 6-4

Published by
Office of Special Programs
University of Minnesota
405 Coffey Hall
1420 Eckles Avenue
St. Paul, Minnesota 55108

January 5, 1984

The information given in this publication is for educational purposes only. Reference to commercial products or trade names is made with the understanding that no discrimination is intended and no endorsement by the Minnesota Agricultural Extension Service is implied.

Issued in furtherance of cooperative extension work in agriculture and home economics, acts of May 8 and June 30, 1914, in cooperation with the U. S. Department of Agriculture. Norman A. Brown, Director of Agricultural Extension Service, University of Minnesota, St. Paul, Minnesota 55108. The University of Minnesota, including the Agricultural Extension Service, is committed to the policy that all persons shall have equal access to its programs, facilities, and employment without regard to race, creed, color, sex, national origin, or handicap.

TABLE OF CONTENTS

		Page
The Effect of Crop Sequence With Alternative Tillage Systems in Minnesota	John Moncrief	1
Corn Production With Conservation Tillage: Fertilizer Management in the Next Ten Years	George Rehm	8
The Rotation Effect--What Causes It?	R. Kent Crookston	11
Corn Disease Control With Reduced Tillage	Ward C. Stienstra	15
PIK Acres - Weed Control	Richard Behrens	22
Weed Control for Corn and Soybeans in Reduced Tillage Acres	G. R. Miller and J. S. Coultas	23
Weed Control in Corn Under Reduced Tillage	Richard Behrens	25
Saving Energy in Corn Drying	R. Vance Morey and Harold A. Cloud	34
Fertilizing PIK Acres in 1984	George Rehm	40
On-Farm Computing: In 1984 and Towards 1994	Earl I. Fuller	43
Farm Estate Planning	Kenneth H. Thomas	50
Instability, Exports and Corn Markets: Some Policy Alternatives for 1985	Carlisle Ford Runge	58
Fertilizer Placement: Something Old, Something New	George Rehm	70
Nitrification Inhibitors	Gary L. Malzer	77
Trends in Corn Improvement	Jon L. Geadelmann	83
What's New in Corn and Soybean Management	William E. Lueschen	92
The Physiology of Corn Maturity	R. Kent Crookston	96
Minnesota Relative Maturity Rating of Corn Hybrids	R. H. Peterson and D. R. Hicks	102
Water Management in Corn Production	Fred G. Bergsrud, Jerry A. Wright and Darnell R. Lundstrom	104
Grain Shrink Calcaulations	Harold A. Cloud	110
Insect Concerns	Whitney S. Cranshaw	116

THE EFFECT OF CROP SEQUENCE WITH ALTERNATIVE TILLAGE SYSTEMS IN MINNESOTA

John Moncrief, Assistant Professor
and Extension Soil Scientist - Tillage
Soil Science Department
University of Minnesota

INTRODUCTION:

Under circumstances where erosion is a concern, tillage alternatives which leave crop residues on the soil surface are imperative. There are also other benefits of conservation tillage. Conservation of soil moisture can be a valuable benefit on many soils in a large geographic region of the United States. The benefits of economizing time during peak labor demand periods are obvious to farmers. There can also be substantial energy savings associated with less fuel consumption. Conservation tillage does, however, require a higher level of management. Such factors as effective disease, insect, and weed control are possible, but require a planned and informed effort.

DEFINITIONS:

Conservation tillage, as the name implies, is any tillage practice that provides protection from wind and water erosion and conserves soil moisture. Because of the myriad of regional and even local terms describing such practices it becomes necessary to begin any paper with a set of definitions. A useful dichotomous scheme for tillage definition subdivides all primary tillage into the following two major groups: full width and strip tillage. Full width systems include: moldboard and chisel plows, plowing discs, and more recently paraplows. These implements leave the soil in a loose condition after tillage. Soil moisture at the time of tillage is more critical for the latter three. Strip tillage is usually combined with the planting operation and can be further divided into wide and narrow strip tillage. Wide strip tillage usually results in tilling about one third of the row area (8 - 12 inches) and leaves the remainder with little disturbnace and most of the previous year's crop residue. A subsequent cultivation can be used for building ridges. Common forms of this category include: till plant, ridge till, intertill, and rotary tillage. Narrow strip tillage results in a much more narrow tilled strip, usually two to four inches. This is done with rippled or fluted coulters on special planters or drills. Common names for this category include no till, zero till, and slot plant. Strip tillage results in more dense soil in zones where there is no tillage.

Conservation Tillage (adequate soil cover after planting)

I. Full Width (usually followed by secondary tillage before planting)
   - A. Chisel
   - B. Disc
   - C. Paraplow

II. Strip (special planters and cultivators)
   - A. Wide
     1. Ridge — Tillplant
     2. Flat — Tillplant
     3. Rotary or Intertill
   - B. Narrow - No Till, Zero till, or slot plant.

IMPORTANCE OF CROP SEQUENCE:

Corn grown after corn requires the highest level of management with extreme reductions tillage (strip tillage). Rotations with other crops allow greater flexibility for herbicide selection. A rotation with a low residue crop (soybeans, potatoes, sunflowers, etc.) would result in preventing excessive trash accumulation and reduced temperature effects on corn. (Corn is sensitive to soil temperature.) Rotation is a valuable tool in managing crop residues for erosion control (optimum soil cover) with little or no tillage. The effect of rotation and tillage on corn yields is shown in table 1. Corn grown after legumes or low residue crops with no tillage generally yield as well as under more intense forms of tillage.

TABLE 1. The effect of tillage and rotation on corn grain yields at Becker, MN - 1982 (Moncrief, Malzer, and True)

	TILLAGE		
	Strip	Full Width	
	Narrow (no till)	Chisel	Moldboard
Rotation	bu/A		
Cont. corn	110	150	144
Corn, soybean	177	-	-
Corn, potatoes	148	153	133
Oats, alfalfa potatoes, corn	175	-	-

All plots received 75 lbs/A of N as anhydrous ammonia spring preplant.

The effect of crop sequence and tillage on yields (with irrigation) is illustrated wtih table 2 and 3. When corn is grown after soybeans there appears to be some benefit to cleaning a strip over the row (table 2). Yields are similar with all tillage treatments except narrow strip (no till). This effect is not present when growing soybeans after corn (table 3).

This is also supported by research at Waseca, Minnesota (table 4). Weed control was more difficult without tillage, however. An interesting aspect of the study is the compensation by the soybean plants to minimize the impact of the soil physical properties imposed by the lack of tillage. Other research has shown a reduction in N availability with corn presumably due to less organic matter release and increased losses. Since the bacteria that reside in soybean nodules are responsible for most of the N that the plant receives and are sensitive to temperature and aeration, one might expect a reduction in availability with soybeans also. This was not the case, however (table 5). The spacial distribution of the nodule mass and total amount present effectively compensated for lower temperatures and aeration without tillage (table 6). Soybeans grown without tillage positioned their nodules at a more shallow depth (warmer and better aerated) and essentially doubled the total nodue mass Even if the bacteria fixing N in the nodules were one half as active as those with moldboard tillage there would be the same net N fixed.

Continous corn does not appear to yield as well without tillage at the Becker (table 7) and Waseca (data not shown) sites (loamy sand under irrigation and clay loam respectively). Data from Goodhue county on a well drained silt loam show no difference in grain yields due to tillage (data not shown). It may be that temperature exerts a stronger influence at the Becker and Waseca sites. Grain moisture at harvest at the Becker site is shown in table 8 for two crop sequences. Corn grown without tillage after potatoes is really a misnomer since digging potatoes requires considerable tillage. In this rotation there would be little soil cover and probably little difference in temperature due to tillage. This is reflected in the grain moisture which can reflect maturity. The only value that stands out is for corn grown after corn without tillage.

The grain yields are shown in table 9 for corn grown after potatoes. In 1979 hail caused a stand reduction that reduced the yields with the strip tillage systems. (They had lower populations to begin with.) When stand was not a problem (1981) there was no difference in yield due to tillage of corn grown after potatoes. The other side of this rotation is illustrated in table 10. There was a reduction in potato yields with strip tillage. This was shown to be due to more dense soil with these systems (data not shown here). Potatoes are very sensitive to soil density. Based on these data full width tillage would appear to be better for potatoes.

SUMMARY:

1. Corn grown after corn appears to do best if wide strip tillage or full width tillage is used on the central sands and south central till soils. On the well drained silt loam soils of the river counties, narrow strip tillage appears to have potential.

2. Corn grown after potatoes showed no difference in yield due to tillage.

3. Potatoes grown after corn required full width tillage.

4. Soybeans grown after corn were not affected by tillage.

5. Corn grown after soybeans at the Becker site appeared to do best if wide strip or full width tillage was used. Other Minnesota data (Waseca, Lamberton, and Morris) show no difference in yields due to tillage.

TABLE 2: The effect of tillage on corn yields following soybeans at Becker, MN (Schuler and Bauder, 1978-80; Moncrief, Malzer and True 1982-83, unpublished data)

	TILLAGE			
	Full Width		Strip	
Year	Moldboard	Chisel	Wide (ridge)	Narrow (no till)
1978	86	89	94	76
1980	157	168	169	153
1982	138	136	-	129
1983	146	140	-	129
Avg.	132	133	132	122

TABLE 3: The effect of tillage on soybean yields following corn at Becker, MN (Schuler and Bauder 1977 - 81; Moncrief, Malzer and True, 1982 - 83, unpublished data).

	TILLAGE			
	Full Width		Strip	
Year	Moldboard	Chisel	Wide (ridge)	Narrow (no till)
1977	53	52	57	53
1979*	37	41	38	38
1981	50	45	47	44
1982	52	49	53	51
1983	48	47	43	45
AVG.	48	47	48	46

* Hail damage occured in 1979.

TABLE 4: The effect of tillage on soybean yields following corn, Waseca, MN (Randall).*

TILLAGE	1980	1981	AVERAGE
	bu/A		
Moldboard	50	56	53
Chisel	46	57	52
Spring disc	50	56	53
Fall and Spr. disc	50	56	53
No till	49	56	53

* Weed control was maintained by hand weeding in 1980.

TABLE 5: Soybean seed nitrogen concentration following corn as affected by tillage, Waseca MN (Randall).

TILLAGE	1980	1981	AVERAGE
	%		
Moldboard	6.19	5.91	6.05
Chisel	6.13	5.82	5.98
Spring disc	6.15	5.85	6.00
Fall & Spr. disc	6.17	5.77	5.97
No Till	6.14	5.80	5.97

TABLE 6: The effect of tillage on soybean root distribution - July 22, 1981, Waseca, MN (Carter, et al)

Depth (in)		TILLAGE No till	Moldboard
		mg/cm^3	
0 - 3		52.8	20.8
3 - 6		.9	3.4
6 - 12		.2	.1
	TOTAL	53.9	24.3

TABLE 7: The effect of tillage on corn yields following corn at Becker, MN (Schuler and Bauder unpublished data).

	TILLAGE			
	Full Width		Strip	
Year	Moldboard	Chisel	Wide (ridge)	Narrow (no till)
1977	133	137	126	131
1978	85	88	86	81
1979*	97	87	81	70
1980	153	160	159	148
1981	117	110	114	95
Avg.	122	124	121	114

* In 1979 hail damage occurred and is omitted from means.

TABLE 8: The effect of tillage on grain moisture at Becker, MN 1981 (Schuler and Bauder unpublished data).

	TILLAGE			
	Full Width		Strip	
Crop Sequence	Moldboard	Chisel	Wide (ridge)	Narrow (no till)
Cont. corn	22.4	22.8	19.8	24.3
Corn - Potato	22.8	21.3	20.5	21.6

TABLE 9: The effect of tillage on corn yields following potatoes at Becker, MN (Schuler and Bauder unpublished data)

	TILLAGE			
	Full Width		Strip	
Year	Moldboard	Chisel	Wide (ridge)	Narrow (no till)
1979*	107	102	91	88
1981	122	127	114	121

* Hail damage occurred in 1979

TABLE 10: The effect of tillage on potato yields following corn at Becker, MN (Schuler and Bauder unpublished data)

	TILLAGE			
	Full Width		Strip	
Year	Moldboard	Chisel	Wide (ridge)	Narrow (no till)
1978	424	387	391	370
1980	373	393	288	305
Avg.	399	390	340	338

CORN PRODUCTION WITH CONSERVATION TILLAGE: FERTILIZER MANAGEMENT IN THE NEXT TEN YEARS

George Rehm
Ext. Soil Scientist - Soil Fertility
Dept. of Soil Science
University of Minnesota

The dramatic increase in the popularity of conservation tillage systems for corn production in Minnesota has dictated that we make some changes in our thinking about management inputs for corn production. The management of fertilizers is no exception--changes in fertilizer management will be needed as we move to conservation tillage systems for corn production.

In recent years, considerable research has been initiated to define changes that will be needed in fertilizer management. To date, the results have not been conclusive. So, firm recommendations are not yet in hand. Nevertheless, we can speculate about the changes that will be needed and some ideas for these changes are described in the following sections.

NITROGEN MANAGEMENT

N Rates

There will be changes in the soil environment as we move to conservation tillage planting systems and these changes will affect the way in which nitrogen fertilizers are managed. Residue on the soil surface and very little soil disturbance lead to cooler soil temperatures in the early part of the growing season. With lower temperatures, less nitrogen is released from the soil organic matter. This means that higher rates of fertilizer N will be needed. Currently, research is being conducted to determine the amount of added fertilizer N that will be needed. The information collected to date suggests that N rates will need to be increased by 20% for ridge-till systems and 40% for no-till systems in a continuous corn cropping system. This percentage may be adjusted especially in a corn-soybean rotation.

N Source

Conservation tillage planting systems may also change the selection of the nitrogen fertilizer that is used. The probability of N loss from urea applied to the soil surface without incorporation is high--especially where the soil pH is high. Therefore, urea or fertilizers containing urea should not be considered as a N source for no-till planting systems. For ridge-till systems, urea can be applied just prior to planting in view of that fact that the ridge-till planting operation will provide some incorporation. Flexibility in using urea will be greater where conservation tillage systems involving some primary tillage operations are used.

Anhydrous ammonia and urea - ammonium nitrate (28-0-0 knifed in) have been compared for corn production in conservation tillage systems in several studies. The results suggest that both sources are equally effective if the 28-0-0 is not applied on the soil surface. The choice between these two sources will depend on the price of the fertilizer, availability of equipment and other factors.

Nitrification Inhibitors

The movement to conservation tillage planting systems may also place more emphasis on decisions relating to the use of nitrification inhibitors. Soil texture should be a major consideration in the decisions regarding the use of these inhibitors.

Potential for loss of nitrate-nitrogen (NO_3-N) due to leaching is high on the sandy soils of Minnesota. Nitrogen for corn production on these soils can be applied either before planting or as a side-dress treatment. Nitrification inhibitors are suggested for preplant applications of N on the coarse textured soils. Applications of fertilizer N should be split during the growing season for irrigated corn production on these soils.

The use of nitrification inhibitors may become more important for corn production with conservation tillage systems on the medium and fine textured soils. This is especially true where the potential for N loss due to denitrification is high. The use of these inhibitors may not produce a yield response each year. Since it's not possible to predict the weather, the use of the nitrification inhibitors might be considered as an insurance policy in the future. The use of these inhibitors may play a more important role in high yield management situations.

PHOSPHATE AND POTASH MANAGEMENT

Considerations for management of these two nutrients in the future will be different from considerations used in N management because these nutrients are not mobile in soils. The use of conservation tillage planting systems provides little or no opportunity for fertilizer incorporation. Therefore, the broadcast application may not be the best choice in the future.

The use of starter fertilizers should increase in the future for the conservation tillage planting systems. If the starter is not placed in direct contact with the seed, relatively high rates of fertilizer can be applied in this way. Therefore, most, if not all, of the requirements for phosphate and potash could be satisfied with the use of a starter fertilizer.

Thinking ahead, some have suggested that surface or subsurface bands of phosphate and/or potash fertilizers might replace the broadcast applications for conservation tillage corn production. It is possible that this approach to banding may have a role in corn production in the future--especially for soils which test low in P and/or K. Research has been started to define the role of these new placements. Results gathered to date are not sufficient to provide a basis for recommendations. Many questions regarding efficiency of fertilizer use, band spacing, and time of application remain to be answered.

NEW MIXTURES MAY BE USED

The switch to conservation tillage planting systems will also affect the choice of herbicides and possibly the way that these herbicides are used. This need for change may also stimulate new ideas with respect to fertilizer-herbicide combinations.

It is possible, today, to mix some herbicides with anhydrous ammonia. This new concept might work but the management system for this combination needs to be refined.

The combination of herbicides with liquid N sources applied after planting in a weed-and-feed program has always been a good management practice. Additional fertilizer/herbicide combinations used in other ways may become important in the future.

Other changes in fertilizer management that we cannot predict now will probably take place in the next 10 years. Changes, however, will probably be slow. There are many new ideas that must still be tested and evaluated.

The Rotation Effect--What Causes It?

R. Kent Crookston
Professor, Dept of Agronomy and Plant Genetics

The positive effect of rotation on crop yields has been recognized and exploited for centuries. In our recent past (1950-1975) the yield benefits of rotations were overlooked and almost forgotten by many farmers however, as it appeared that chemical fertilizers, herbicides, and insecticides could be used as a substitute for rotation. Research evidence then began mounting in the 1970's which indicated that in spite of all the management inputs a farmer might impose, there was still a yield advantage to be obtained from rotations. A recent U.S. study reported the yield advantage to corn from rotating with some other crop to be at least 10%. Minnesota research suggests that soybean yields are also improved by 10% when the crop is rotated out of a continuous pattern.

A 1982 survey of corn growers showed that 30% of U.S. corn is grown on soil planted to corn the previous year. One third of this, or 10% of the total, is considered to be continuous (sown to corn for three or more years in a row). Approximately 10% of the U.S. soybean crop is also planted continuously. If the total acreage of these two crops that are not rotated were spared the yield reduction that is associated with continuous cropping, the U.S. would produce nearly one billion dollars worth of extra corn and soybeans annually.

Individual farmers can markedly increase their net returns by exploiting the rotation effect. Average yields on U.S. corn farms are now just over 100 bushels/acre. It takes about 90 bushels worth of corn to cover the expenses of growing the crop (includes average machinery and land costs, labor, taxes, insurance, etc. An increase of only 5 bushels (essentially assured if one rotates rather than crops continuously) would raise the net return from 10 to 15 bushels, which is an increase in profits of 50%. And the rotation effect is not limited to corn and soybeans. Many crops, such as wheat, sunflower, sugarbeets, cotton, sorghum and barley reportedly benefit from the presence of a different crop the preceding year.

Table 1

An example of yields and expected returns from continuous cropping versus a corn-soybean rotation in the central corn belt.

	Continuous		Rotation	
Per Acre	Corn	Soybeans	Corn	Soybeans
yield (bushels)	130	40	143	44
price ($/bushel)	$3	$7	$3	$7
gross return	$390	$280	$429	$308
total cost	$300	$180	$285*	$180
net return	$90	$100	$144	$128
Average from system	$95		$136	

* Some savings on nitrogen and insecticides

Unproven Explanations

The exact reason for improved yields with rotations is to date, unknown. Differences in soil nutrients, soil physical properties, soil moisture, diseases, insects and weeds have all been considered to have an effect. In some cases, one or several of these factors may account for yield improvements. In most corn-belt states, however, research trials have established that yield increases from rotation persist even beyond optimum levels of fertility, soil tilth, soil moisture and pest control. Some unknown factor (or factors) results in a rotation yield benefit which has not been adequately explained.

Chemicals in Residue

Natural organic chemicals in crop residue have recently been receiving attention in research on the rotation effect. One theory is that products of crop residue decomposition are detrimental to the growth of that same crop the next season. Corn would be negatively affected by last year's decomposing corn residue whereas other crops would not. The opposite theory is that the residue of one crop contains compounds which are growth stimulatory for a different crop. Corn growth would be stimulated by chemicals left in the residue of other crops, and vice versa.

This theory has been supported by work done at Iowa State University where scientists have studied the effect of crop residue extract on the growth of corn seedlings. They found that corn seeds germinated and grew poorly when watered with corn residue extract rather than water. When watered with soybean residue extract corn seedlings did better than when given water.

Field Trials

Over the past 5 years, we have conducted many replicated field trials at 3 locations in Minnesota to investigate the effect of corn residue on the yield of a subsequent corn crop. Each plot in our study was planted to corn on one part and soybeans on the other. After grain harvest, all above-ground corn residue from one half of the corn plots was collected and then distributed over one half of the soybean plots. All the plots were then moldboard plowed. In the second year, all plots were planted to corn. Depending upon cropping history and the movement of corn residue, four cropping situations therefore existed in the second year: (1), corn on corn ground with all above-ground residue removed; (2), corn on corn ground with no residue adjustment; (3), corn on soybean ground with corn residue added; (4), corn on soybean ground with no residue adjustment. In contrast to our expectations, we found that corn residue did not decrease corn yields. In fact, the incorporation of corn residue into the soybean ground contributed slightly to higher corn yields the next year. Removing all residue from the corn ground decreased yields slightly.

An obvious question is: why did our results disagree with the results of the Iowa scientists? A probable answer is that we conducted quite different experiments. The Iowa work measured seedling growth in the greenhouse as affected by freshly-prepared residue extract. We measured grain yield in the field as affected by residue incorporated into the soil the previous autumn and allowed to overwinter. Overwintering and prolonged exposure of crop residue to soil microbes may affect its potential toxicity. The Iowa scientists have recently found, in fact, that corn residue extract is largly detoxified if it is filtered through columns of sterilized soil before it is used to water the seedlings. Based on the results of our field trials and the Iowa soil-filter experiments, we therefore conclude that above-ground corn residue does not reduce next years corn yields in the field.

We have not yet measured the effect of corn residue on soybean yields (studies are underway), nor have we determined the effect of soybean residue on corn yields in a field situation. However we do not expect that a chemical in the residue of soybeans can account for increased yields of corn grown on the same field the next year. If soybean residue contains a chemical which boosts corn yields, then what does corn residue contain that boosts soybean yields? It can't be the same chemical in both cases.

Studies have shown that wheat or alfalfa in a rotation increases corn yields just as much as soybeans do. Yields of soybeans, sorghum, barley and sunflower are all greater when they are rotated rather than grown continuously. It is not likely that the residue of all of these crops contains a chemical which increases the yields of all other crops. It is more likely that all crop plants are adversely affected by themselves. And since we found that corn residue plowed under in the fall does not reduce the yield of corn the next season, it doesn't appear that the yield depressant is contained in above-ground residue.

Another Proposal

A remaining proposal is that it is a soil microbiological factor which accounts for the rotation effect. The soil is, in many ways, a living medium. We might therefore assume that when corn roots grow into a living soil, the soil reacts to that invasion--like an animal body reacts when a foreign organism invades its system. I'm referring to antibodies. Is it not possible that antibodies, or antimicrobes are produced in a healthy soil in response to the proliferation of the roots of a crop into that soil? Crop antibodies would most likely be specific to one crop.

Once a soil became laden with antibodies, it might take a while for them to disappear, or even be diluted when the crop that produced them was withheld from the soil. Many farmers report bumper yields when a crop is grown on a field that has not been planted to that crop for some time. This effect has been substantiated in research trials. Research has also shown that rotating hybrids can partially offset the yield depression associated with growing continuous corn. Antibodies if they exist, might thus be cultivar specific as well as species specific.

Table 2

Research data showing the positive effect on soybean yields of having had corn on the field sometime during the previous three years. The more recent and frequent the corn history, the better the soybean yield. Data from the University of Minnesota.

Cropping History			Average yield of soybeans in 1981
1978	1979	1980	
			–bu/A–
SB	SB	SB	48
SB	CORN	SB	54
SB	SB	CORN	56
CORN	CORN	CORN	61

Future Research

The crop antibody theory suggests the possibility of promising future research. The following are important questions. Do crop antibodies exist? If so, do they cause the yield depression associated with continuous cropping, and can they be controlled or inactivated?

Experience with continuous-cropped wheat may shed light on these questions. The wheat disease called "take-all" caused by a soil-borne fungus, is the most important root disease of wheat. It occurs in fields that are cropped continuously, and may devastate the crop in as short a time as 3 years.

If wheat monoculture continues, the severity of take-all eventually begins to diminish however. The phenomenon is known as "take-all decline" and as a natural control of the disease it can be highly effective. Scientists have discovered that a specific change in the microflora occurs in soils where take-all fungus is established. Included in the new microflora is the "vampire amoeba", which attacks the fungus and controls it (see Crops and Soils Magazine, November, 1982).

We need to know more about what persistence with continuous cropping over a long period of time does to soil microbiology. We need to determine whether an inoculum could be developed for crop seeds which would protect them against the negative effects of continuous cropping.

In the meantime

It should be emphasized that even though the rotation effect cannot yet be satisfactorily explained by scientists, it can be exploited by farmers--every year. It is interesting that the age-old practice of rotating crops which was, for a while, considered unnecessary, has returned to modern agriculture with proven benefits. It is even more interesting to agricultural scientists, that they are unable to explain the cause of the rotation effect. The mystery continues.

CORN DISEASE CONTROL WITH REDUCED TILLAGE

Ward C. Stienstra
Professor and Extension Plant Pathologist
Department of Plant Pathology
University of Minnesota
St. Paul, Minnesota 55108

Corn production is more than disease control, just as disease control is more than clean plowing. Three factors are required for plant disease development to occur: 1) a susceptible host, 2) a pathogen, i.e. disease causing agent and 3) an environment favorable for disease development. When one (or more) factor(s) is missing or limited plant disease development is stopped or reduced. This simple model of disease development allows us to visualize disease as standing on a 3 leg stool. Remove a leg and the stool falls down.

Since many pathogens survive in soil or on crop refuse what is done or not done with soil and crop refuse can have a major influence on pathogen survival, disease development and disease severity. Predicting increased or decreased pathogen survival and performance is not simple but complicated. The ability or success of pathogens to survive and perform in reduced tillage - crop systems is dependent upon what other organisms it completes with, how vigorous the host is and what the new reduced tillage environment is. Clean plow down has been a standard practice for disease control in cultivated crops for years and some have predicted and observed serious disease problems without clean plowing. Increased disease problems have been observed in some reduced tillage crop systems.

CORN

Disease and Pathogen

Southern Corn Leaf Blight - Helminthosporium maydis race T
Northern Corn Leaf Blight - Helminthosporium turcicum
Anthracnose - Colletotrichum graminicola
Yellow Leaf Blight - Phyllosticta maydis
Stalk Rot - Fusarium monoliforme
Goss's Bacterial Blight - Corynebacterium nebraskense
Holcus Leaf Spot - Pseudomonas syringae
Brown Spot - Physoderma maydis
Eyespot - Kabatiella zeae
Seedling and Root Rot - Pythium
Nematodes - several species

The benefits from reduced tillage such as - reduced wind erosion - soil moisture conservation - absence of root damage due to cultivation - reduced soil compaction - better root distribution and reduced cost of crop production may indeed outweigh the call for conventional plowing to eliminate surface residues for the control of plant diseases. Indeed some diseases, i.e. foliar blights and leaf spots, usually associated with increased surface residue can be and presently are effectively controlled by resistant varieties. Selection and development of other resistant or tolerant varieties can be produced I believe, with further research.

Selection of resistant lines is an accepted, standard procedure of disease control, a second and important standard procedure of disease control is the avoidance of monoculture. When crop rotation is practiced, the debris of a given crop that may harbor pathogens is generally deteriorated before the same crop is planted again. The double crop system, in which 3 crops are rotated in a two year period means that each crop is planted once within the two years, thus allowing any crop debris to decompose before planting the same crop again. Debris of the other two crops in the system generally does not harbor pathogens damaging to the third crop.

While "clean tillage" may remain an important control measure of many diseases, alternate controls are provided by crop rotation, resistant varieties, chemical protectants, balanced fertility and good crop health techniques. The elimination of "clean tillage" means more planning is required to combine all the other procedures and more effort is required to properly implement the remaining control measures.

Does conservation tillage increase the threat of Plant Disease? Yes, but not all diseases!

Does plant disease justify conventional tillage? No, but it may be required in some cases!

The challenge is that there is no simple solution, only intelligent choices.

P.I.K. and Disease

Farmers participating in P.I.K. programs usually planned for an inexpensive crop to meet cover requirements, prevent soil erosion and reduce weed reproduction. Some crop diseases can be influenced by P.I.K. actions. What disease control opportunities do you have?

Crop rotation is a very powerful tool and farmers should use crop rotation to manage disease and improve yield. What are the potentials for disease increase or control. A desirable situation would be Corn '81, Soybeans '82 and P.I.K. on this land in '83. In 1984 rotation back to corn followed by soybeans in '85 which allows for 2 years without corn or soybeans thus reducing many foliar diseases of both corn and soybeans.

The choice of cover crops planted in '83 may be a problem if:

1) it produced high levels of organic matter - green manure.

   This material in or on the surface can increase the incidence of pre- and post-emergence damping off for both corn or soybeans. The problem will be greater in poorly drained, cool wet soils. Reduced tillage may also increase damping off as the seed bed often is wetter and cooler than conventional tillage seed beds. The use of good quality seed with fungicide seed treatment is recommended.

2) it allowed disease organisms to increase and/or survive.

   Two fungi, Colletotrichum graminicola and Helminthosporium turcicum are reported to survive and increase on sorghum sudan. Anthracnose and Northern Corn Leaf Blight, corn diseases may increase on corn following this cover crop.

Soybean brown stem rot, present every year in Minnesota to some degree does increase when rotation is not observed and is usually at very low levels when soybeans are rotated with corn. The brown stem rot fungus, *Phialophora gregata* may survive on alfalfa, clover and other legumes.

The soybean cyst nematode, while not a major acreage problem in Minnesota can also increase on many cover crops. See Table. Several clovers are hosts for SCN yet in tests in Illinois all red clovers tested were not host to SCN nor were white (Ladino) Egyptian, Strawberry-headed, holy and white sweet.

Host Plants for the Soybean Cyst Nematode*

Crop and Ornamental Plants	Weeds
SOYBEAN, CULTIVATED AND WILD	HENBIT (Lamium amplexicaule)
BEANS, GREEN (SNAP), BUSH, KIDNEY OR LIMA	HOP CLOVERS (Trifolium spp.)
LESPEDEZAS	CHICKWEED, COMMON (Stellaria media)
VETCH, COMMON, HAIRY, OR WINTER	CHICKWEED, MOUSEEAR (Cerastium vulgatum)
LUPINES, WHITE (ORNAMENTAL SPECIES)	MULLEIN, COMMON (Verbascum thapsus)
Clovers, crimson, scarlet, or alsike	SICKLEPOD (Cassia obtusifolia)
Sweetclover	Digitalis penstemon (penstemon digitalis)
Birdsfoot-trefoil	Pokeweed (Phytolacca americana)
Crownvetch	Purslane (Portulaca oleracae)
Pea, garden	Bittercress (Cardamine sp.)
Cowpea or black-eyed pea	Rocky Mountain beeplant (Cleome serrulata)
Locust, black	Spotted geranium (Geranium maculatum)
Bells of Ireland	Toadflax, old-field (Linaria canadensis)
Borage (Borago)	Pigweed, winged (Cycloloma atriplicifolium)
Canarybirdflower	Vetch, American, Carolina, or wood (Vicia micrantha)
Caraway	Burclover or toothed medic (Medicago sp.)
Chinese lanternplant	Dalea (Dalea alopecuroides)
Coralbells	Milkvetch, Canadian (Astragalus canadensis)
Cup-flower	Beggars weed or tick clover (Desmodium nudifolorum, D. marilandicum, D. viridiflorum)
Delphinium	Corn Cockle (Agrostemma githago)
Foxglove	Hogpeanut (Amphicarpa bracteata)
Geranium	Milkpea (Galactia volutilis)
Geum	Wildbean (Strophostyles helvola)
Horehound, common (Marrubium vulgare)	
Poppy	
Sage	
Snapdragon	
Sweet pea	
Verbena	

*Entries in capital letters indicate highly susceptible hosts.
Table Provided by: Dr. Walker Kirby, Ext. Pl. Path., Illinois.

Corn Stalk Rot

Stalk rot is one of the most common diseases of corn in Minnesota and it occurs every year to some degree. A conspicuous symptom of stalk rot is lodging and 30-50% incidence of lodged stalks have been reported in Minnesota corn fields. On the average, a 5% yield loss occurs in the state. Yield loss is sustained from one or more of the following: 1) early plant death that results in poor grain fill and low test weights, 2) broken stalks, ear drop, and slowing down in picking corn, and 3) ear rots that frequently result from lodged corn especially in wet seasons.

Usually stalk rot is caused by a complex of several fungi and bacteria that becomes obvious in the plant as it matures. Stalk rot is often due to the combined effects one or more organisms and post flowering stresses such as leaf diseases, low light intensity (cloudy), high plant populations, wounds (hail damage, or insect injury) and wet weather. The common stalk rot diseases and fungi in Minnesota are Gibberella stalk rot - *Gibberella roseum* 'Graminearum', Fusarium stalk rot - *Fusarium moniliforme* and occasionally Diplodia stalk rot - *Diplodia maydis*, Pythium stalk rot - *Pythium* species and Bacterial stalk rot occasionally occur following heavy rains with hail.

The stalk rots common in Minnesota do not occur until several weeks after pollination. The first symptoms seen in leaves turning a dull grayish-green and the lower internodes soften and turn from green (healthy) to tan or dark brown. The stalk may be easily crushed and when split open, top to bottom, the pith tissue is soft and decayed and the vascular strands are intact. If the hybrid is susceptible, the entire plant dies and the field may appear to be frosted or suffering from drought.

Gibberella infected stalks have a pink to reddish color of pith and vascular strands. Fusarium infected stalks are difficult to distinguish from Gibberella stalk rot as the color is white to pink or salmon color. This rot also infects roots, the plant base and lower internodes. These rots progress rapidly when the plant matures and small black perithecia (Fungal reproductive structures) are formed on the stalk surface in the fall and mature next spring on Gibberella infected stalks.

Diplodia stalk rot has the same overall symptoms as Gibberella and Fusarium, but small raised black spots, pycnidia (fungal reproductive structure) are produced near the nodes. These are embedded in the rind and are not easy to scrape off. Sometimes a single stalk may be infected by several fungi and have more than one type of fruiting body present. Diplodia is not common in Minnesota.

Stalk rots are diseases of stressed corn plants and the degree of stalk rot severity is often determined by the extent of stress. Nearly all stresses such as excess of lack of moisture, nutrient deficiency or imbalance, insects (root worms and corn borers), nematodes, hail, mechanical injury to roots or stalks and loss of effective leaf area, increase stalk rot. Foliar diseases and excessive plant populations for a given hybrid will influence the degree of stalk rot. Sudden changes from very dry or wet weather before pollination to wet or very dry conditions after silking also favor stalk rot. Hybrids that are top grain producers often have relatively high losses from lodging. High grain production can cause the plant to be deficient in nutrients which cause pith cells in the stalk to die early, allowing a faster fungal colonization. High nitrogen and low potassium levels or sudden loss of available nitrogen (denitrification or leaching) can greatly increase the incidence of stalk rot. Plant injury by nematodes, insects (corn borers and root worms) or hail also increases stalk rot. The injury may simply provide an opening for entry of stalk rot fungi and also carry the fungus into the corn plant.

Stalk rots presently cannot be completely controlled (eliminated) but damage can be reduced through use of an integrated management program. Practices to reduce stalk rot losses:

1) SELECT LODGING-RESISTANT HYBRIDS.

   Full season hybrids are generally reported the more resistant to stalk rot than those that mature early. Some of this resistance is due to rapid loss of resistance mechanisms as stalk color changes from green to brown. The low incidence of Diplodia zeae in recent years is due to success in breeding stalk rot-resistant hybrids. Stalks with a thick-strong rind will resist lodging even when extensive internal decay is present.

2) PLANT SOUND, LOCALLY ADAPTED, FUNGICIDE TREATED SEED.

   Fusarium species are consistently present over a wide area where corn is grown. Infection can occur at many sites in the corn plant. Planting seed without seed coat cracks and with fungicide seed treatment aids in plant establishment and slows or delays fungal infection of the seedling.

3) ADJUST PLANT POPULATION TO HYBRID, FERTILITY LEVEL, SOIL TYPE AND AVAILABLE SOIL MOISTURE.

   Planting at high fertilizer rates can result in thin, spindly stalks are prone to lodging. Observe seed corn company recommendations for recommended planting rates.

4) PROVIDE BALANCED SOIL FERTILITY.

   Fertilizer must be applied based on results of a reliable soil test. Adequate nitrogen levels throughout the season reduces severity of stalk rot. Where leaching or denitrification loss of nitrogen is expected, the use of nitrification inhibitor may help reduce stalk rot.

5) CONTROL WEEDS, CONTROL ROOT AND STALK-ATTACKING INSECTS USING RESISTANCE, USE RECOMMENDED CULTURAL PRACTICES AND CHEMICALS, AND MANAGE FOLIAR DISEASE.

   Corn growers should follow cultural and chemical recommendations for your area. Scouting will reveal insect, weed and disease problems and may reduce unnecessary applications of pesticides. Crop rotation and/or clean plow down of refuse may reduce foliar diseases.

6) HARVEST WHEN CROP IS MATURE.

Delay in harvest can increase loss to stalk rot as resistance to Fusarium decreases rapidly with stalk color change from green to brown.

7) PRACTICE FIELD SCOUTING.

Corn growers should scout fields for stalk rots and lodging when corn grain is at 30-40% moisture. Test corn plants for stalk rot by 1) pinching the stalk below the lowest node for firmness and 2) pushing random plants 5" from the vertical at arm height. When 10% or more of the plants lodge or have soft internodes it becomes beneficial to harvest the field early to prevent potential harvest losses. When scouting also look for each plant kill which can directly reduce yields.

PIK ACRES - WEED CONTROL

Richard Behrens
Extension Agronomist - Weeds
Department of Agronomy and Plant Genetics
University of Minnesota

Weed control in 1983 PIK acres varied greatly; ranging from no control to excellent control obtained by using herbicides, mowing, tillage, or cover crops. Many farmers discovered that it is more difficult to control weeds if no crop is present than if a crop is being produced. Vigorous crops are highly competetive with weeds and greatly reduce weed growth, vigor, and seed production.

On 1983 PIK acres where weeds were adequately controlled no special tillage practices or herbicide treatments will be necessary to produce a good crop of corn in 1984. Weed densities and species should be much the same as in the past. However, if weeds were allowed to grow undisturbed throughout the 1983 growing season, special weed control efforts will be required. Annual weed species should not differ but population densities are likely to be much greater. If this is the case, moldboard plowing should be considered as a means to reduce weed densities. Plowdown of weed seeds will bury many of them to such a depth that germination will not occur. While tillage in future years may return some of these seeds to the soil surface, the viability of many seeds, especially those of weedy grasses, will be destroyed after being buried for a few years. Moldboard plowing will also aid in reducing the vigor of perennial weeds that prospered on PIK acres. However, the high level of food reserves accumulated in the roots and other underground storage organs if the plants grew undisturbed in 1983 will result in more vigorous growth of a greater number of shoots in 1984.

If reduced tillage or no-till corn production practices are to be used in 1984 following heavy weed growth in 1983, increased efforts will be required to control the heavy weed stands that are likely to occur. Corn should be planted in a freshly prepared seedbed so that weeds will not get a head start on the corn. Exceptional care will be necessary in selecting and applying herbicides in order to obtain the best possible control of the weed species present. Herbicide application rates should be increased to the higher end of the rate range. Preplanting treatments should be incorporated thoroughly by incorporating twice in soil with a moderate moisture content to assure maximum effectiveness in weed control. Preemergence treatments should be applied as soon as possible after planting so there will be the greatest opportunity for an activating rainfall. If rainfall does not occur before the weeds germinate, use timely harrowing or rotary hoeing to control young weed seedlings. Annual weeds are much easier to kill when they are small, so do not delay application of postemergence herbicide treatments or cultivation. Most perennial weeds should be controlled in corn when top growth is 6 to 8 inches tall.

Identification of weed species present and careful selection of the most appropriate herbicide(s) for their control in corn is essential for success. Consult Extension Folder 641 "Weed Control in Corn" for suggestions on appropriate control practices.

AGRICULTURAL EXTENSION SERVICE
UNIVERSITY OF MINNESOTA

AGRICULTURAL CHEMICALS
FACT SHEET No. 12–1979
G.R. MILLER and J.S. COULTAS

Weed Control for Corn and Soybeans in Reduced Tillage Systems

The effectiveness of chemical weed control is often a key to success of crops in reduced tillage systems. Much of the tillage in conventional cropping systems is to control weeds. When tillage is reduced, reliance is primarily on chemicals. More consistent performance of recently developed herbicides makes reduced tillage systems practical.

Reduced tillage systems mean primary and/or secondary tillage have been decreased to save time, labor, energy and soil. Historically, extensive tillage loosened the soil, prepared a fine seedbed, and lessened weed competition. A more recent system includes tilling the entire field with a chisel plow or disk, leaving a rough surface covered with a crop residue. Other systems include: tillage in a narrow band where the crop is planted; reducing the number of secondary tillage operations; or complete elimination of all tillage operations. In systems where the total area is tilled to some extent, pre-plant incorporated herbicide applications can be used. However, in most systems where tillage is reduced substantially, pre-plant and some preemergence herbicide applications may not be effective. Herbicide treatments used in these systems will vary according to the type of tillage used and the expected weed problem.

Reduced tillage systems present several weed control problems which conventional tillage systems usually do not. The species of weeds usually change under reduced tillage. Biennial weeds (bull thistle, musk thistle, plumeless thistle, wild carrot) can become a problem because the life cycle is not broken by fall or spring tillage. Perennial weeds (milkweed, dandelion, nutsedge, Canada thistle, perennial sowthistle, quackgrass) can increase under reduced tillage. If these perennials become a serious problem, use appropriate herbicides or revert to conventional methods until the weeds are controlled. Annual grasses (panicum, crabgrass) may also increase under reduced tillage. The trashy soil surface seems to collect windborne weed seeds. These and small grass seeds germinate easily in the moist soil surface. With conventional plowing, many of the weed seeds are too deep to germinate and will decay before surfacing again. With reduced tillage, weed seedlings may not be destroyed prior to planting and will compete more vigorously with the crop. Uneven planting depth and poorly covered crop seed can be a problem with limited soil disturbance, causing crop injury as a result of greater herbicide contact with the crop seed. Many of these problems can be eliminated with proper use of herbicide combinations.

The trashy soil surface under reduced tillage systems often is not favorable for applying herbicides that act in the soil. The trash on the soil surface may intercept the spray preventing it from coming in contact with the soil where weeds are germinating, resulting in untreated spots where weeds can later become established. Larger volumes of water or herbicide granules can be used to reduce this problem. Soil may become compacted where reduced tillage systems are used. This condition limits the rate of herbicide penetration, particularly for herbicides tightly held by soil particles and those with low water solubility. More rainfall may be required to move the herbicides into the compacted soil than into the looser surface soil of conventional seedbeds.

Under reduced tillage systems, the alternative weed control practices available are limited. Some cultural practices such as narrow rows, higher plant populations, and adequate fertility for rapid crop growth will help the crop compete with weeds. Rolling cultivators, cultivators with few shanks and wide sweeps, and cultivators equipped with discs may be used effectively to control weeds. However, cultivating tools commonly used for early shallow cultivations may not perform well. For example, rotary hoes tend to clog; harrows, spring-tined weeders, and sweep cultivators tend to act like rakes. Late season weeds which overtop low-growing crops may be controlled by treating the weeds with specially designed applicators such as recirculating sprayers, roller applicators, and rope wick applicators.

Although weed control in reduced tillage systems presents some problems, effective chemical programs have been developed. Herbicides in reduced tillage crops must provide the following:

- Eliminate existing vegetation
- Control germinating weeds
- Avoid injury to the crop or succeeding crops
- Prevent buildup of new weeds

There is no single herbicide for this. Therefore, a suitable mixture or sequence of herbicides must be planned according to the existing vegetation, kinds of weeds expected to germinate, soil characteristics, and crops. Buildup of resistant weeds can be prevented by using different herbicides in rotation and rotating crops occasionally. At some time during the crop rotation, reverting to conventional moldboard plowing may be necessary to control some weeds.

Carryover of persistent herbicides in unplowed soil may be a serious problem in low rainfall areas. Herbicides remain concentrated and are toxic to succeeding crops when left on dry, unplowed surfaces. Moldboard plowing dilutes the chemical and enhances herbicide decomposition because the herbicides are distributed throughout the plowlayer which increases moisture contact with the herbicides. The combination of moisture and soil microbes is needed to break down the herbicides. Triazine [atrazine, simazine (Princep)] and dinitroaniline [trifluralin (Treflan), profluralin (Tolban), fluchloralin (Basalin), pendimethalin (Prowl)] herbicides may cause injury in subsequent crops because of herbicide carryover. A nonpersistent chemical should be used for 1 or 2 years before growing a sensitive crop in the rotation.

Table 1. Herbicides for corn grown in reduced tillage systems[1]

Treatment	Chemical
Before planting	Paraquat*
	Glyphosate (Roundup) fall or spring
Preemergence	Alachlor (Lasso)
	Atrazine
	Cyanazine (Bladex)
	Metolachlor (Dual)
	Propachlor (Bexton, Ramrod)
	Alachlor + atrazine
	Alachlor + cyanazine
	Metolachlor + atrazine
	Propachlor + altrazine
	Glyphosate + metolachlor + atrazine
	Glyphosate + alachlor + atrazine
	Glyphosate + alachlor + simazine
	Paraquat* + atrazine
	Paraquat* + cyanazine
	Paraquat* + atrazine + simazine
	Paraquat* + alachlor + atrazine
	Paraquat* + metolachlor + atrazine
	Paraquat* + pendimethalin (Prowl) + atrazine
	Paraquat* + pendimethalin + cyanazine
Postemergence	Atrazine + oil
	Bentazon (Basagran)
	Cyanazine (Bladex) 80W only
	2,4-D
	2,4-D + dicamba
	Dicamba (Banvel)
Postemergence-directed	Ametryne (Evik)
	Linuron (Lorox)

*plus nonionic surfactant

[1] Refer to labels for specific information on use of these herbicides. *Cultural and Chemical Weed Control in Field Crops,* Extension Bulletin 400, also gives additional information on use of these chemicals.

Table 2. Herbicides for soybeans grown in reduced tillage systems[1]

Treatment	Chemical
Before planting	Paraquat*
	Glyphosate (Roundup)
Preemergence	Alachlor (Lasso)
	Chloramben (Amiben)
	Linuron (Lorox)
	Metolachlor (Dual)
	Alachlor + chloramben
	Alachlor + linuron
	Alachlor + metribuzin (Sencor, Lexone)
	Metolachlor + linuron
	Metolachlor + metribuzin
	Glyphosate + metolachlor + linuron
	Glyphosate + alachlor + linuron
	Glyphosate + alachlor + metribuzin
	Glyphosate + metolachlor + metribuzin
	Paraquat* + linuron
	Paraquat* + metribuzin
	Paraquat* + metolachlor + linuron
	Paraquat* + alachlor + linuron
	Paraquat* + alachlor + metribuzin
	Paraquat* + metolachlor + metribuzin
Preemergence + postemergence	Alachlor + bentazon (Basagran)
	Metolachlor + bentazon
Postemergence	Bentazon
	Glyphosate (recirculating sprayer or spot treatment)

*plus nonionic surfactant

[1] Refer to labels for specific information on use of these herbicides. *Cultural and Chemical Weed Control in Field Crops,* Extension Bulletin 400, also gives additional information on use of these chemicals.

Tables 1 and 2 list some of the chemicals that may be used in reduced tillage systems.

Paraquat is an effective contact herbicide for quickly killing annual weeds and the topgrowth of perennial weeds. Paraquat does not control regrowth of perennial weeds nor does it have residual soil activity to control later germinating annual weeds. Paraquat works most effectively on young, rapidly growing vegetation. A nonionic surfactant such as Ortho X-77 must be used with paraquat to give complete coverage and improved control. Paraquat is a *restricted* use chemical; it is extremely important to follow use precautions on the label.

Glyphosate (Roundup) is a rapidly translocated herbicide that kills all existing vegetation, including the underground vegetative parts of perennial weeds. It does not have residual soil activity to control later germinating weeds. Glyphosate may be applied in either fall or spring to kill actively growing perennial weeds or crops . Planting or tillage should be delayed 3 to 7 days following a glyphosate treatment.

Several preemergence herbicides used for weed control in corn and soybeans may be used to control annual weeds in reduced tillage systems. Refer to tables 1 and 2 for chemicals registered for tank mixing with paraquat or glyphosate. Preemergence herbicides with some postemergence activity [atrazine, cyanazine (Bladex), or linuron (Lorox)] can be used without the assistance of a contact herbicide on very small annual weeds. Preemergence treatments can be a followup treatment after paraquat or glyphosate applications, or a tank mixture with paraquat or glyphosate and applied before the crop emerges. Several of these mixtures may be used with appropriate fertilizer solutions. Read label instructions regarding mixtures. Some herbicides are not compatible with fertilizer solutions.

The selection of mixtures or sequential applications depends on the extent of the weed problem. Where the crop will be established in sod or if perennial weeds exist, sequential treatments could be beneficial. Where tillage was done before planting or weed problems are less serious, tank mixtures can be more economical. Select a mixture which will specifically control problem weeds.

Any of the postemergence herbicides for corn and soybeans may be used as needed in reduced tillage systems. These herbicides should be selected according to the kinds of weeds, size of weeds, and stage of crop development. Early postemergence treatments are more effective for increasing crop yields than later treatments.

For further information on chemicals refer to *Cultural and Chemical Weed Control in Field Crops,* Extension Bulletin 400, which can be requested from local county extension offices.

Issued in furtherance of cooperative extension work in agriculture and home economics, acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture. Roland H. Abraham, Director of Agricultural Extension Service, University of Minnesota, St. Paul, Minnesota 55108. The University of Minnesota, including the Agricultural Extension Service, is committed to the policy that all persons shall have equal access to its programs, facilities, and employment without regard to race, creed, color, sex, national origin, or handicap. 5 cents

WEED CONTROL IN CORN UNDER REDUCED TILLAGE

Richard Behrens
Extension Agronomist - Weeds
Department of Agronomy and Plant Genetics
University of Minnesota

Reduced tillage practices usually result in increased weed problems in corn for the following reasons. 1) Annual weed seeds are not buried in reduced tillage as they are in conventional tillage so there will be a greater number of weeds to control. 2) Increased trash on the soil surface tends to reduce the effectiveness of herbicides. 3) Annual weed species that are readily controlled by conventional tillage may survive and increase under reduced tillage. 4) Biennial weeds that are controlled by conventional tillage may become established under reduced tillage or no till. 5) Perennial weeds will be more competitive because disruption of their underground reproductive organs (e.g. roots and underground stems) is less under reduced till.

Better herbicide selection and proper timing of uniform applications will be necessary to obtain satisfactory weed control. Refer to Agricultural Chemicals Fact Sheet No. 12 "Weed Control in Corn and Soybeans in Reduced Tillage Systems" for more information on how to minimize the effects of reduced tillage on weed control in corn.

AG-FO-0892 – REVISED FOR 1984

AGRICULTURAL EXTENSION SERVICE
UNIVERSITY OF MINNESOTA

Weed Control in Corn

Richard Behrens and Gerald R. Miller, Extension Agronomists

Weed control in corn should be based on an optimum combination of cultural, mechanical, and chemical practices. The ideal combination for each field will depend on several factors including crop being grown, kinds of weeds, severity of the weed infestation, soil characteristics, tillage practices, cropping systems, and availability of time and labor.

Cultural Practices

Cultural practices for weed control in corn include seedbed preparation, establishing an optimum stand, adequate fertility, and timely cultivations. Weeds that germinate before planting can be destroyed with tillage operations or herbicides. Killing weeds just before planting gives the young crop seedlings a competitive advantage and often improves performance of preplanting or preemergence herbicides.

Early cultivations are most effective for killing weeds and for preventing crop yield reduction due to weed competition or corn root damage. The rotary hoe or harrow works best if used after weed seeds have germinated and are in the "white stage" or just emerging. A rotary hoe, harrow, or cultivator should be used as soon as weeds appear, even if preplanting or preemergence herbicides have been applied, unless a properly timed postemergence herbicide treatment is planned.

Set cultivators for shallow operation to avoid pruning the corn roots and to reduce the number of weed seeds brought to the surface. Throw enough soil into the row to cover small weeds, but avoid excessive ridging that may encourage erosion or interfere with harvesting. Shallow cultivation should be repeated as necessary to control newly germinated weeds.

Herbicides

When selecting an appropriate herbicide or combination of herbicide treatments, consider carefully the following factors:

- Label approval for use
- Use of the crop
- Corn tolerance to the herbicide
- Potential for chemical residues that may affect later crops
- Kinds of weeds
- Soil texture
- Soil pH
- Amount of organic matter in the soil
- Climate

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

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

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

—Weather
—Formulation of the chemical
—Application equipment available
—Potential for drift problems

There are a number of herbicides available for use in corn. In setting up a weed control program for several years, it may be advisable to rotate a selection of herbicides from different chemical families, particularly in continuous corn.

Chemical rotations reduce the likelihood of a buildup of resistant weeds or of herbicide residues in the soil. Even if corn is being rotated to other crops, a chemical rotation can be planned for several years in the cropping system. Commonly used herbicides for corn in different chemical families are:

Acetamides—alachlor, metolachlor, propachlor
Benzoic acids—dicamba
Dinitroaniline—pendimethalin
Other—bentazon
Phenoxys—2,4-D
Substituted ureas—linuron
Thiocarbamates—butylate, EPTC
Triazines—ametryne, atrazine, cyanazine, simazine

This folder summarizes herbicide suggestions for corn, based on numerous experiment station and U.S. Department of Agriculture tests to determine their overall effectiveness. Herbicide labels should be followed.

Table 1 indicates corn tolerance to herbicides suggested for use in corn and relative effectiveness and reliability of these herbicides in controlling common weeds. This table shows general comparative control ratings based on field observations. Under unfavorable conditions, any of the herbicides may give unsatisfactory results. Under favorable conditions control may be better than indicated.

Preplanting Applications

Some herbicides may be applied to the soil before planting and incorporated 2 to 3 inches into the soil with a disk, field cultivator, or similar implement. The disk or field cultivator should be set to operate twice as deeply as the desired depth of incorporation. Use sweep shovels on the field cultivator to get more uniform mixing of the chemical and soil.

The field should be disked or cultivated twice, crosswise and lengthwise, after applying the chemical. If the soil is not too moist or rough and is in a good tilth condition, adequate incorporation may be achieved with one pass over the field with some combination implements. To avoid excessive loss of volatile chemicals like EPTC or butylate, the first tillage operation should follow immediately behind the sprayer.

Butylate (Sutan +) or EPTC (Eradicane, Eradicane Extra) applied preplanting and incorporated at 3 to 6 pounds per acre has given good control of annual grasses and fair control of a few annual broadleafs, but these chemicals do not control several annual broadleafs or most perennial weeds. Both chemicals are effective against nutsedge. EPTC may be used to control quackgrass, but trial results have been inconsistent. Butylate and EPTC are formulated with an antidote chemical to prevent corn injury. With repeated annual use, the weed control performance of EPTC may decline due to more rapid breakdown of EPTC in the soil.

Preplanting and disked-in applications of atrazine have resulted in weed control equal to or, under dry conditions, better than preemergence applications without incorporation. Broadcast applications, necessary when preplanting treatments are used, may increase the potential of atrazine carryover, compared to banded preemergence applications.

Mixtures of butylate or EPTC (Eradicane) and atrazine or cyanazine (Bladex) applied preplanting and incorporated have controlled both annual grasses and broadleafs. These mixtures improve broadleaf control compared to butylate or EPTC alone. Cyanazine does not carry over to the following year, and the lower rate of atrazine used in the mixtures reduces carryover problems from atrazine compared to those caused by the higher rates used when atrazine is applied alone. Cyanazine with butylate is not recommended for use on coarse-textured soils with less than 1 percent organic matter because of potential corn injury.

Preplanting, incorporated applications of alachlor (Lasso) at 3 to 4 pounds per acre or metolachlor (Dual) at 2 to 3 pounds per acre have controlled nutsedge effectively. Under dry conditions, control of annual weeds usually has been improved over preemergence applications by shallow preplanting incorporation of alachlor or metolachlor. Atrazine or cyanazine may be tank mixed with alachlor or metolachlor to improve broadleaf control.

Preemergence Applications

Atrazine at 1 to 3 pounds per acre has given good control of annual weeds with no injury to corn. A 3-pound-per-acre rate of atrazine should be used on fine-textured soils or those high in organic matter. One to 2 pounds per acre of atrazine is adequate on sandy soils that are low in organic matter.

Atrazine sometimes affects small grains, flax, sugarbeets, sunflowers, soybeans, other legumes, vegetables, and other sensitive crops planted the following spring. The label recommends that small grains, flax, sugarbeets, vegetables, and small-seeded legumes or grasses not be planted in the year following atrazine application.

Soybeans may be injured the year following atrazine use if the rate of atrazine application was more than 2 pounds per acre of active ingredient in western Minnesota or 3 pounds in eastern Minnesota, or if application was made after June 10. However, in some years, soybean injury has occurred following use within these restrictions, especially on highly alkaline soils of western Minnesota.

Residue can be minimized by using the lowest rate of chemical consistent with good weed control, using band rather than broadcast applications, and plowing or thoroughly tilling the soil before planting soybeans. Atrazine residues are more likely to persist if soil moisture or temperatures are low.

Cyanazine (Bladex), chemically similar to atrazine, has given good control of annual grasses and most broadleafs when applied preemergence. There has been no soil residue the following season except from granules following dry years. Weed control is not as good under dry conditions as under moderate to heavy rainfall. Within the suggested rates of 1.25 to 4.75 pounds per acre, the higher rates are required on soils higher in organic matter and finer-textured soils. Corn injury may occur on sandy soils. Granular formulations of cyanazine have been less effective than sprays under limited rain conditions.

Propachlor (Ramrod) has given good annual grass control when applied preemergence at 4 to 6 pounds per acre. Propachlor does not consistently control most broad-leaved or perennial weeds, but it may be used in mixtures with atrazine or linuron for annual grass and broadleaf control. Corn is very tolerant to propachlor.

Alachlor (Lasso) and metolachlor (Dual) control annual grasses in corn. Both chemicals also have given good control of redroot pigweed, but control of other broadleafs has been erratic. Preemergence applications have controlled nutsedge on coarse soils that are low in organic matter, but on finer-textured, dark soils, preplanting incorporated applications have controlled nutsedge better than preemergence treatments. Corn has good tolerance to alachlor and metolachlor. Suggested rates for alachlor are 2¼ to 4 pounds per acre in the liquid formulation and 2.4 to 3.9 pounds per acre in the granular formulation (Lasso II). Metolachlor is labeled for preemergence application at 1.5 to 3 pounds per acre in the liquid and granular formulations. Corn, soybeans, sorghum, root crops, potatoes, pod crops, buckwheat, or small grains may be grown the year after using metolachlor; other crops should not be planted for 18 months after application of metolachlor. Any crop may be grown the year following alachlor use.

Pendimethalin (Prowl) may be used alone at ¾ to 2 pounds per acre or in mixtures at ¾ to 1½ pounds per acre for preemergence control of most annual grassy weeds and some broadleafs such as common lambsquarters, pigweed, smartweed, and velvetleaf in corn. In Minnesota trials, preemergence applications of this compound have been somewhat less effective on grasses but more effective on broadleafs than alachlor. Tank mixes with atrazine, cyanazine, or dicamba provide a broader spectrum of weed control.

Corn root injury and lodging have sometimes occurred from preemergence applications of pendimethalin. Corn injury may occur on sandy soils. With dicamba, do not use it on sandy soils or on loams, silts, and silt loams with less than 3 percent organic matter. Incorporating pendimethalin or ridging soil along the row when cultivating may increase corn injury.

Preemergence Herbicide Mixtures

Mixtures of atrazine with alachlor, linuron, metolachlor, pendimethalin, or propachlor are registered for preemergence application on corn to control annual grasses and broadleafs. Soil residues of atrazine are reduced by using these mixtures since application rates are lower than if atrazine is used alone. These mixtures are less effective than atrazine alone on quackgrass. Do not apply the mixture with linuron after corn is up, or severe corn injury may occur.

A 1:1 ratio of active ingredients of an atrazine-linuron mixture has given weed control comparable to an equivalent rate of atrazine alone on soils low in organic matter. Using linuron in combination with atrazine reduces the likelihood of corn injury and usually improves weed control, compared to using linuron alone. Rates vary from ½ to 1½ pounds per acre of each chemical according to soil type. Corn tolerance to this mixture is not as great as to atrazine alone. Corn injury may occur on coarse-textured soils that have low organic matter content.

The mixtures of atrazine or cyanazine with alachlor, metolachlor, or propachlor control broad-leaved weeds better than alachlor, metolachlor, or propachlor alone and give more consistent control on high organic matter soils or with limited rain than atrazine or cyanazine alone. Corn has good tolerance to these mixtures.

Using mixtures of linuron and propachlor or alachlor reduces the potential for corn injury compared to using linuron alone since lower rates of linuron are used. These mixtures control broadleafs better than propachlor or alachlor alone. Suggested rates are 1 to 1½ pounds per acre of linuron, with 3 pounds per acre of propachlor or 1 to 3 pounds per acre of alachlor. Do not use these mixtures on sandy soils because of possible crop injury from linuron.

A preemergence mixture of alachlor or metolachlor with dicamba (Banvel) improves broadleaf control compared to alachlor or metolachlor alone and improves grass control and reduces corn injury compared to dicamba alone. Dicamba

Table 2. Suggestions for chemical control of weeds in corn

Method of application Chemical-common name (Trade name[1])	Rate–lb/A of active ingredient or acid equivalent broadcast[2]	EPA registration limitations on crop use	Remarks[3]
PREPLANTING INCORPORATED			
Alachlor (Lasso)	2 to 4	None	Preplanting application of alachlor or metolachlor at the high rates is suggested if nutsedge is a problem, but for annual grasses only, shallow incorporation or preemergence application is preferred. Incorporate butylate or EPTC immediately after application. Do not use butylate or EPTC on corn
(Lasso II)	2.4 to 3.9		
Atrazine (AAtrex, others)	2 to 3	Do not graze or feed forage for 21 days after treatment.	
Butylate (Sutan+)	4 to 6	None	
Cyanazine (Bladex)	2 to 4	None	
EPTC (Eradicane or Eradicane Extra)	3 to 6	None	
Metolachlor (Dual) (Dual 25G)	1½ to 3	None	
Atrazine + alachlor	1 to 2 + 1½ to 2½	Do not graze or feed forage for 21 days after treatment.	
Atrazine + butylate (Sutazine or tank mix)	1 to 1½ + 3 to 4	Do not graze or feed forage for 21 days after treatment.	
Atrazine + EPTC	1 to 1½ + 3 to 4	Do not graze or feed forage for 21 days after treatment.	
Atrazine + metolachlor (Bicep or tank mix)	1 to 3 + 1¼ to 3	Do not graze or feed forage for 21 days after treatment.	
Cyanazine + alachlor	1 to 2.2 + 2 to 2½	None	
Cyanazine (Bladex) + butylate	1½ to 2 + 3 to 4	None	
Cyanazine + EPTC	1½ to 2 + 3 to 4	None	
Cyanazine + metolachlor	0.8 to 2½ + 1¼ to 2½	None	
PREEMERGENCE			
Alachlor (Lasso)	2 to 3½	None	Atrazine may carry over and affect crops the next year. Other chemicals do not carry over. Because of potential crop injury, do not use preemergence applications of cyanazine, dicamba, or linuron on sandy soils. Linuron is suggested for use only on soils between 1 and 4 percent in organic matter. Use dicamba only on medium- and fine-textured soils with more than 3% organic matter. Propachlor does not persist long enough in sandy soils to give satisfactory weed control.
(Lasso II)	2.4 to 3.9		
Atrazine (AAtrex, others)	1 to 3	Do not graze or feed forage for 21 days after treatment.	
Cyanazine (Bladex)	2 to 4	None	
Metolachlor (Dual)	1½ to 3	None	
Propachlor (Ramrod)	4 to 6	None	
Atrazine + alachlor	1 to 2 + 1½ to 2½	Do not graze or feed forage for 21 days after treatment.	
Atrazine + metolachlor (Bicep or tank mix)	1 to 3 + 1¼ to 3	Do not graze or feed forage for 21 days after treatment.	
Atrazine + propachlor	1 to 1½ + 2 to 3-3/4	Do not graze or feed forage for 21 days after treatment.	
Cyanazine + alachlor	1 to 2.2 + 2 to 2½	None	
Cyanazine + metolachlor	0.8 to 2½ + 1¼ to 2½	None	
Cyanazine + propachlor	1 to 1.8 + 2½ to 6	None	
Dicamba (Banvel) + alachlor	½ + 2 to 2½	Do not graze or feed silage prior to milk stage.	
Dicamba + metolachlor	½ + 2 to 2½	Do not graze or feed silage prior to milk stage.	
Linuron (Lorox) + alachlor	½ to 1½ + 1 to 3	Do not graze or harvest immature corn for feed within 12 weeks after treatment.	
Linuron + propachlor	1 to 1½ + 2 to 3	None	
POSTEMERGENCE			
Atrazine (AAtrex, others) + oil	1.2 to 2	Do not graze or feed for forage for 21 days after treatment.	Apply atrazine when weeds are less than 1½ inches tall.
Bentazon (Basagran)	3/4 to 1	None	Apply bentazon when weeds are 2 to 6 inches. Earlier application is more effective on most weeds.
Bentazon + atrazine (Laddok) + oil concentrate	½ to 3/4 + ½ to 3/4 + 1 qt/A	Do not graze or feed for forage 21 days after application.	Controls only broadleafs. Apply when weeds are less than 2 to 4 inches and corn has 1 to 5 leaves.
Bromoxynil (Brominal, Buctril)	¼ to ½	None	Apply before weeds are 6 inches and corn 14 inches tall.
Cyanazine (Bladex 80W)	2	None	Apply cyanazine when weeds are less than 1½ inches tall and before corn has more than 4 leaves. Use vegetable oil or surfactant under acid conditions only. See label.
Pendimethalin (Prowl) + atrazine	3/4 to 1½ + 1 to 1½	None	Apply spike to 2-leaf stage of corn and up to 1-inch weeds.
Pendimethalin + cyanazine 80W	3/4 to 1½ + 1 to 2	None	
Dicamba (Banvel)	¼	Do not graze or harvest for feed before milk stage.	Apply dicamba before corn is 2 feet tall and not within 15 days of tasseling. Follow drift control precautions on label.
Dicamba + 2,4-D amine	¼ + ¼	Do not graze or harvest for feed before milk stage.	
2,4-D amine	¼ to ½	Do not forage or feed fodder for 7 days following 2,4-D application.	Apply 2,4-D at these rates when corn is 4 inches to 3 feet tall. Use drop nozzles after corn is 8 inches tall. Earlier applications on small weeds are more effective.
2,4-D ester	1/6 to 1/3	Do not forage or feed fodder for 7 days following 2,4-D application.	
2,4-D amine	½ to 1	Do not forage or feed fodder for 7 days following 2,4-D application.	Apply 2,4-D at these rates only after corn is 3 feet tall. Use drop nozzles so only base of stalk is sprayed. Do not apply between tasseling and dough stage of corn.
2,4-D ester	1/3 to 2/3	Do not forage or feed fodder for 7 days following 2,4-D application.	

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

[2] These rates will need to be properly interpreted for the formulation you use and for band width and row width if the chemicals are not applied broadcast. See AG-FS-0917, ***How to Calculate Herbicide Rates and Calibrate Herbicide Applicators.*** The proper rate depends on such things as soil characteristics, kinds of weeds, size of weeds and crop, temperature, and moisture conditions.

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

should be applied preemergence only on medium- or fine-textured soils with more than 2.5 percent organic matter. Do not incorporate this mixture prior to corn emergence. Harrowing or dragging before corn emerges may increase corn injury.

Early Postemergence Sprays

Postemergence sprays of atrazine effectively control most annual weeds in corn. Broad-leaved weed control is especially good. Grass control is less consistent. It is important to apply early postemergence treatments at the proper time or results may be poor. Apply atrazine while the weeds are less than 1½ inches tall. Application may be made until corn is 30 inches tall. Drop nozzles should be used to keep the spray out of the tops of the corn and to give better spray coverage on the weeds.

Adding 1 gallon per acre of special oils with an emulsifier or ¼ to ½ gallon per acre of special adjuvant-oil emulsions to the spray increases the effectiveness of early postemergence applications of atrazine. Labeled emulsions of either vegetable or petroleum oils are satisfactory.

Various formulations of surfactants and detergents used with atrazine have not improved weed control as much as using oils. Suggested atrazine rates for postemergence application with oil are 1.2 pounds per acre for broadleafs and 2 pounds per acre for annual grasses.

When atrazine is used, early postemergence treatments are preferred to preemergence if the soil is high in clay or organic matter and in western Minnesota, where rainfall is less certain. These are the areas where preemergence applications of atrazine have given less satisfactory weed control.

Severe corn injury has resulted from adding 2,4-D to this mixture. Corn injury has occurred also when atrazine and oil were applied to corn growing under cold, wet conditions, or if frost occurred shortly before or after application.

Cyanazine (Bladex 80W) is effective on annual grasses and broadleafs as an early postemergence herbicide. It is cleared for use through the 4-leaf stage of corn and before weeds are more than 1½ inches tall. Pigweed and lambsquarters have shown some tolerance. Oils or surfactants added to the spray increase the potential for corn injury and have resulted in severe corn injury and stand reduction under conditions of heavy rains or dews, cool temperatures, and cloudiness.

Under dry conditions, vegetable oils or certain surfactants may be used to improve weed control. Use only the wettable powder or dry flowable formulations for postemergence application. Do not use on sands with less than 1 percent organic matter.

Bentazon (Basagran) may be applied alone or in a mixture with atrazine as a postemergence treatment in corn to control certain annual broad-leaved weeds, Canada thistle, and nutsedge. Corn has good tolerance to bentazon, but do not apply it when corn is stressed from adverse growing conditions. Apply when annual weeds are less than 2 inches tall, but some species may be controlled up to 10 inches tall. Rain within 24 hours after application will reduce the effectiveness of bentazon. Do not mix bentazon with fertilizers. A non-phytotoxic oil concentrate or crop oil may be mixed with bentazon or with a combination of bentazon and atrazine for applications in corn to improve weed control.

Alachlor (Lasso) may be applied postemergence in a mixture with dicamba (Banvel) to corn less than 3 inches tall. Alachlor or metolachlor (Dual) may be applied with atrazine on corn that is no more than 5 inches tall to control weeds in the two-leaf stage or smaller. Weed control may be less consistent than that from preemergence applications. Propachlor (Ramrod) alone or mixed with atrazine may be applied after corn has emerged to control grasses up to the two-leaf stage.

Table 3. Herbicide names and formulations

Common name	Trade name	Concentration and commercial formulation[1]
Alachlor	Lasso Lasso II	4 lb/gal L 15% G
Alachlor + atrazine	Lasso/atrazine	2½ + 1½ lb/gal F
Atrazine	AAtrex, others	80% WP, 4 lb/gal F 90% WDG
Atrazine + metolachlor	Bicep	2 + 2½ lb/gal F
Bentazon	Basagran	4 lb/gal L
Bentazon + atrazine	Laddok	1.66 + 1.66 lb/gal F
Bromoxynil	Brominal, Buctril	2 or 4 lb/gal L
Butylate and protectant	Sutan+	6.7 lb/gal L, 10% G
Butylate + atrazine	Sutan + atrazine, Sutazine	18% + 6% G 4.8 + 1.2 lb/gal L
Cyanazine	Bladex	80% WP, 15% G, 4 lb/gal F, 90% DF
Dicamba	Banvel	2 or 4 lb/gal L
EPTC and protectant	Eradicane	6.7 lb/gal L
EPTC + protectant + extender	Eradicane Extra	6 lb/gal L
Linuron	Lorox	50% WP, 4 lb/gal F
Metolachlor	Dual	8 lb/gal L, 25% G
Pendimethalin	Prowl	4 lb/gal L
Propachlor	Ramrod	65% WP, 20% G, 4 lb/gal F
Propachlor + atrazine	Ramrod and atrazine	48.1 + 20.9% WP
2,4-D	several	various

[1] G = Granular, L = Liquid, WP = Wettable Powder, WDG = Water Dispersible Granule, F = Flowable.

Pendimethalin (Prowl) in mixtures with atrazine or cyanazine wettable powder may be applied after corn emergence, but not later than when corn is in the two-leaf stage and when weeds are no more than 1 inch tall. These mixtures have been effective against annual grasses and broadleafs. The early postemergence application of pendimethalin and cyanazine used following a preplanting application of EPTC has improved the control of wild proso millet and woolly cupgrass.

Bromoxynil (Brominal, Buctril) applied at ¼ pound per acre as an early postemergence spray controls some annual broad-leaved weeds, including annual smartweeds, wild buckwheat, cocklebur, kochia, common lambsquarters, pigweed, common ragweed, Russian thistle, wild sunflower, and wild mustard. Bromoxynil does not control grasses or perennial weeds. To be most effective, bromoxynil must be applied when weeds have 2 to 4 leaves and corn is less than 6 inches tall. Corn leaf burn may occur, especially under conditions of high temperature or high humidity. Follow specific label information.

Postemergence Applications

Annual broad-leaved weeds can be controlled with broadcast postemergence applications of ¼ to ½ pound per acre of 2,4-D amine when the corn is 4 to 8 inches tall. More severe onion leafing may occur from 2,4-D applications made in the 2- to 3-leaf stage of the corn.

The ¼-pound rate has been adequate for susceptible weeds and is less dangerous to corn. The ½-pound rate has been satisfactory for moderately resistant weeds, but corn usually has been injured by this rate. Rainfall within 8 hours after application reduces the effectiveness of 2,4-D amines more than the effectiveness of 2,4-D esters. About 1/3 less acid equivalent of 2,4-D esters is needed than of the 2,4-D amines.

Spray drift from either amines or esters of 2,4-D will injure susceptible plants. Since the ester forms are volatile, vapor injury to nearby susceptible crops is a possibility. Low volatile esters should be used rather than high volatile esters. Using amines eliminates the danger of vapor injury because amines are not very volatile.

To reduce the danger of 2,4-D injury when the corn is more than 8 inches tall, avoid spraying the upper leaves and leaf whorl of corn by using drop nozzles between the rows. However, adequate spray coverage of the tops of the weeds is necessary for maximum weed control. If nozzles are directed toward the row from both sides, the herbicide concentration must be reduced to compensate for the double coverage. Do not use spray additives with 2,4-D as corn injury may be increased.

Some injury may result when corn is sprayed with 2,4-D. Brittleness, followed by bending or breaking of stalks, is the most serious type of injury, and it may result in severe stand losses when applications of 2,4-D are followed by a storm or careless cultivation.

Several factors influence the degree of injury resulting from 2,4-D. Hybrids vary in tolerance to 2,4-D. Corn growing rapidly is more susceptible than corn developing under less favorable growth conditions. When temperatures exceed 85°F. just before or at the time of 2,4-D application, the corn is more likely to be injured.

At the rates of application commonly used, the stage of growth at which treatment is made during the period from emergence to tasseling is less critical than the effects of environmental factors.

If broad-leaved weed control is necessary after the last cultivation, 2,4-D ester at ½ pound per acre or 2,4-D amine at 3/4 to 1 pound per acre may be applied using drop nozzles. Do not apply 2,4-D from tasseling to dough stage, or poor kernel set may occur. 2,4-D can be applied at ½ to 1 pound per acre after the dough stage if necessary, but it is more beneficial to control weeds earlier.

Dicamba (Banvel) as a postemergence spray in corn has given better control of Canada thistle and smartweed than 2,4-D with less effect on the corn. Dicamba also controls other broad-leaved weeds except mustard, but it does not control grasses. But when used, dicamba drift has often affected soybeans in the vicinity of treated cornfields.

Dicamba may be used in corn at ¼ pound per acre, either alone or in mixtures with 2,4-D amine at ¼ to ½ pound per acre. The lower rate of dicamba has given satisfactory weed control with less crop effect than the higher rate. Applications can be made until corn is 2 feet tall or until 15 days before tassel emergence, whichever occurs first. Do not use on corn grown for seed. Later applications, especially when corn is tasseling, may result in poor kernel set. Use drops after corn is 8 inches tall. Do not use additives with dicamba.

Mixtures of dicamba and atrazine or cyanazine are cleared for use on corn as early postemergence treatments. These mixtures have given good broadleaf control, but grass control has been erratic. Oils and other additives should not be used.

Caution: Soybeans and other broad-leaved plants are very sensitive to dicamba. In recent years, there were many instances in which dicamba drift affected soybeans. Users of dicamba must take special precautions to avoid spray drift at the time of application or vapor drift for several days after application. Spray drift can be minimized by reducing sprayer pressure, increasing water volumes with larger nozzles, and using drop nozzles to keep the spray release as low as possible and still give weed coverage. Drift potential is greater with windy or high temperature conditions.

Applications are not recommended at temperatures above 85°F. Spray and vapor drift effects on soybeans can be reduced by spraying corn early in the season when temperatures are lower and before soybeans have emerged, or when they are small. Do not graze or harvest for dairy feed prior to the milk stage of the grain if corn is treated with dicamba.

Directed Sprays

These cannot be used on small corn. Therefore, early season weed growth must be controlled by some other means (rotary hoe, harrowing, herbicides, or cultivation) to prevent yield losses from early weed competition. Directed sprays are considered emergency measures to control heavy weed stands within corn rows.

Specially designed equipment has been developed to make directed spray applications in corn. When applying directed sprays, the nozzles should be mounted so that wheels, skids, cultivator shanks, or similar devices control the nozzle height. To minimize spray contact with corn leaves, use attachments to lift the corn leaves and direct the spray to the base of corn plants and onto weeds in the row.

Directed sprays of linuron at 1½ pounds per acre can be applied when the corn is not less than 15 inches tall. Ametryne (Evik) is cleared for use as a directed spray at 1.6 to 2 pounds per acre after corn is 12 inches tall. Do not apply ametryne later than 3 weeks prior to tasseling. Ametryne should not be used on sandy soils. Adding a wetting agent is necessary for effective weed control with linuron or ametryne.

Care must be taken in application to minimize spray on the corn leaves while covering most of the weed foliage with the spray. Either chemical will kill the corn leaf tissue it contacts and, if leaf kill is extensive, corn yields may be reduced.

Issued in furtherance of cooperative extension work in agriculture and home economics, acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture. Norman A. Brown, Director of Agricultural Extension Service, University of Minnesota, St. Paul, Minnesota 55108. The University of Minnesota, including the Agricultural Extension Service, is committed to the policy that all persons shall have equal access to its programs, facilities, and employment without regard to race, creed, color, sex, national origin, or handicap.

Read the pesticide label and follow the instructions as a final authority on pesticide use.

AGRICULTURAL EXTENSION SERVICE
UNIVERSITY OF MINNESOTA

AGRONOMY
FACT SHEET No. 35—Revised 1982
O.E. STRAND and R. BEHRENS

Identification and Control of Wild Proso Millet

Wild proso millet (*Panicum miliaceum L.*) was first identified as a serious weed problem in Minnesota in 1970. Since then it has been found in 41 Minnesota counties ranging from Dakota and Chisago in the east to Lincoln, Lac Qui Parle, and Wilkin in the west. Found mainly in corn and soybean fields, wild proso millet is a prolific seed producer and a vigorous competitor in row crops.

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

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

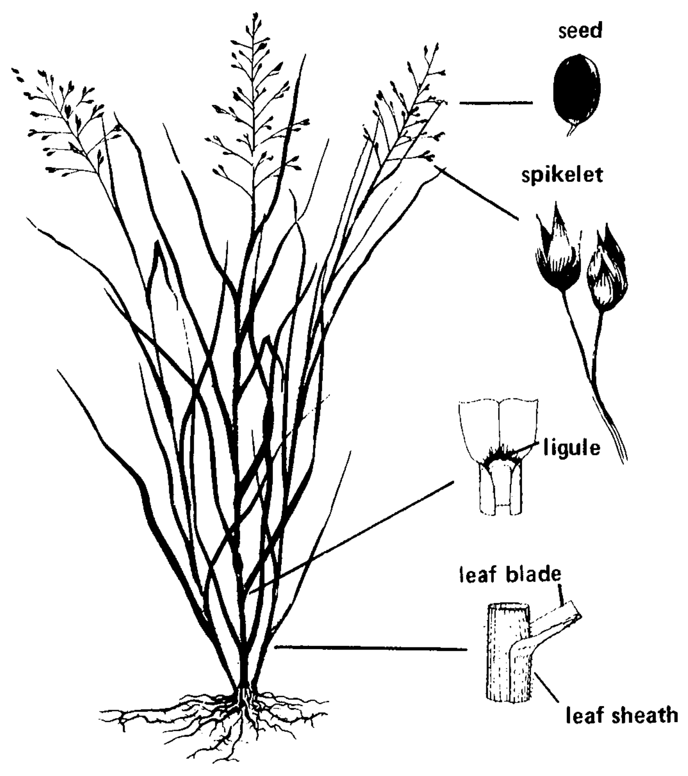
DESCRIPTION AND TAXONOMY OF WILD PROSO MILLET

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

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

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

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



CONTROL OF WILD PROSO MILLET IN FIELD CROPS

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

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

Corn

Wild proso millet germinates readily from deep in the soil (2 to 3 inches or more). For this reason herbicides such as EPTC with protectant (Eradicane), butylate with protectant (Sutan Plus), alachlor (Lasso), or metolachlor (Dual), when applied at the full label rate for the soil type and incorporated into the soil before planting, have given the best control of wild proso millet in Minnesota trials.

Of these four herbicides, EPTC has given the most consistent control. However, repeated annual usage of EPTC has resulted in reduced effectiveness on wild proso millet due to rapid breakdown of EPTC. In recent research, the addition of (Dyfonate) or related compounds (called extenders) have prevented this rapid inactivation of EPTC. Use of extenders has not yet been cleared in Minnesota, however. With rainfall soon after application, alachlor and metolachlor applied preemergence have given good, early season control of wild proso millet. However, a single application of any of these four herbicides usually fails to give full-season control of wild proso millet. Combinations of EPTC plus protectant (Eradicane) applied preplant incorporated followed by a delayed preemergence application of cyanazine (Bladex) plus alachlor or metolachlor, or an early postemergence application of cyanazine plus pendimethalin (Prowl) have given satisfactory season-long control of wild proso millet in corn.

Soybeans

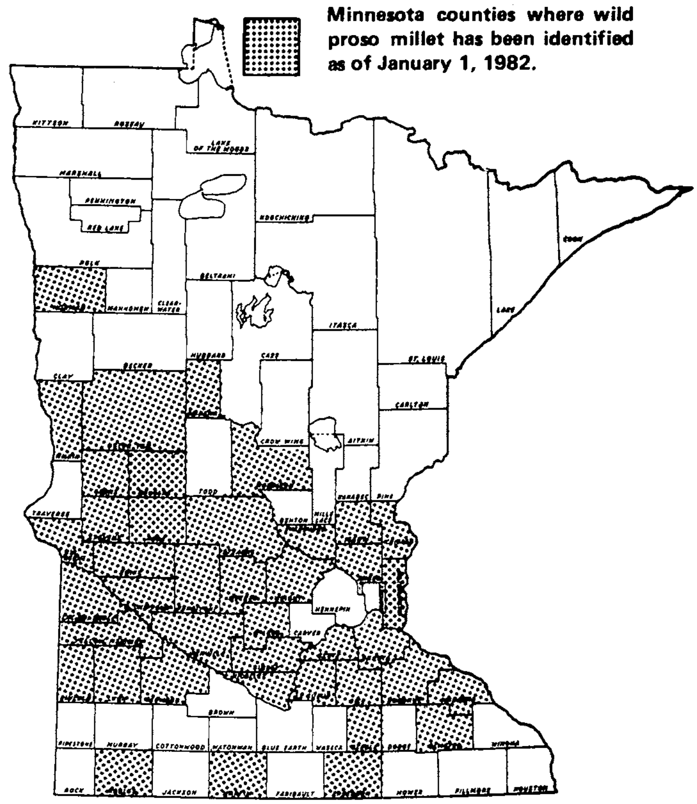
The herbicides trifluralin (Treflan), profluralin (Tolban), fluchloralin (Basalin), pendimethalin (Prowl), or vernolate (Vernam) applied preplanting and incorporated have given only fair control of wild proso millet when used alone. However, if one of these herbicides is used preplanting, incorporated, followed by preemergence use of alachlor (Lasso), metolachlor (Dual), or chloramben (Amiben), good control of wild proso millet usually has resulted.

These preemergence herbicides may be banded and one or two cultivations used to control weeds in the row. Chloramben (Amiben) may be tank-mixed with trifluralin (Treflan) and the mixture incorporated. Alachlor or metolachlor, applied preplant and incorporated at the full label rate for the soil condition, also has given acceptable control in some trials when applied alone or in combination with chloramben as an overlay or tank-mix treatment.

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

Small Grains

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



Minnesota counties where wild proso millet has been identified as of January 1, 1982.

Sunflowers

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

Dry Edible Beans

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

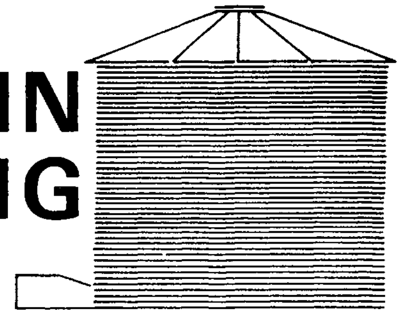
Flax

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

Issued in furtherance of cooperative extension work in agriculture and home economics, acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture. Norman A. Brown, Director of Agricultural Extension Service, University of Minnesota, St. Paul, Minnesota 55108. The University of Minnesota, including the Agricultural Extension Service, is committed to the policy that all persons shall have equal access to its programs, facilities, and employment without regard to race, creed, color, sex, national origin, or handicap. 5 cents

Agricultural Extension Service — University of Minnesota M - 161—1982

SAVING ENERGY IN CORN DRYING



R. Vance Morey, professor
Harold A. Cloud, extension agricultural engineer

Rising energy costs and concern about the availability of propane and natural gas, the fuels commonly used for grain drying, are leading many corn producers to consider ways of reducing the energy required in their high-speed drying operations. A high-speed dryer is any dryer which uses heated air to rapidly reduce the moisture content to the desired level. As shown in figure 1 these include: continuous flow; batch, both automatic and manual; batch-in-bin; stirring bins; and continuous-flow, bottom-unloading bins. With any high-speed dryer, most of the energy to evaporate water comes from the fuel that is burned.

The following alternatives should be considered when looking for ways to reduce energy in drying shelled corn.

- Reduce overdrying.
- Use dryeration.
- Use in-storage cooling.
- Use a combination of high-speed drying followed by natural-air drying.
- Use a natural-air drying system when it is feasible.

The first alternative should be at the top of everyone's list when considering ways to reduce energy for corn drying. One or more of the other alternatives also may be applicable in many drying systems. The purpose of this publication is to help sort out the alternatives that may apply in each situation. Five other publications in this series provide more detailed information on each alternative. They include "Dryeration and In-Storage Cooling for Corn Drying" (M-162); "Combination High-Speed, Natural-Air Corn Drying" (M-163); "Natural-Air Corn Drying" (M-164); "Management of Stored Grain with Aeration" (M-165); and "Fan and Equipment Selection for Natural-Air Drying, Dryeration, In-Storage Cooling, and Aeration Systems" (M-166).

There are two other reasons that make it worthwhile to explore all of these alternatives. In addition to saving energy, each of these alternatives has the potential for *increasing drying capacity* and *improving grain quality.* Comparative estimates of energy requirements and dryer capacities are summarized in table 1.

REDUCE OVERDRYING

Everyone needs to take a careful look at this alternative first (figure 2). Overdrying is removing more moisture than necessary for safe storage over the period of time corn is stored. Table 2 shows the moisture contents at which corn can be stored in Minnesota in *well-managed, aerated storages.* When corn is dried to lower moisture contents, extra energy is required at levels shown in table 1. Many farmers are still drying corn to 12 percent because they feel it is necessary for safe storage. This may be based on past experience where higher moisture corn spoiled because it was not stored in a suitably aerated and properly managed facility. A properly equipped and well-managed storage facility allows higher moisture corn to be stored successfully, thus realizing the benefits of the energy savings indicated in table 1. The publications "Management of Stored Grain with Aeration" (M-165) and "Fan and Equipment Selection for Natural-Air Drying, Dryeration, In-Storage Cooling, and Aeration Systems" (M-166) provide information on aeration management and design.

Table 3 shows the penalties for drying shelled corn to lower moisture contents. If corn is marketed, an economic loss will be incurred if the corn is sold at moisture contents below 15.5 percent. If the corn is fed, there is no extra shrinkage cost; but overdrying still requires extra fuel, and overdried corn may not be as palatable to livestock as corn at higher moisture contents. Corn which is to be fed during the winter months can often be safely held at moisture contents above 15.5 percent if enough airflow is provided in the storage to keep it cold. The key to saving corn drying fuel is to remove only as much moisture as necessary for safe storage.

As indicated in table 1, the increase in dryer capacity can be significant when overdrying is reduced. Less drying can also reduce stress cracking of the kernels, decreasing their susceptibility to breakage in subsequent handling operations. Also, reducing overdrying will normally provide an increase in test weight. These improvements in corn quality may result in less dockage when the corn is marketed.

Table 1. Comparative estimates of energy requirements and dryer capacities when drying 25.5 percent moisture corn.[1]

Alternative		Gallons of propane/100 bu[2]	Kilowatt hours of electrical energy/100 bu	Change in high-speed dryer capacity relative to drying from 25.5 to 15.5% with in-dryer cooling
Reduce overdrying (High-speed drying with in-dryer cooling)	to 15.5%	20	10	------
	to 14%	23.5	11	12% less
	to 13%	26	12	18% less
	to 12%	28.5	13	24% less
	to 11%	31.5	14	30% less
Dryeration	to 15.5%	14.5	7	60% more
In-storage cooling	to 15.5%	17.5	8	35% more
Combination drying	to 15.5%	8	70	300% more
Natural-air drying[3]	to 15.5%	----	140	------

[1]These are estimates intended to help compare alternatives. There is wide variation in energy use from one system to another. The high-speed drying comparisons are representative of typical automatic batch or continuous-flow dryers removing 10 points of moisture (25.5 to 15.5%).

[2]Comparisons are made on the basis of 100 bu of corn at 15.5 percent moisture content. For example, overdrying to 11 percent will yield only 94.9 bu at 11 percent instead of the 100 bu. If comparisons are made on actual 56-lb. bushels at the reduced moisture contents, the fuel and electrical requirements would be higher.

[3]Natural-air drying may not be a feasible alternative as a complete drying system. See the publication "Natural-Air Corn Drying" (M-164) for more information.

Table 2. Moisture contents at which shelled corn can be stored in Minnesota in properly-aerated, well-managed storages[1]

Storage period	Corn moisture content
12 months	14%
Harvest through June	15.5%
Harvest through March	16-17%

[1]Assumes corn that normally meets No. 2 corn standards.

Table 3. Overdrying penalties when marketing shelled corn below 15½%[1]

Moisture content	Extra energy requirements per 100 bushels[2]		Loss in bushels sold due to additional shrinkage per 100 bushels[2]
	Propane Gallons	Electricity Kilowatt hours	
14	3.5	1	1.7
13	6.0	2	2.9
12	8.5	3	4.0
11	11.5	4	5.1

[1]Based on high-speed drying with in-dryer cooling.

[2]100 bushels of #2 corn, 56 pounds at 15½% M.C.

Additional Equipment

It is necessary for storage bins to be equipped with adequate aeration facilities. Since this is highly recommended for *all* storages, no extra equipment is required when you reduce overdrying.

DRYERATION

With dryeration, corn is not cooled in the dryer but delivered hot to a separate cooling bin (figure 3). The hot corn is allowed to "steep" or "temper" at least 4 to 6 hours, then cooled slowly. After cooling has been completed, the corn is transferred to storage.

Dryeration provides the following benefits:

- Tempering followed by slow cooling increases the efficiency of moisture removal during the cooling process.
- It reduces the stress in the kernels developed during the final stages of high-speed drying and rapid cooling. This leads to improved corn quality.
- Significant increases in dryer capacity are achieved because of the increased efficiency of moisture removal, elimination of cooling in the dryer, and the possible increase in drying air temperature in the high-speed dryer.

During the tempering or steeping process, condensation can build up around the walls of the cooling bin. As a result, corn that has been tempered in a cooling bin should always be transferred out after cooling and never left for storage in the cooling bin. At the end of the drying season the dryeration bin can be used for storage, possibly with in-storage cooling. This is discussed in the next section.

Additional Equipment

At least one and preferably two cooling bins are required along with additional materials handling equipment to accommodate the extra corn transfer. Generally, dryeration is more adaptable to larger operations—50,000 bu per year and larger. However, it is a flexible system and may, in many instances, fit the needs of smaller operations.

IN-STORAGE COOLING

Instead of cooling the corn in the high-speed dryer, it is discharged hot to storage and cooled there (figure 4). Experience has shown that as long as the cooling fan delivers adequate air and is turned on immediately, corn can be cooled and stored in the same bin. Because cooling is delayed somewhat, the heat contained in the corn is used more efficiently for the removal of water. Probably the biggest advantage of in-storage cooling is the significant increase in capacity that occurs when the cooling cycle in a batch dryer is eliminated, or when the cooling section in a continuous-flow dryer is converted to full heat.

In-storage cooling provides some of the advantages of dryeration without the extra transfer operation. However, when corn is to be stored in the bin in which it is cooled, a tempering period is *not recommended.* The resulting condensation can cause problems around the bin walls.

Additional Equipment

In general, an increase in aeration airflow is required, depending on the capacity of the high-speed dryer.

COMBINATION HIGH-SPEED, NATURAL-AIR DRYING

Combination drying is high-speed drying followed by in-storage cooling and natural-air drying (figure 5). The purpose of the high-speed dryer is to reduce the moisture content of the corn to a level where drying can be safely completed in storage with natural (unheated) air. Natural-air drying is accomplished by moving unheated air through the stored corn. This may take from 4 to 8 weeks or even longer to complete. In many situations, drying may be stopped in the late fall and completed the following spring. Propane or natural gas requirements are substantially reduced compared to normal high-speed drying with in-dryer cooling since only the water above 20 to 22 percent moisture content is removed in the high-speed dryer. The savings depend on the moisture content at which corn is discharged from the high-speed dryer. As shown in table 1, electrical energy requirements are increased because of the fan operation in the natural-air drying stage. However, the net result is a reduction in total energy requirements.

Additional Equipment

The bins used for in-storage, natural-air drying must be equipped with drying floors and fans capable of delivering an airflow of at least one cubic foot per minute per bushel (cfm/bu) of corn in storage. This is ten times the amount of air required for normal storage aeration.

Who should consider combination drying? Potentially, it can be included in a wide range of situations. Because of the in-storage drying facility, it is probably more feasible for operations less than 50,000 to 60,000 bu of corn per year. The substantial increase in capacity of the high-speed dryer occurring when corn is discharged at higher moisture contents makes this an attractive alternative for those who need to expand their drying capacity. The characteristics of the combination system make it particularly suitable to producers who feed their corn.

NATURAL-AIR DRYING

Natural-air drying is an in-storage system which relies mainly on unheated air for all of the drying (figure 6). This may take 4 to 8 weeks or longer, depending on the natural air conditions and the initial moisture content of the corn. The key to natural-air drying is to provide enough air to complete drying within the allowable storage time as determined by the deterioration of the corn. The quantity of air required depends on the moisture content of the corn being delivered to the bin. If the bins are filled rapidly, it is difficult to deliver enough air to satisfactorily dry corn higher than 22 to 23 percent moisture in a natural-air system. Wetter corn can be dried in storage if filling is delayed. However, for corn above 25 percent moisture content, the necessary delay and/or larger fan requirements often become impractical. Usually, it is more practical to use high-speed drying to reduce wetter corn to 21 to 22 percent, a moisture content more easily dried with natural air (combination drying).

In some cases, enough supplemental heat is added to the natural air to increase its temperature an additional 2° to 4° F. When this is done, it is commonly referred to as "low-temperature" drying. The additional 2° to 4° F supplements the drying ability of the natural air. The desirability of adding supplemental heat to a natural-air, in-storage drying system is discussed in more detail in "Natural-Air Corn Drying" (M-164).

MORE THAN ONE SOLUTION?

Producers may decide to incorporate several of these alternative methods in their systems. For example, reducing overdrying can be done in conjunction with in-storage cooling. Or a bin equipped with a drying floor and fan can be added to complement existing storage. This bin can be used for dryeration while filling the existing storage. After the existing storage has been filled, the dryeration bin can be used for natural-air drying as part of a combination system, or as a complete natural-air system if harvest moisture contents have dropped below 21 to 22 percent. It is likely that a mixture of these alternatives will best suit most situations.

Economics

Economic comparisons of the alternatives can be complex; since each situation is different, it is very difficult to make general statements about costs and returns for alternative methods.

Energy costs will be reduced by using any of these alternatives. However, energy is only one part of the total cost of the drying and storage system. For instance, investment or fixed costs are always significant. We recommend that your economic analysis include:

- Costs
  a. Investment costs associated with additions to, and changes in, materials handling equipment and storage bins (For storage bins, cost factors may include drying floors, fans, shallower bins for natural-air drying, and less storage space due to level-fill requirements and space lost for drying air plenums.)

b. Larger electrical service required in some cases to meet increased power demands

- Returns
  a. Energy cost savings
  b. Increased dryer capacity, which may allow more timely harvesting or eliminate the need to increase high-speed drying capacity
  c. Improved grain quality, which may result in less dockage
  d. Reduced reliance on propane fuel

Some of these factors will affect the economic analysis and some will not. Each situation needs to be analyzed separately.

This is one publication in a series that evaluates alternatives for saving energy, improving grain quality, and increasing capacity in corn drying. The series provides information on how to incorporate these alternatives in drying systems. The publications include:

M-161 Saving Energy in Corn Drying
M-162 Dryeration and In-Storage Cooling for Corn Drying
M-163 Combination High-Speed, Natural-Air Corn Drying
M-164 Natural-Air Corn Drying
M-165 Management of Stored Grain with Aeration
M-166 Fan and Equipment Selection for Natural-Air Drying, Dryeration, In-Storage Cooling, and Aeration Systems

Development of these publications was partially supported by the Minnesota Energy Agency under an Energy Policy and Conservation Act (P.L. 94-163) grant. The authors are members of the Department of Agricultural Engineering at the University of Minnesota.

Figure 1. Schematic diagrams for five types of high-speed dryers

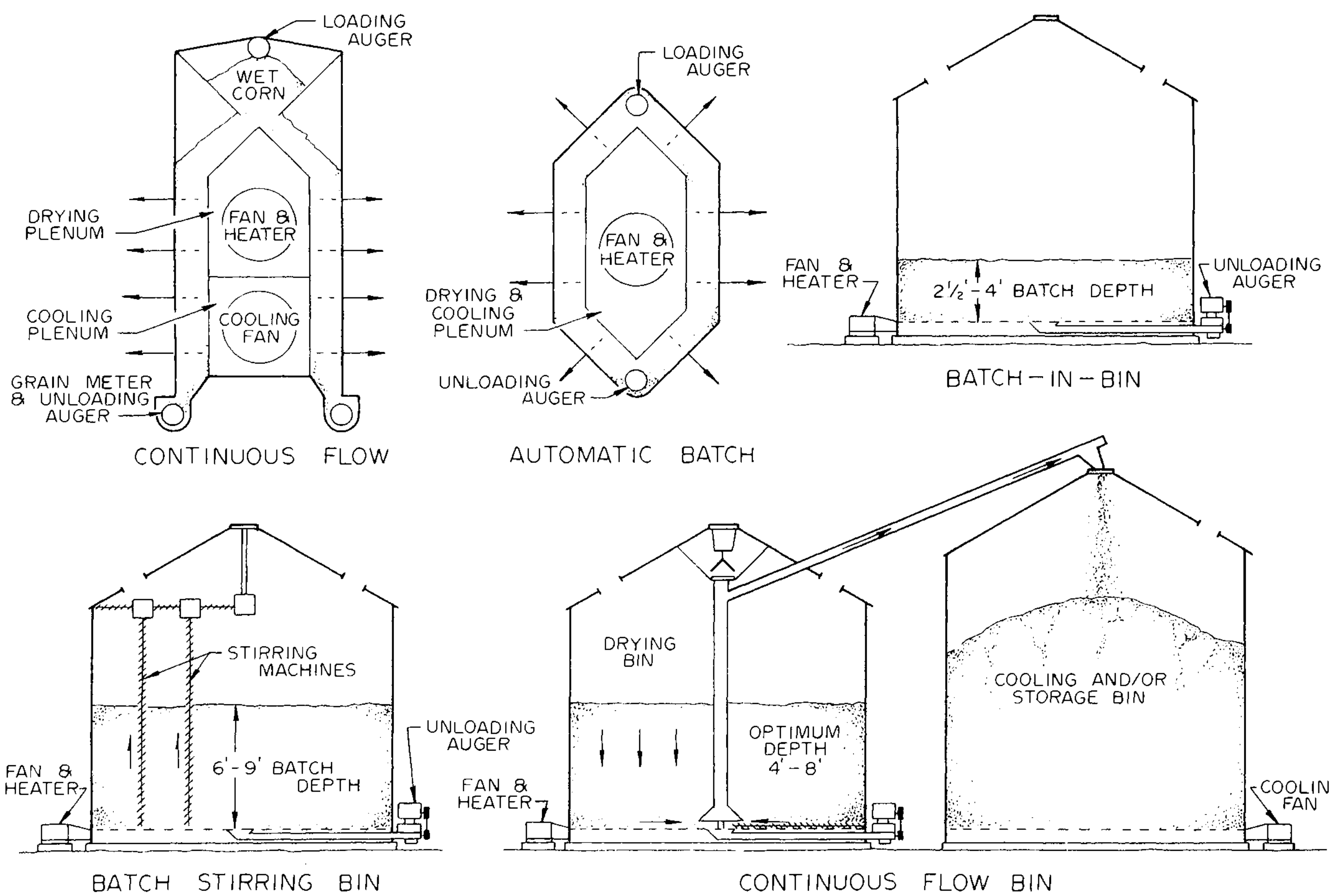


Figure 2. Energy used in overdrying

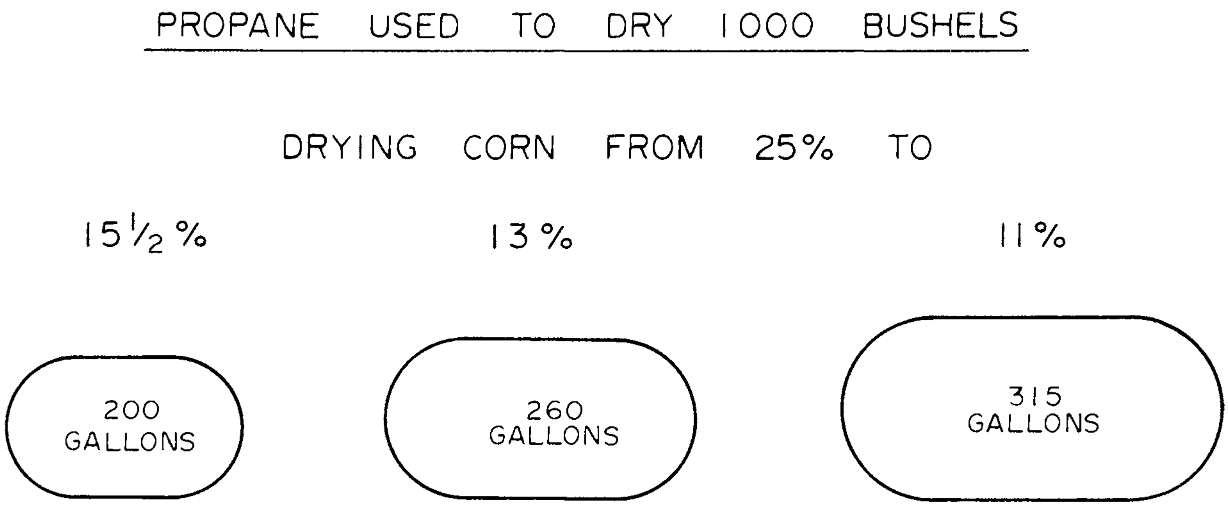


Figure 3. Schematic of dryeration system

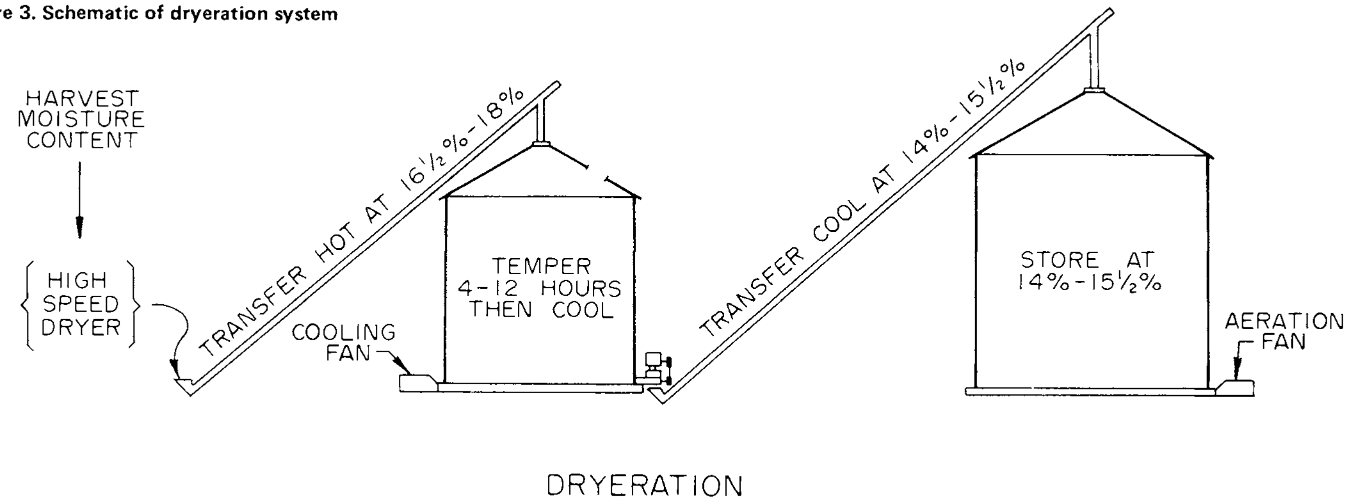


Figure 4. Schematic of in-storage cooling system

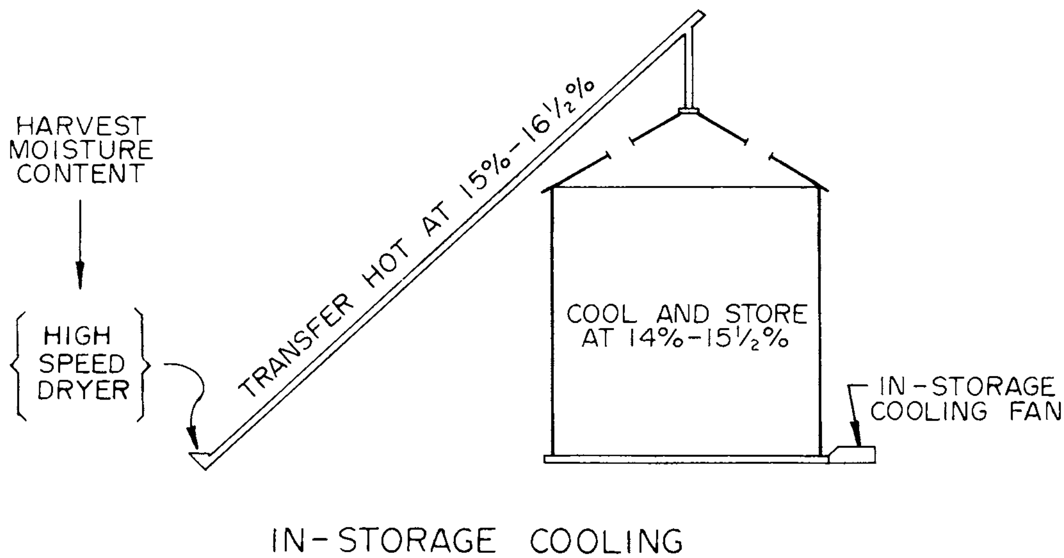


Figure 5. Schematic of combination high-speed, natural-air drying system

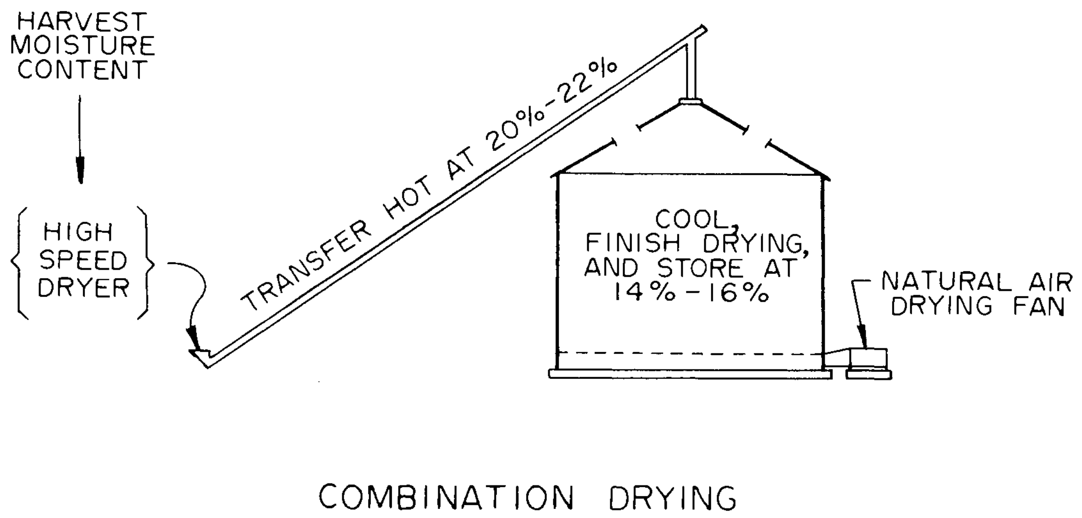
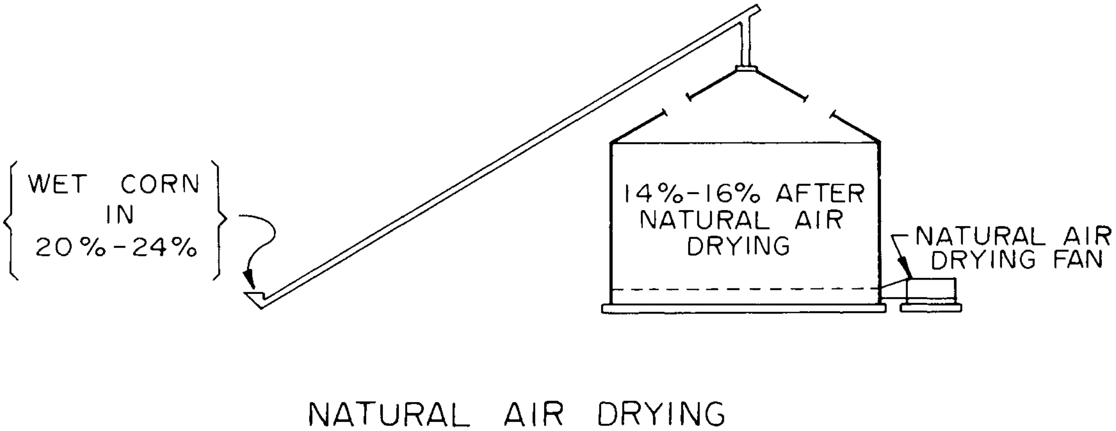


Figure 6. Schematic of natural-air drying system



WARNING: Flowing Grain Is Dangerous

Never enter a grain bin or other grain storage area while the grain is flowing. Flowing grain will exert forces against the body great enough to pull the average size person under the grain in only a few seconds leading to death by suffocation.

Issued in furtherance of cooperative extension work in agriculture and home economics, acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture. Norman A. Brown, Director of Agricultural Extension Service, University of Minnesota, St. Paul, Minnesota 55108. The University of Minnesota, including the Agricultural Extension Service, is committed to the policy that all persons shall have equal access to its programs, facilities, and employment without regard to race, creed, color, sex, national origin, or handicap. 20 cents

FERTILIZING PIK ACRES IN 1984

George Rehm
Ext. Soil Scientist - Soil Fertility
Dept. of Soil Science
University of Minnesota

The 1983 PIK program had a major impact on crop production in Minnesota. In addition to the effect on commodity prices, the PIK program will also create some changes in fertilizer management recommendations for the 1984 season.

As the 1983 PIK acres are brought back into production in 1984, it would be ideal if we could make some broad, general statements about fertilizing these acres that would fit all situations. There was, however, considerable variability in the management practices that farmers chose to use on their PIK acres. Therefore, fertilizer management suggestions for the 1984 growing season need to be modified to match these varied management practices.

In general, the acres placed in the PIK program were the problem or least productive acres on the farm. Normally these acres would need special attention with respect to fertilizer management in 1984. The fact that these acres were placed in the PIK program only serves to add a few more problems from a fertilizer management standpoint.

MANAGEMENT PRACTICES USED

Those who traveled throughout Minnesota this past summer generally agreed that the management practices used on PIK acres could be classified into 6 main groups. These are:

- Clean residue from a previous crop of corn, soybeans or small grain. Weeds were controlled with chemicals throughout the growing season.
- Weedy stubble from a previous crop of corn, soybeans or small grain. Weeds were not controlled during much of the growing season. Weeds were controlled late in the season by either tillage practices or chemical treatment.
- Small grain was planted. The crop was planted both early and late in the season. Crop was destroyed.
- Bare fallow. Weed control on these acres was accomplished by using one or more tillage practices.
- Planted to sorghum-sudan.
- Planted to soybeans.

Some of these management practices will dictate that some special attention should be given to fertilizer management in 1984.

For those farmers who planted either soybeans or small grains on their PIK acres in 1983, no changes are suggested. The fertilizer program that would normally be used in 1984 should be followed. For these fields, P and K would be applied as suggested from the results of a soil test. The N recommendations would be based on yield goal (soil nitrate test in western Minnesota) and a previous cropping history of either soybeans or small grains.

The fields where there was a substantial growth of weeds throughout the season do not present any special problem from the standpoint of fertilizer management. The N recommendations for these fields would be based on yield goal (soil nitrate test in western Minnesota) and a previous cropping history of small grains.

The use of a starter fertilizer has always been an important management tool for corn production in Minnesota. Past experiences in Minnesota and other states as well as some recent research conducted at four locations throughout the state point out the special importance of the use of a starter fertilizer for corn production on fields where bare fallow was used or where weeds were controlled throughout the growing season in the residue from a previous crop of corn, soybeans, or small grain. In South Dakota studies, the stunted early growth of corn following fallow was eliminated by the use of a starter fertilizer containing N and P.

The statements above which deal with the use of a starter fertilizer will also be appropriate for fields where weeds were controlled throughout the season and the stubble of corn, soybeans, or small grains from the previous year was not disturbed. These fields do not fit the true definition of a fallow situation. From a fertilizer management standpoint, however, these fields would resemble the fallow situation.

In areas of Minnesota where a soil test indicates a possible need for zinc fertilizer, there would be no objection to applying a small amount of zinc (about 1 lb/acre) in the starter. Remember that zinc deficiencies generally occur in western and southwestern Minnesota and are often associated with soils that have a high pH (> 7.5). It would certainly be advisable to get a soil test for zinc if there is any doubt.

The acres planted to sorghum-sudan present some special problems. It appears that most farmers who planted this crop plowed it under before the middle of September. As this relatively large amount of plant material is incorporated into the soil and starts to decompose, there is a high potential for immobilization of a significant amount of soil N. Even though decomposition takes place and there is some mineralization, it is highly probable that the amount of N that is immobilized will be larger than the amount released through mineralization. Therefore, it is anticipated that there will be some deficit of soil N when this crop is plowed under. To compensate for this anticipated deficit, it is suggested that N rates for corn be increased by 40-50 lb/acre on fields where sorghum-sudan was grown in 1983. In arriving at N recommendations for these fields, corn should be considered as the previous crop. The additional N suggested can be applied when the farmer would normally apply N in his individual fertilizer management program.

THE SOIL NITRATE TEST AS A MANAGEMENT TOOL

The soil nitrate test can be an important tool in arriving at N recommendations for corn in western Minnesota. This test will be especially important for the fields that were placed in the PIK program. This soil test is an easy way to determine if carryover N is either higher or lower than levels which are typical.

If the nitrate test shows that there are high levels of carryover N in the soil, rates of fertilizer N can be reduced for crop production in 1984. If, however, there are lower levels of carryover N in the root zone, N rates which are higher than normal may be needed to get the best yields. The sorghum-sudan may have depleted the amount of nitrate-nitrogen in soils in 1983. So, it is especially important to sample these fields in western Minnesota for residual or carryover nitrogen.

MANAGING N FERTILIZER

The grower may also want to consider some changes in the way that N is managed on PIK acres. It is obvious that weed control will be a major problem for these fields in 1984. So, some may want to consider combining their herbicide with some liquid N (weed and feed concept) as an aid in weed control. There may also be problems with the application of anhydrous ammonia where the sorghum-sudan was either disked or plowed under. Application equipment may collect some of the residue which, in turn, may cause problems with application. For these fields, a broadcast application of urea with some incorporation would be a reasonable alternative.

It should be noted that the above discussion has focused on fertilizer management for corn planted on PIK acres. If other crops are to be planted, fertilizer management presents no special problems. For other crops, fertilizer should be applied as suggested from the results of a soil test. Again, the importance of collecting soil samples from PIK acres is emphasized.

SUMMARY

As growers look ahead to fertilizing PIK acres in 1984, there are some important points to remember. These are:

1. The PIK acres were usually the least productive on the farm. They normally would need special attention. The PIK program underscores this need for attention.

2. Soil testing has always been an important management tool. The collection of soil samples is especially important for the PIK acres.

3. The use of a starter fertilizer for corn production has been widely used throughout Minnesota in the past. Experience tells us that starter fertilizer may be especially important for the bare fallow fields and the fields where crop stubble was kept free of weeds throughout the growing season.

4. Traditional N rates should be increased by 40-50 lb./acre where sorghum-sudan was planted then plowed under in 1983.

ON-FARM COMPUTING: IN 1984 AND TOWARDS 1994*

Earl I. Fuller
Profesor - Farm Management
Department of Agricultural and Applied Economics
University of Minnesota

It is now 1984, proclaimed to be the year when we become the captives of a controlled society. Meanwhile, some state that we live in an "information age" or in the time of a "post industrial revolution". Others, speaking more simply, say we are witnessing a "computer revolution" where the economics of low hardware cost, powerful capability, easy access and available software are impacting every aspect of our daily lives.

Things are changing--but then they always have! Change is normal. It's stability that isn't. Without change, life--and more specifically farm management--would be dull and without challenge. American farming has changed a lot in the last 50 years. Why would anyone expect that it won't in the next 50? Historical parallels can help us to understand change in our lives; in this case the mechanization of farming some 50 years ago compared to the computerization ones of today.

A HISTORICAL PERSPECTIVE

By 1933 row crop tractors had been around for a good 5 years. But the majority of the farmers didn't own one; a depression was delaying purchase. Horse breed association people were concerned, though horses were still the major power source beyond the family's own labor to operate the farm. Farmers were asking themselves when and whether to buy a tractor.

Microcomputers have now been on farms for a good 5 years. The majority have not yet decided to buy one; a farm recession delayed many purchases. Farm cooperatives are trying to find a way to be helpful as are many others who supply advisory services to farm managers.

In 1934 steam tractors had a 50 year history behind them. Farm management applications of computers have a 30 year history tracing to Fred Waugh of the USDA. First, in batch (stationary) mode where the data (material) was taken to the machine not unlike old time threshing. Since about 1968 farm managers have "custom hired" time share computing to evaluate alternatives and otherwise aid in the decision process. High plains feedlots have kept lot records and used computerized control system procedures of this type for at least 15 years.

---

* A contribution to Minnesota Agricultural Experiment Station project 14-036, Management Information Systems for Farm Firms.

Prepared for presentation at "Bloomington Corn Conference", Jan. 5 & 6, sponsored by Minnesota Corn Growers Association and the University of Minnesota.

SYSTEMS RECLASSIFIED AND COMPUTERIZED

Farmers knew then and know now that it takes more than a fancy power unit to get a job done. It takes tools that harness the use of that power--whether it is tillage or software. It takes management too; decisions about when to use, how to fix, how to adjust, measure, hook up, etc. Together the elements make a system; a mechanized farming or a computerized farming system.

Systems thinking in mechanized farming hadn't come very far by 1934 compared to where it is today. Cultivators took a long time to attach to the tractor they were designed for and often couldn't be adapted to any other. Most implements were still horse drawn designs with the adjusting levers lengthened and turned forward. Hydraulic controls, electronic sensors and "ergonomically" grouped con-trols or designed operator work spaces were at best only dreams.

Implement companies sold bright red, green, yellow and orange models as they attempted to lock the buyer into their color line. The little grey one with its "farming system" and today's defacto standard 3-point hitch hadn't appeared. The talk of a "systems approach" to mechanization which it later illustrated was not yet common.

Farmers viewed the choices about how to compare tractors as confusing. Many saw at least one job where a tractor had strong merit. But few thought they could replace the older way--the horse. Few were yet ready to risk taking a mechanized farming approach to the way crops were grown. There were drawbacks; mechanical reliability, new skills needed, acceptance in the community and many others.

Life in 1984 has its parallels. Many see at least one task a computer system could help do. Few have spent the time necessary to work out a true systems approach to the greater formalization of the farm's management information and activity control systems. There are still drawbacks to using a computer in most cases. Some, but not all, are ready to risk the first steps of adoption of computing power to the set of tools used in managing the business.

Five years ago a farmer had few choices in software tools to "harness" a microcomputer. Most were adaptations of an earlier generation of time share (horse drawn? steam powered?) tools; or one could develop tailor made tools. Today more specifically designed and user friendly (egronomically sound) software packages can be found to do many decision aiding management tasks. Some vendors are offering rather complete lines of software which do work together more as a system.

Progress is observable in making farm software work as a system. Several work from the same data base for more than one type of use. A greater degree of software transferability is also noted. More applications are being written in fairly standard language dialects and know-how now eases their transfer even when the floppy disks are not interchangeable. (Remember the early power lifts and P.T.O. linkages weren't very interchangeable either without adapters.)

In short, there are many parallels between considerations today's managers need to recognize in deciding when and how to move into computerized farming and those our parents or grandparents faced in mechanizing 50 years ago. How did they, and should we, approach the tool?

TAKE A SYSTEMS APPROACH TO THE DECISION

Most of them did not take a systems approach, but we should. We should do a management audit. A systems approach makes sense. Before acquiring a computer is a good time to review the family's and the management team's objectives and goals. Why do you farm? How do you weight income and/or growth in both psychic and dollar terms? How important is feeling in control and/or making life simpler? How action oriented are you? Are you action oriented, i.e. how do you like to spend time--thinking, planning, directing or doing? Are communications between people in your business and/or with your vendors (creditors) a problem? Where do you see you and your farm business to be 5 years from now?

No matter what your answers to these questions, there are alternatives besides joining the computer era just yet to deal with them and to reach your goals. Remember too that goals will change just as the feasibility of computerizing as an aid to attaining them will change as time goes on.

WHAT OTHERS ARE DOING ABOUT COMPUTERIZATION

In today's setting, the majority of farmer-purchasers have as a first objective the creation of a historical data base of some type of records. For some it is financial records; for most of the rest it is physical enterprise records. In both instances the interest is often on day to day control of operations rather than the more strategic or planning issues of a longer run.

But for those who start one, even before the record system is complete other potential uses for the computer are often seen. Many are workable with "off-the-shelf" software. Thus a standard recommendation for most purchasers holds for farmers too. Acquire a data base manager, an electronic worksheet, personal word processing, and a hardware-software communications package the day you buy the hardware.

Single application installations can be justified. Many are paying their way; but the potential is much greater. A systems approach similar to what happened in farm mechanization is the way to go.

The major cost to get there is time not hardware and software. It is manage-ment type time, either your own or that of consultant's doing a "systems analysis" for you. In the latter case, you may pay for it by buying software, but it's really all the thought and care in making it work in your operation that runs up the cost.

Software developments further improve and integrate the component applications each year. A systems approach is making the computer a productive tool to aid in controlling and planning the farm business. (Fuller, 1 and 2).

To make it happen smoothly requires an understanding of control modeling with its use of "cybernetic loops" and "management by exception" rules. The idea that data contains "noise" and at best can only be structured so as to increase its "potential information content" is essential. The principles of the management sciences are sound. Economic marginality, risky decision approaches, present value, etc., as opposed to "average cost of production", "allocated overhead" and "factors affecting profits" to name a few. (Fuller, 3 and 4).

These ideas are necessary if progress is to be made. They are crucial to solving the riddle of how to relate the felt need to sound use of the firm's data base and other available data. Without them, data of little or no value (noise) will obscure the crucial elements necessary to decision making. Progress is being made in this work on farms by software vendors and in the land grant universities. What one is doing by such work is increasing the formalization of the firm's management information systems.

At this point a note of caution is in order. Even after start up, most people will say that the computer is not saving them time. Keying in data takes about as long as recording it any other way. Most people are now recording more data and taking more time to analyze it than they used to. Within 5 years more electronic sensed semi and fully automated data collection devices will be involved. They will cut the time to use the system.

For now, it means less time for other activity, often the action oriented activity of running the farm. Computing is often a productive use of limited time. But the caution should be noted. So should a caution that unless the time is committed to computing the investment will not have a high probability of paying out.

FARM COMPUTING IN THE YEARS AHEAD

To this point, this paper has drawn some parallels with mechanization to give a better understanding of where farming is today with computerization. More parallels are observable, but seem unnecessary in this context. Then a brief description of the current situation was offered. It is now appropriate to look ahead 5 to 10 years.

To look ahead means going beyond specific applications to a time of broader and better integrated control and planning systems. It means going from keeping, sorting and printing livestock records to computing as a component of livestock enterprise control systems with predictions of performance and monitor input use. It means using (a) decision aids, (b) data base managers, (c) other time share accessed data base sources and (d) word processors in combination as the situation requires. It means cutting costs by substituting electronic data sensing and recording devices whenever economic technology will allow. It also means avoiding a data overload on the manager with its associated large noise factor. Only a systematic analysis of objectives, problems, opportunities and a clear distinction between information and data will do this.

The direction that farm financial management (FFM) is taking illustrates many of these ideas. FFM once meant just the keeping of financial records to many. Various groups did gather and use the data as a financial diagnostic tool based on between-farm comparisons or farm business analysis. The state of the art is now beyond that.

Some workers argue for uniformly specified accrual accounting procedures which can produce standard financial statements (Frey). These are said to be necessary to tell lenders where the business has been and is now. Perhaps sò; but from a FFM perspective, a forward looking perspective is imperative.

A set of computerized financial tools has been widely used and carefully refined over the last 10 to 15 years. They will be operable on microcomputers within the year. They work with most currently available record systems. But the user has to review the data in the data base before each new projection. Projections include measures of (1) profitability, (2) liquidity and (3) solvency so as to be applicable to various sets of objectives concerning income, growth, security or risk, as well as more personal factors. Financial and physical production sensitivity analysis is automatic.

The system deals with the "Where am I?", "Where do I want to be?", and "How can I get there?" questions of planning (Thomas et.al., 5). One data base drives all modules which are:

(1) FINAN - Financial analysis of a set of "standard" income statement, balance sheet and prior year's sources and uses of funds.

(2) FINLRB - Financial long range budgeting - a projection and comparative evaluation of the existing plan and two alternative organizational plans 3 to 5 years ahead.

(3) FINTRAN - Transitional planning projections by quarters and/or years of the selected plan over 3 years.

(4) FINFLO - Monthly cash flow projections and their financial implications of the selected plan for the next year.

Much of the data used is physical or technical. Default data banks exist to help one get started. They can be combined with projected planning prices and the current financial condition as appropriate. The system also has the ability to review actual performance with that previously planned. Sources of error can be noted and sometimes reduced (Nordquist & Hawkins, 6).

This system, when integrated with an accounting record system for purposes of tax records and controlling the cash flow, is a prototype of FFM systems of the future. It will be available and useful to lenders and borrowers alike. Its use has already shown an ability to rationalize credit use, to put money where it can be productive at reasonable risk. Further, it helps communications between the management team and the lender-advisor. It encourages setting goals and measures progress towards them. It helps control cash flow and the other aspects of FFM.

Livestock record systems are evolving in the same direction. New developments in data collection devices will speed development. Marketing management and crop record applications show similar developments. It should be interesting both to watch and to be a part of it. Perhaps in another 50 years our children will be drawing parallels between the computerization of farms in the 1980's and some yet to be seen next major change in American farming!

REFERENCES

1. Fuller, Earl, Using Data Base Management Software to Formalize The Control of Swine Farm Operations, Department of Agricultural and Applied Economics and Agricultural Extension Service, University of Minnesota, prepared for presentation at a workshop entitled "On-Farm Computers", Purdue University, November 21-23 1982.

2. Fuller, Earl, Think Systems - Putting A Dairy Farm Management Information and Control System Together, Department of Agricultural and Applied Economics and Agricultural Extension Service, University of Minnesota, prepared for Ohio State University workshop entitled "Computers and the Dairy Farm Family", January 18-19, 1983.

3. Fuller, Earl, Options Available For Farming In The "Information Age", Department of Agricultural and Applied Economics and Agricultural Extension Service, University of Minnesota, presented at "Computers Working For Farmers", University of Saskatchewan, Canada, January 13, 1983.

4. Fuller, Earl, Some Concepts and Definitions Useful For Coping With The Information Age," Department of Agricultural and Applied Economics and Agrciultural Extension Service, University of Minnesota, prepared for presentation at seminar in Department of Ag Economics, University of Saskatchewan, Canada. Staff Paper P83-13, June 1983.

5. Thomas, K., R. Hawkins, R. Luening, and R. Weigle, Managing Your Financial Future, North Central Regional Extension Publication 334, 1981.

6. Nordquist, D. and R. Hawkins, Project Progress Report And Proposal - Computerized Financial Management Assistance Project, Agricultural Extension Service, University of Minnesota, June, 1982.

7. Frey, T. and N. Johnson, "Financial Planning and Management," 1982 Yearbook of Agriculture, United States Department of Agriculture.

FARM ESTATE PLANNING

by
Kenneth H. Thomas
University of Minnesota

I. Key Federal Estate Tax Provisions - A Brief Review

- Unlimited marital deduction at death of first spouse = no tax on first death

- Unified credits increasing from $325,000 in 1984 to $600,000 in 1987 = major tax savings if make full use of both spouses' credits; live to 1987

- Unlimited marital gifting makes estate balancing much easier = removes order of death problem

- Joint tenancy ownership now 50/50 between spouses. Larger estates should sever joint tenancy

- Special use valuation a key provision if have large real estate holdings. Can reduce estate value by maximum of $750,000 per spouse

- Annual gift exclusion = $10,000 per recipient per year per $20,000 if spouse consents

- Installment sale of land = 6 percent interest between family members

- Maximum gift and estate tax rates reduced from 70 percent to 50 percent by 1985

- Payment of estate taxes may be made over a 15 year period

- Generation skipping may be in your future if your children are already financially well off

II. Estate Planning - Getting Our Priorities Straight

A. Your #1 Priority Should Be To Take Good Care Of Yourself

1. Financially - make sure you have adequate income and financial security for your lifetime

2. Personally - your retirement years should be a time to enjoy life--things other than farming

B. Your #2 Priority Should Be To Treat Your Heirs Fairly

1. Helping a farming heir get started is fine

2. Giving him the whole farm may destroy the most precious thing you have--your family!

C. Your #3 Priority - To Keep Taxes And Other Costs To A Minimum

1. Under current law, estate taxes are not a threat during the parents' lifetime--no tax

2. You can reduce the burden for the next generation dramatically if you do your homework

III. The $64 Question - Do We Have An Income Security Or Estate Tax Problem?

A. Your Net Estate = All Of Your Assets - Your Debts

B. Some Guidelines

Table 1.

FEDERAL ESTATE/GIFT TAX

(after unicredit and before State Death Tax Credit)

Amount in 1,000's	'83	'84	'85	'86	'87	% on Excess
275	0	0	0	0	0	34
325	17	0	0	0	0	34
400	42.5	25.5	0	0	0	34
500	76.5	59.5	34	0	0	37
600	113.5	96.5	71	37	0	37
750	169	152	126.5	92.5	55.5	39
1,000	266.5	249.5	224	190	153	41
1,250	369	352	326.5	292.5	255.5	43
1,500	476.5	459.5	434	400	363	45
2,000	701.5	684.5	659	625	588	49
2,500	946.5	929.5	904	870	833	50
3,000	1,211.5	1,194.5	1,154	1,120	1,083	*
3,500	1,496.5	1,469.5	1,404	1,370	1,333	*
4,000	1,796.5	1,744.5	1,654	1,620	1,583	*
4,500	2,096.5	2,019.5	1,904	1,870	1,833	*
5,000	2,396.5	2,294.5	2,154	2,120	2,083	*

a. Estates of $300,000 or less = small estate

- single or combined estate--little or no tax problem; concern = financial security (see above table)

b. Estates of $300,000 - $600,000 = moderate estate

(1) Swing-sized estate: grow into tax problem; erode into security problem (see above table)

(2) If single/widowed = tax problem now; will become less of a problem as credits increase unless estate grows rapidly.

(3) Married couples with simple will/joint tenancy = tax problem now if both die in 1983; no tax problem in 1987 if estate doesn't grow to much

(4) Married couples with trust will/life estate = no tax problem now if estate is reasonably balanced; likely none later.

c. Estates of $600,000+ = <u>large estate</u>

(1) Single person or widowed = tax problem even if die after 1987

(2) Married couple with simple will/joint tenancy = tax problem now and after 1987 (see table on page 2)

(3) Married couple with trust will or life estate = tax problem now may or may not have tax problem as credits increase (above $1,200,000 by 1987 = tax problem)

IV. Planning The Moderate To Small Estate
(If this doesn't fit your situation, it may fit your children's.)

A. Major Concern - Your Financial Security

1. Some joint tenancy = okay → all to surviving spouse

2. Get rid of state's "will" → have your own will

- joint tenancy, insurance, homestead to spouse
- rest distributed according to state law (Minnesota = 1/3 to spouse, 2/3 to heirs)

3. Have at least a simple will

a. All property goes to spouse = protection

b. If minor children, consider children's trust in case wife dies

c. Consider having a flexible will

- all to spouse, but have disclaimer in case taxes become a problem or spouse becomes incapacitated

B. Fair Treatment Of The Heirs--Later On!

1. Overall Plan

a. Distribution plan is part of will--fair/equal?

b. Minor children--consider children's trust

c. Before death transfers??

- sale would provide income; gift would not

2. Future of farm business

   a. What does the spouse want to do with business/life if something should happen to you?

   b. Will any of the heirs want to farm?

V. Planning The Moderate To Large Estate

A. Protecting Parents' Security While Protecting Estate From Tax

1. Tax management strategies with single person/surviving spouse

   a. Live until 1987--$600,000 credit

   b. Live it up--spend it

   c. Give it away

   d. Sell it

   e. Check special use/delayed tax payment provisions

2. Tax management strategies when both spouses living

   a. Be sure to have a will--with no will, could have to pay tax on first death: 2/3 to heirs (see table 2). (With unlimited marital deduction, shouldn't have to pay tax.)

Table 2. Estimated estate taxes for persons dying with a $600,000 estate with alternative estate plans, first death 1983, second death 1985

		No will		Simple Will		Credit, trust will	
		First death (1983)	Second death (1985)	First death (1983)	Second death (1985)	First death (1983)	Second death (1985)
Net estate	(7)	$600.000	$260.000	$600.000	$580.000	$600.000	$305.000
Estate administrative costs	(8)	20.000	10.000	20.000	20.000	20.000	10.000
Adjusted net estate (7-8)	(9)	580.000*	250.000	580.000	560.000	580.000	295.000
Marital deduction	(10)	260.000*	0	580.000	0	305.000	0
Taxable estate	(12)	320.000+	250.000	0	560.000	275.000	295.000
Tentative tax	(15)	94.600	70.800	0	178.000	79.300	86.100
Unified credit	(17)	79.300	121.800	0	121.800	79.300	121.800
Estimated estate tax (15-17)	(18)	15.300	0	0	56.200	0	0

* Assumes $100.000 homestead plus 1/3 balance of estate ($160.000) outright to spouse
+ Passes outright to heirs, with taxes paid from heirs portion

b. Major task: Make effective use of both spouses' credits

(1) Get rid of simple will and joint tenancy
(2) Consider use of trust or life estate (see table 2)
(3) Real large estate = credit portion outright to heirs?
(4) Balance your estate so can make good use of credits regardless of order of death (table 3)

Table 3. Federal estate tax liability with unbalanced estate with simple will and credit trust, and balanced estate with credit trust will*

	Unbalanced estate				Balanced estate with credit trusts	
	Simple will		Credit trust			
	First to die	Second to die	First to die	Second to die	First to die	Second to die
Gross estate	0	$1,000,000	0	$1,000,000	$400,000	$712,500
Deductions	0	25,000	0	25,000	12,500	22,500
Adjusted gross estate	0	975,000	0	975,000	387,500	690,000
Marital deduction	0	0	0	0	112,500	0
Taxable estate	0	975,000	0	975,000	275,000	690,000
Tentative tax	0	336,100	0	336,100	79,300	226,100
Unified credit/ state credit	0	192,800	0	192,800	79,300	192,800
Federal estate tax due	0	143,300	0	143,300	0	33,300

*Assumes first death in 1983, second death in 1987.

By 1987 can pass $1.2 million to heirs tax-free

c. If still have tax problems → some options

(1) Qualify for special use valuation
(special formula designed to reduce valuation - by up to $750,000)

(2) "Freeze" the size of part of the estate
(don't let it grow)

- option to buy
- corporation--debentures, preferred stock
- limited partnership - frozen units
- sales

(3) Reduce size of estate

- live it up
- gifting
  - annual exclusion--$10,000 per recipient per year

(4) Deferred payment of estate tax

B. Fair Treatment Of Heirs - Transferring The Business

1. Should we try to farm together?

   a. Assessment - three key questions

      (1) Do you really want to farm?
      (2) Is the business adequate?
      (3) Can a realistic transfer plan be developed?

   b. Testing stage - seeing if we can work together

      - wage-incentive plan
      - joint arrangements?

2. Getting established - the smaller farm unit

   a. Spin-off - farming together but separately

   b. Holding pattern - until Dad retires

   c. Expanding the business

3. Getting established - larger farm unit

   a. Some general guidelines

      (1) Parents should maintain considerable asset base

      (2) Personal property and management should be key transfer concerns in early going

      (3) Use extreme care in transferring real estate--later → people and tax considerations

   b. The partnership as a transfer aid

      (1) Good beginning tool - very flexible

      (2) Early going arrangements - keep them simple

         - who's going to contribute what? share arrangement?
         - who's in charge?
         - how will we dissolve it if something happens?

      (3) Begin to think about the longer term

         - after establishment, retirement, death

c. The corporation as a transfer aid

(1) Strengths: tax saver, ease of transfer, control

(2) Key issues

- what property to put in corporation
- what capital structure to use
- tax year/type of corporation

d. The limited partnership as a transfer aid

(1) Good tool to use in transferring real estate

- can sell or gift units as desired
- keep control as long as have 51 percent
- farming heir can eventually control and manage while other heirs get income

VI. Retirement - A Time To Enjoy The Fruits Of Your Labor

A. Begin Now To Plan Your Retirement Years

1. Your wife will appreciate it!

2. Your farming son will appreciate it!

3. You will too!

B. Use The "A Time To Enjoy" Worksheet (page 8) To Begin Planning Your Future

A Time To Enjoy

Our lives are filled with many different types of activities. In retirement you may find that some activities which were not important while farming full time become more significant during your retirement years. What will you do? When? Will it involve additional expenses? Will your health limit your involvement?

RETIREMENT LIVING	What Will You Do And Where Will You Do It?	How Much Time Per Week? (or which months)	Related Expenses (dues, clothing, travel, materials)	Will Health Limitations Affect Involvement? (if so, how much)
1. Farm Work				
2. Involvement in Organizations				
3. New Job-Second Career				
4. Special Interests (Hobbies)				
5. Travel				
6. Visiting, Walks, Time by Yourself				

INSTABILITY, EXPORTS AND CORN MARKETS: SOME POLICY ALTERNATIVES FOR 1985

Carlisle Ford Runge
Assistant Professor
Department of Agricultural and Applied Economics
University of Minnesota

INTRODUCTION

The U.S. produces about half of the worlds' corn. On average, about 10 million acres are harvested for silage and forage and the rest is harvested for grain. Acreage harvested for grain has varied since 1950 from a low of 54.6 million acres in 1969 to a high of 73.1 million acres in 1980. The most dramatic change since 1950 has been the growth in corn exports, which increased over 370 percent during the 1970's - a trend which turned sharply downward after 1980. The increasing reliance of U.S. corn producers on export markets is an important source of instability in producers' incomes.

The purpose of this short presentation is first, briefly to explore the problem of income instability faced by corn growers and some of its basic causes. The second objective is to discuss two proposals which may receive considerable attention as we move toward consideration of the 1985 farm bill. These are (a) export subsidies, and (b) a program of income insurance.

CAUSES OF INCOME INSTABILITY IN CORN MARKETS

Table 1 shows how the price of corn, the quantity of corn sold off farms, and the gross revenue from corn sales (price times quantity sold) have changed from 1962 through the early 1980's. These statistics show that the instability of corn gross revenues has increased over this period from between 150 to 200 percent, depending on how this instability is measured. This trend is a little easier to see if trends are expressed graphically. Figure 1 shows average nominal farm prices of corn with trend lines for 1962-1971 and for 1971-1983. Clearly, the price of corn has become less stable (although nominally higher) since the 1970's. Figure 2 shows what this price instability has done to gross farm revenues. Again, trends are upward and show increasing instability.

This instability arises in large measure from the changing demand picture in the world economy as a whole. Despite growth in domestic demand for corn and corn products, notably increases in use of corn sweeteners and other corn derived products, the increasing reliance of U.S. producers on export markets means that a growing share of earnings depend on the ups and downs of international economic forces. These forces are contributing relatively more to the instability which corn producers feel in their income. Figure 3 illustrates the sharp decline in exports since 1980. This decline reminds us that the increasing reliance on world markets can cut both ways - raising and lowering farm incomes depending on world demand. Unfortunately, recent trends are cutting into these incomes by cutting into this demand. From 1980-1983, corn exports fell by 505 million bushels, equivalent to 4.6 million acres.

Table 1

Increased Instability in the Corn Market: The 1960's vs. the 1970's

Variable	CVM[a] %			CVT[b] %		
	62/63-70/71	71/72-82/83	% Increase	62/63-70/71	71/72-82/83	% Increase
Farm Price of Corn	7.2	23.6	227.8	7.7	21.3	176.6
Gross Farm Revenue from Corn[c]	11.4	30.4	166.7	5.0	15.7	214.0
Quantity of Corn Sold off Farms	9.8	15.4	57.1	6.3	8.0	27.0
Production of Corn	10.2	17.2	68.6	8.4	9.1	8.3

a Coefficient of variation measured by deviations from the mean value over the period.

b Coefficient of variation measured by deviations from a simple linear trend over the relevant period.

c Farm price of corn multiplied by quantity of corn sold off farms.

Source: Robert J. Myers and C. Ford Runge, "Instability in North American Grain Markets I: Corn 1962-83," Department of Agricultural and Applied Economics, University of Minnesota, December 1983.

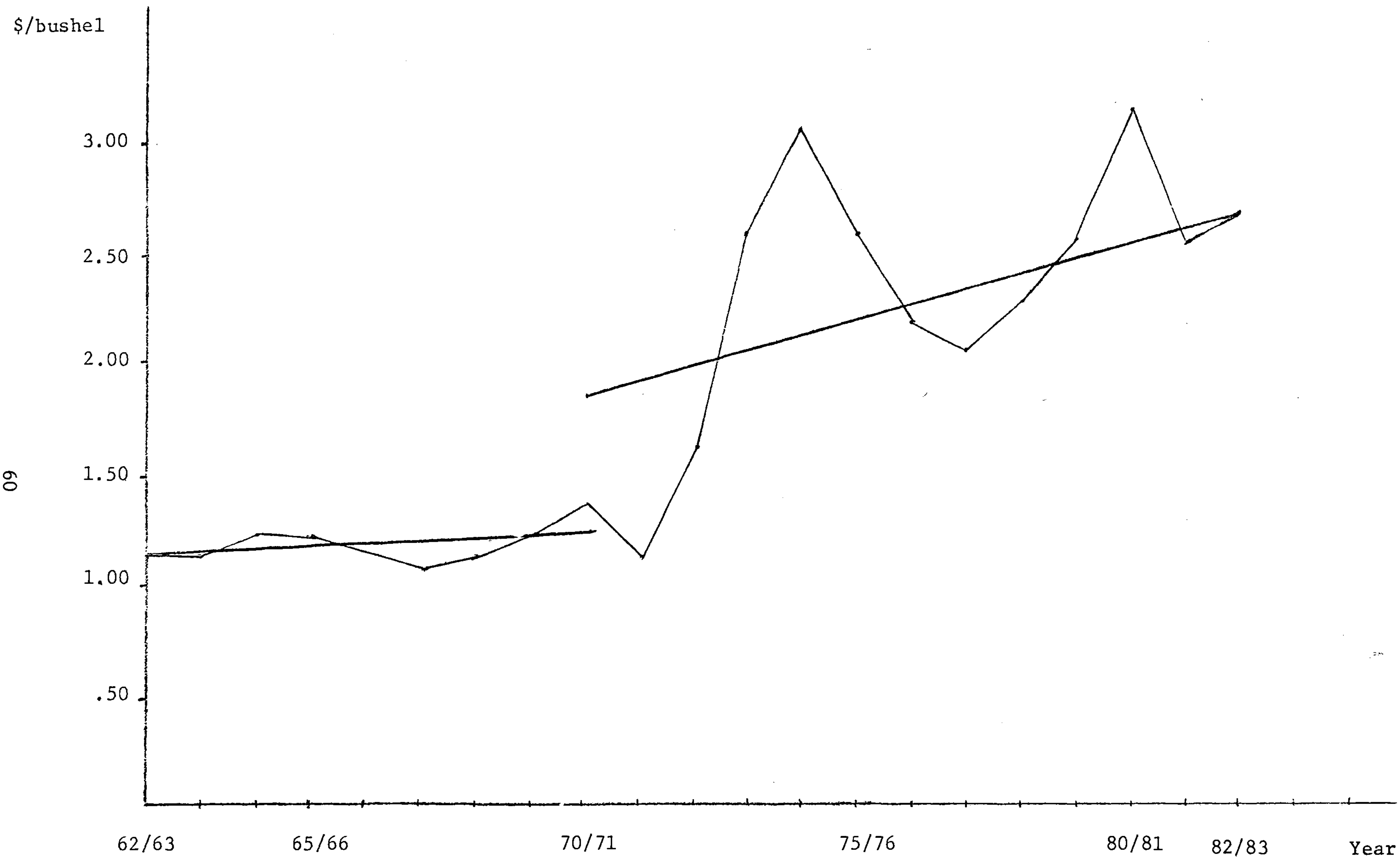


Figure 1. Average U.S. Farm Price of Corn With Linear Trends Computed over 1962/63 Through 1970/71 and 1971/72 Through 1982/83.

Source: Myers and Runge, 1983.

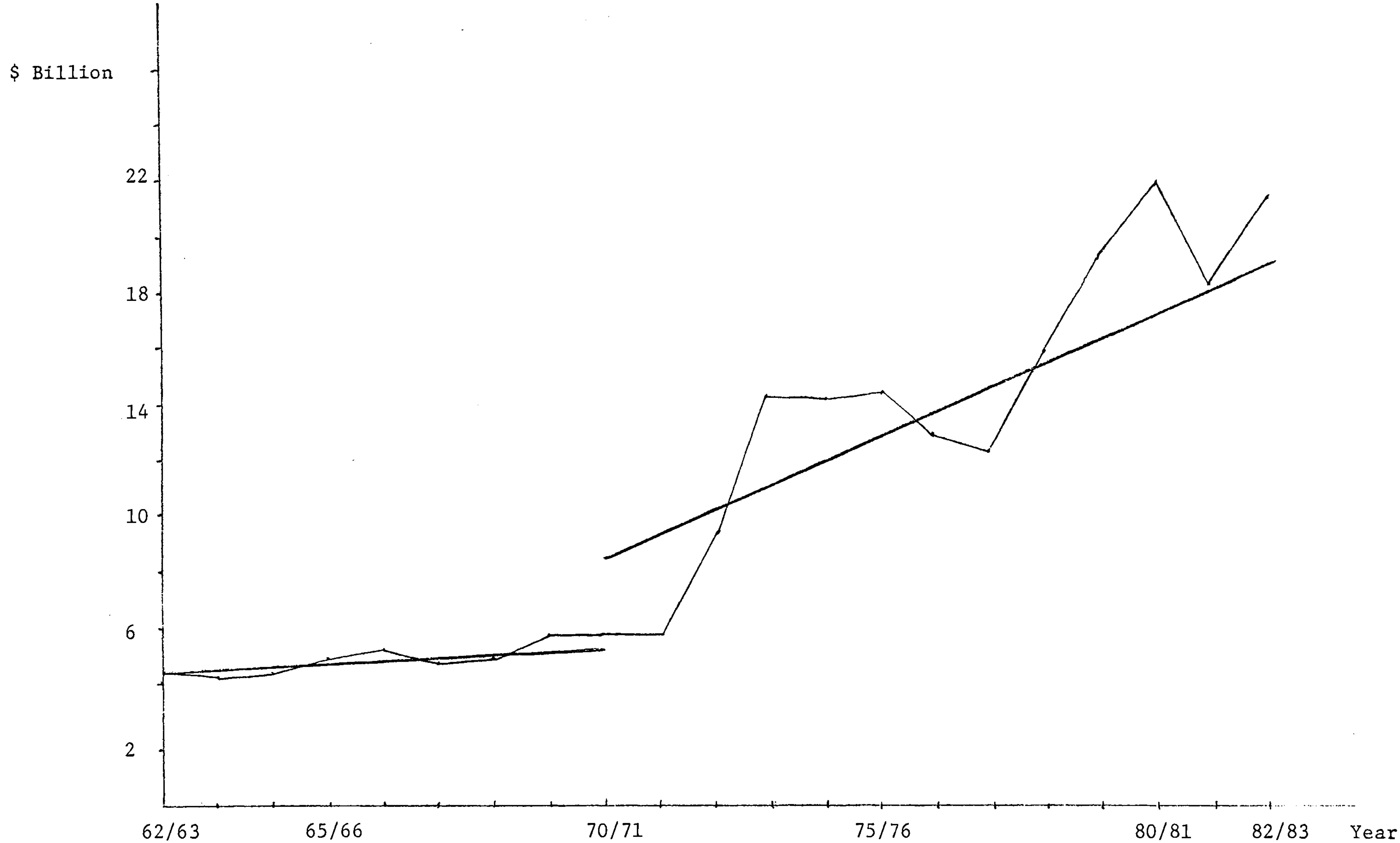


Figure 2. Gross Farm Revenue from U.S. Corn Sales With Linear Trends Computed Over 1962/63 Through 1970/71 and 1971/72 Through 1982/83.

Source: Myers and Runge, 1983.

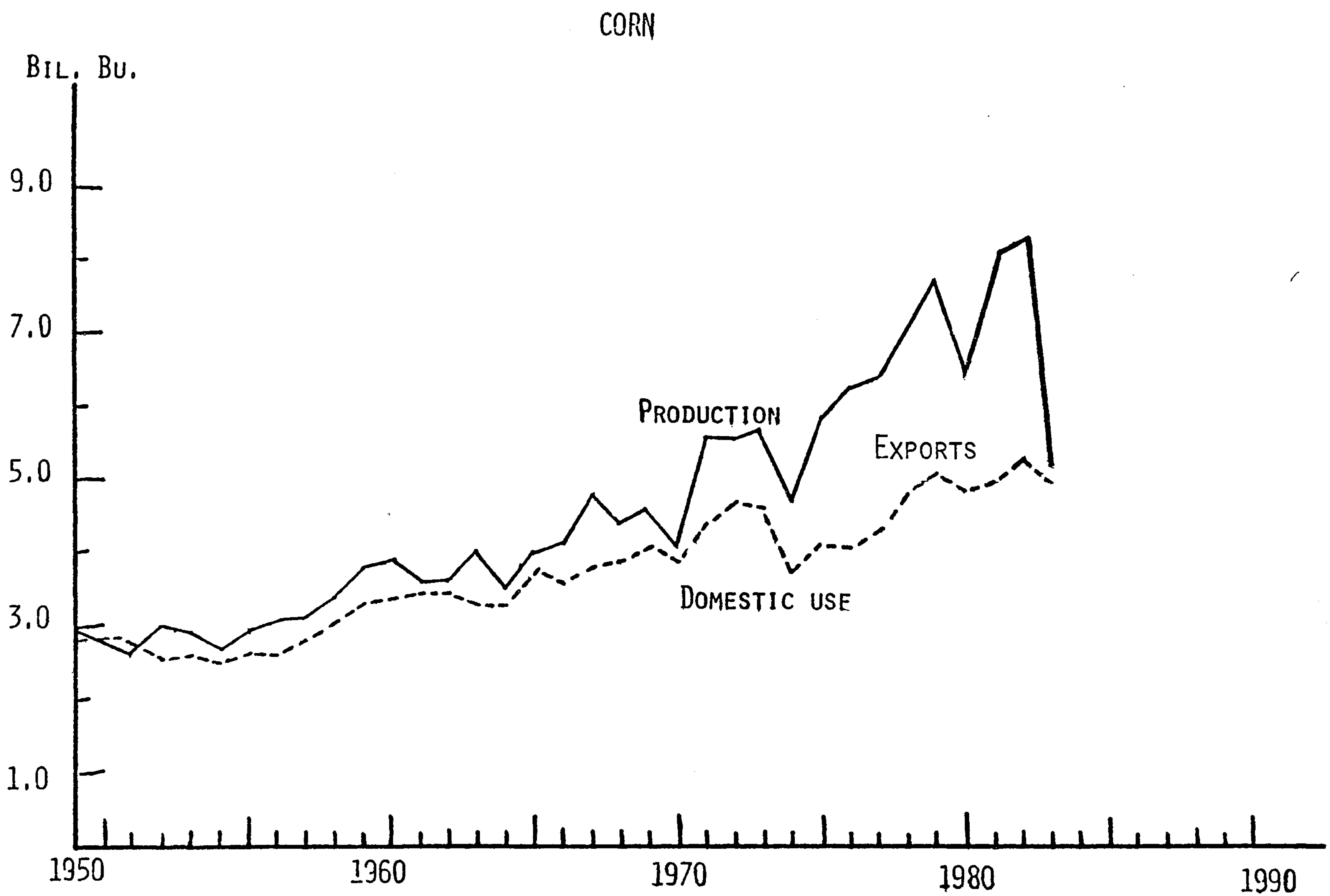


FIGURE 3.

Source: U.S. Department of Agriculture.

What are the causes of these export declines? A popular explanation is the 1980 Carter grain embargo against the Soviets. The embargo experience provided dramatic evidence of the importance of international trade to U.S. agriculture. Unfortunately, we seem to have learned some wrong lessons from the experience. Rather than recognizing that too much dependence on a single buyer of U.S. exports is destabilizing, we have recently negotiated a new long-term agreement with the Soviets, while doing little to improve our overall corn price competitiveness. The Russians, meanwhile, have negotiated long-term purchase agreements with Argentina, Canada, Hungary, and Brazil. No matter how much we want to be a reliable supplier to the Soviets, it is clear that the Soviets have no intention of making the U.S. their only supplier in the future. We would do well to pursue similar risk-spreading by diversifying our long-term export agreements.

Instead, we have allowed huge deficits to drive up real interest rates, attracting foreign capital and leading to a significant upward movement in the dollar relative to other major currencies. Who cares if the U.S. is a reliable supplier of corn - when this corn costs 25 percent more today than it did two years ago because of the dollar's value? Figure 4 illustrates what has happened to the price of U.S. corn from a point of view of importers compared to U.S. producers. While U.S. farm prices have moved only slightly over the quarters from 1980-1983, the price paid by importers of U.S. corn has risen higher and higher.

POLICY RESPONSES TO UNSTABLE DEMAND

Two policy responses to this unstable demand situation have been proposed in the early discussions leading up to the 1985 omnibus farm bill. One is to increase export subsidies so that U.S. corn will be more "competitive" on world markets. The second is to provide a buffer against the instability of market forces through a program of farm income insurance. Today I would like to argue that the first of these proposals is bad, and reinforces the mistakes of the past. The proposal for income insurance, while not all bad - has some problems which will need treatment before it is brought forward as a saving grace.

Export Subsidies

Many other countries have used and are using export subsidies to capture markets for agricultural surpluses. Subsidies have not been a large component of our own agricultural trade policy. Because we have a comparative advantage in grain production, we should be competitive in world markets without direct subsidies. Naturally, export subsidies are not the only form of export promotion - the so-called "blended credit" programs, P.L. 480 concessional sales, and food aid to low income nations are some examples of less direct approaches. Setting aside these programs, the direct subsidy cost of the remaining government programs is less than 1 percent of the total value of agricultural exports. The rapid decline in U.S. grain exports has led to a new call for direct subsidies. As I will argue in a minute, this response is misconceived - a remedy not unlike the old notion of bleeding a dying patient.

Two general approaches to subsidies are put forward. One is a uniform subsidy on all exported goods; the other is a subsidy targeted to specific markets. While targeted subsidies are generally more effective (and less expensive),

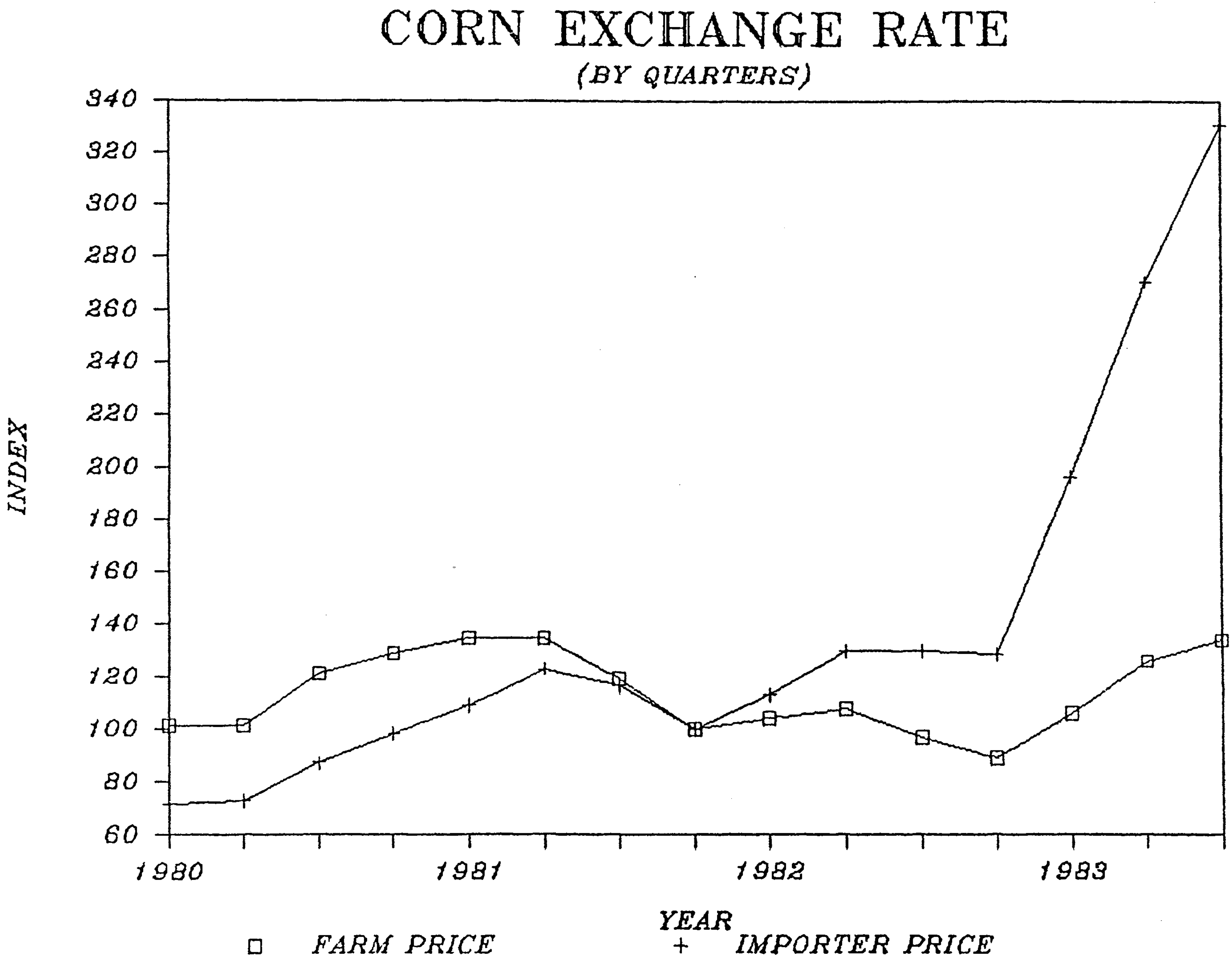


FIGURE 4.

Source: U.S. Department of Agriculture.

they are likely to lead to retaliation, either directly through import restrictions, or through increases in other countries' own export subsidies or barriers to nonagricultural trade. In addition, the subsidized portion of U.S. exports is likely to displace commercial exports. Because the United States is the world's largest producer and exporter of corn, its position is quite different from a country subsidizing the export of a small corn surplus. The cost of subsidizing the export of the huge U.S. corn crop, even under a targeted program, can be seen by looking at Figure 5. The figure shows just how large the physical volume of U.S. corn exports was compared to other exporting nations in 1982-83. Subsidizing even a portion of this crop for export is an expensive proposition. But the cost alone is less important than who bears this cost, and its overall effect on export competitiveness.

Export subsidies do no more than reduce the cost of U.S. corn to foreign buyers at U.S. taxpayers' expense. This cost adds to the federal deficit, which in turn contributes to increases in interest rates and the strength of the dollar. Since it is the strength of the dollar which is largely behind the decline of U.S. corn exports, a program of export subsidies is analogous to bleeding a sick patient. The cost of subsidies drains the Federal Treasury, raises the price the government must pay to get this money back, and thus attracts foreign capital, increasing the value of the dollar and destroying the very foundation of U.S. corn competitiveness.

Rather than focusing on corn exports in isolation - which I grant is a natural tendency if you are a corn producer - it is important to see that corn producers as exporters are affected adversely by budget deficits and a strong dollar just like any other exporter. This is especially tragic for corn producers, since the U.S. has an underlying comparative advantage in this commodity. We are better at growing it cheaply than anyone else in the world. Without the current level of deficits, corn producers would not need subsidies; with the current level of deficits, subsidies will only make the problem worse. Corn producers need to think about lowering deficits, not raising export subsidies.

INCOME INSURANCE

Income or revenue insurance is an idea which is being proposed as an alternative to the costly commodity price support programs. Largely due to the increasing role of exports, adjustments in commodity programs can do little to reduce income instability arising from forces outside the U.S. Because the commodity programs tend mainly to finance farm inventories, drops in demand in the export sector lead to large increases in corn program outlays. In fiscal year 1983, these outlays are estimated at $13.1 billion, about two-thirds of total price outlays of $21.3 billion. These costs arise in part from the attempt to stabilize corn prices and corn supplies separately. The appeal of revenue insurance is that it aims directly at stabilizing farm income. A program of income insurance would guarantee that revenue per acre of each crop would not fall below some proportions of "expected" revenues. For example, a corn farmer might insure 50 percent of revenues per acre based on an average of recent earnings. If revenue from the crop fell below the insured level, whether due to low yields <u>or</u> low prices, the producer would receive an indemnity equal to the difference. If revenues were

Corn Throughout The World

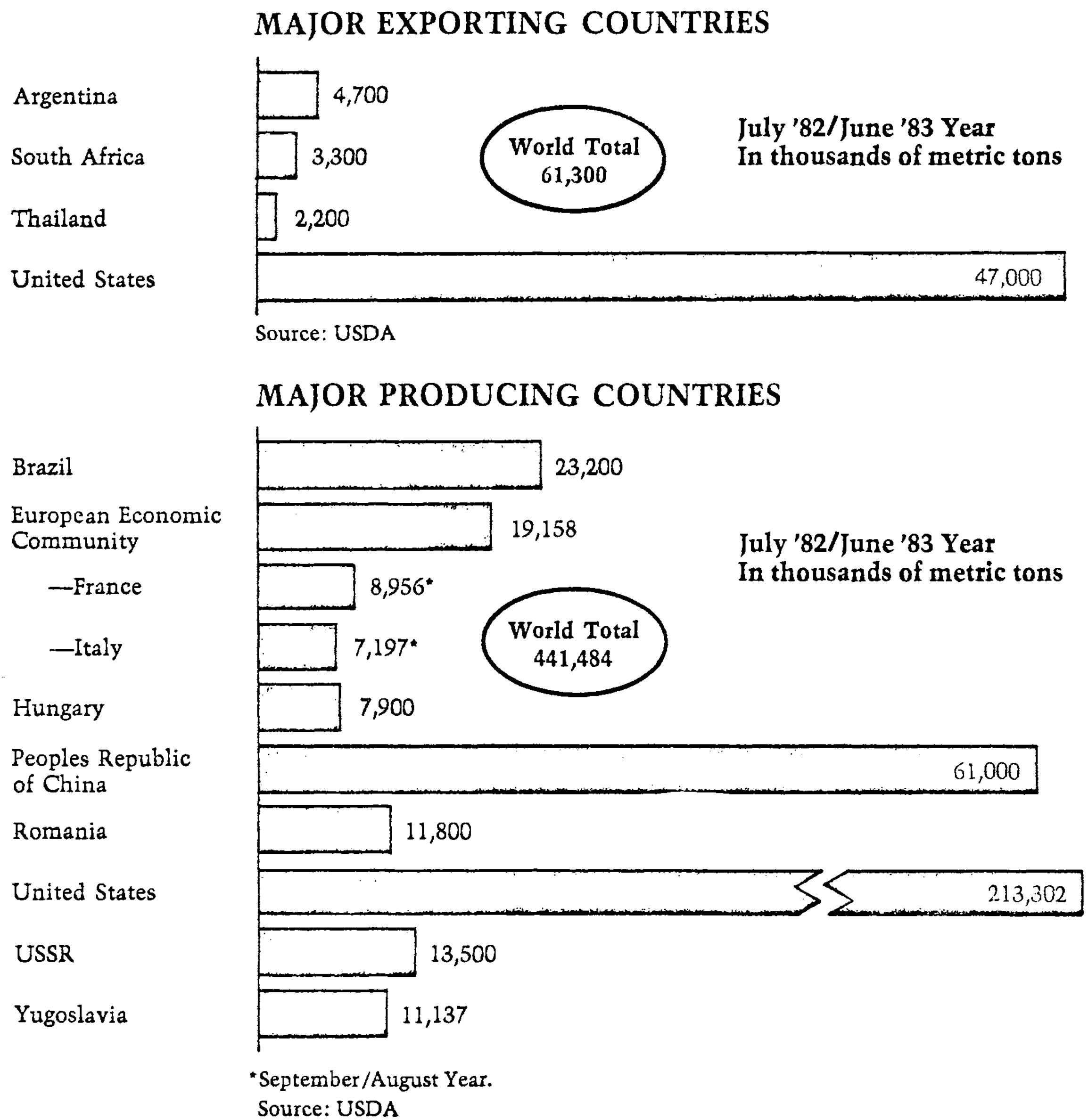


Figure 5.

Source: 1983 Corn Annual.

above the insured level, no indemnity would be paid. The premium paid for this protection would need to be adjusted to reflect the riskiness of individual producers' operations, again based on an average of prior yields.

This idea, which was originally proposed in the 1981 farm bill, is argued to be a step in the direction of letting market forces operate more freely while protecting producers from the revenue instability associated with the recent growth in exports. The costs of the program would depend on the level of coverage, the premiums, and the extent of participation, but would appear to be less than current programs, although this is not saying very much. Secretary Block has expressed considerable interest in the program. However, the higher the mean level of revenue used as a basis for calculating the indemnity, the lower the premiums, and the lower participation, the more costly the program becomes. Each of these issues is likely to be worked out in the Congressional committees, and will be subject to intensive pressure from various groups.

The most important questions facing the revenue insurance proposal are whether the risks facing those who are insured are positively correlated, and how large a pool of participants is necessary to provide a base out of which to pay indemnities. Positive correlation of risk means that the same bad things happen to everybody at the same time. This issue is related to the size of the pool, since the larger the pool the more spread out the participants are likely to be in terms of exposure to price and/or quantity risks, and the less likely it is that all participants will suffer the same negative consequences simultaneously. If the pool is small and concentrated in terms of geographic area or commodity, then changes in yields due to a drought, for example, will tend to affect the entire group. Since insurance is based on the idea that everybodies' premiums pay for the few losers' indemnities, this type of situation could be disastrous, especially if the drought was not sufficiently widespread to lead to price increases which would offset reduced yields. Another concern is whether those most willing to pay the premiums are also those who have the riskiest farm operations overall. This problem, which is called "adverse selection," has been a major difficulty in crop insurance programs, since it skews the whole calculation of payments, and makes it more likely that indemnities will be paid to high-risk producers. One way of reducing this problem is to write multi-year contracts, so that bad years are averaged against what are hoped to be good ones. Of course, a string of bad years would make this fruitless.

CONCLUSION

I have tried to isolate two policy proposals which will be important for the 1985 farm bill. Despite its problems, the concept of revenue insurance as a response to instability is a good one. Perhaps its major advantage is that it is within the control of U.S. policymakers, and will not lead to further conflicts in the trade area. It is important to develop programs, such as income insurance, which help buffer farmers against the downside risks of fluctuations in export demand while allowing them to reap the benefits of upswings in these markets. However, it is possible to act more directly to affect the instability of export earnings. This can be accomplished by making U.S. corn more competitive through reductions in the value of the dollar. This can only occur if U.S. federal budget deficits are reduced. Proposals for expanded export subsidies will only increase the deficit and lead to further trade conflicts.

Bibliography

Congressional Budget Office (CBO), "Agricultural Export Markets and the Potential Effects of Export Subsidies," CBO Staff Working Paper, Washington, D.C., June 1983.

Congressional Budget Office (CBO), "Farm Revenue Insurance: An Alternative Risk Management Option for Crop Farmers," CBO Study, Washington, D.C., 1983.

Corn Refiners Association, Inc., 1983 Corn Annual, Washington, D.C. 1983.

Edelman, Mark A. and Marshall A. Martin, "An Analysis of U.S. Farm Commodity Program Alternatives for Corn and Soybeans Under Different Export Growth Scenarios," Purdue University, Department of Agricultural Economics, Agricultural Experiment Station Bulletin No. 408, January 1983.

Farm Income Protection Task Force, Farm Income Protection Insurance: A Report to the U.S. Congress, Washington, D.C., June 1983.

Leath, Mack N., Lynn H. Meyer, and Lowell D. Hill, U.S. Corn Industry, U.S. Department of Agriculture, ERS, Agricultural Economic Report No. 479, Washington, D.C., February 1982.

Myers, Robert J. and C. Ford Runge, "Instability in North American Grain Markets I: Corn 1962-83," Department of Agricultural and Applied Economics, University of Minnesota, December 1983.

Schuh, G. Edward, "U.S. Agricultural Policy in an Open World Economy," Testimony before the Joint Economic Committee of the U.S. Congress, May 26, 1983.

FERTILIZER PLACEMENT: SOMETHING OLD, SOMETHING NEW

George Rehm
Ext. Soil Scientist - Soil Fertility
Dept. of Soil Science
University of Minnesota

The topic of fertilizer placement sometimes becomes complex and confusing if we consider N, P, and K together. Since P and K are generally considered to be immobile in soils, the principles which affect the placement of these nutrients for crop production will differ from those which influence the placement of N, a mobile nutrient.

STARTER OR BROADCAST

Until recently, corn growers had essentially two choices when deciding on the placement of P and K for corn production in Minnesota. They could either place the fertilizer somewhere to the side of and below the seed at planting (starter) or broadcast the fertilizer and incorporate it into the soil with some type of tillage operation.

Through the years, many studies have been conducted throughout Minnesota to compare the effect of starter and broadcast applications of fertilizer on corn production. The results shown in table 1 are typical of information collected in the mid to late 1950's. When the soil test P level was in the low range, highest yields were usually produced by a combination of starter and broadcast fertilizer.

TABLE 1. Effect of placement of fertilizer on corn yield in Minnesota county

Treatment	County	
	Lac qui Parle	Sibley
	--- bu./acre ---	
Control [a]	101	65
Starter only [b]	105	92
Broadcast only [c]	110	87
Starter & broadcast	113	112

a. all treatments received 60 lb. N/acre
b. 30 lb. P_2O_5 /acre used in starter treatment
c. 60 lb. P_2O_5 /acre used in broadcast treatment
Source: Overdahl

These early studies demonstrated the efficiency of nutrient use when fertilizer was applied in a band to the side of and below the seed. This advantage in efficiency has been demonstrated in several studies throughout the Corn Belt.

During the 1960's and early 1970's fertilizer was a good buy, consequently high rates of P_2O_5 and K_2O were broadcast for crop production throughout Minnesota. As a result, soil test values for P and K changed from low or medium levels to high or very high throughout much of the state. There was also an increased emphasis on early planting during this period. The earlier and faster planting emphasis encouraged the broadcast application of fertilizer because it was commonly believed that the use of a starter fertilizer slowed the planting operation.

As soil test levels for P and K moved to higher levels it was reasonable to ask if it was necessary to continue with broadcast applications or would starter placement of fertilizer be satisfactory for high yields. To answer some of these questions, studies with P and K were conducted from 1970 through 1974 in Martin and Waseca counties.

In Martin County, there was a significant yield increase from the application of starter fertilizer in 7 of 10 trials (table 2). There was a response to starter in 3 of 10 trials at the Waseca County site. These responses were observed even though the soil test value for P was in the high range and the soil test for K was in the medium - high category.

TABLE 2. Responses to use of starter fertilizer in Martin and Waseca counties from 1970 through 1974.

County	Experiment	Year 1970	1971	1972	1973	1974
		-- yield increase above control (bu./acre) --				
Martin	P	4*	2	7*	8**	13**
	K	16*	3	1	9**	8*
Waseca	P	13**	4	4	2	2
	K	10**	7*	4	3	5

** significant at the 1% confidence level.
* significant at the 5% confidence level.
Source: Overdahl, Fenster and Randall

The relative importance of either broadcast or starter application of P_2O_5 and K_2O has changed through the years. When soil test levels for P and K from many fields were in the low or medium range, the broadcast application of P_2O_5 and K_2O was a major management tool for many growers. Although lower rates of nutrients could be applied if a starter placement was used, the broadcast applications had the advantages of building the soil test levels for P and K and labor requirements were reduced with this method of application.

There is ample evidence to show that the importance of broadcast applications is reduced when soil test levels for P and K rise to high or very high levels. For these situations, the use of a starter fertilizer becomes more important. At these soil test levels, the use of a starter may not increase corn yields every year. There are, however, many years in Minnesota when spring planting conditions are cold and wet. The use of a starter fertilizer is especially important for these situations. Since weather cannot be predicted, the use of a starter fertilizer acts as an insurance policy against reduced yields caused by cold, wet spring planting conditions.

NEW TILLAGE SYSTEMS AFFECT PLACEMENT THINKING

In recent years, some have raised questions about the placement of P and K. Could there be something better? New ideas about fertilizer placement have been stimulated by the increased emphasis on reduced or conservation tillage systems for corn production.

With these new tillage systems, primary tillage is not used and, as a result, applied fertilizer is not uniformly mixed in the upper portion of the root zone (see table 3). These nutrients become layered near the soil surface. Therefore, it would be logical to think that broadcast applications of P_2O_5 and K_2O might not be appropriate for reduced or conservation tillage planting systems. The next choice might be to apply the P_2O_5 and K_2O in a starter fertilizer at planting. There are, however, limits to the amount of fertilizer that can be placed close to the seed without causing some seedling injury (table 4).

TABLE 3. The soil test P level after eight years of fertilization as affected by tillage systems used at Waseca.

Depth	Plow	Chisel	Tillage System: Ridge - Plant, Between ridges	Tillage System: Ridge - Plant, In the ridges	No - Till
in.	Soil P (lb./acre)				
0 - 2	62	72	66	136	92
2 - 4	58	42	37	84	59
4 - 6	55	22	25	39	39
6 - 9	41	10	14	24	30
9 - 12	14	5	8	15	10

TABLE 4. The amount of N plus K_2O that can be applied for corn as affected by soil texture and distance between seed and fertilizer.

Placement	Soil Texture: Coarse	Soil Texture: Fine
	Maximum amount of N & K_2O (lb./acre)	
In contact with seed	5	5 - 8
1/4 to 1/2 inches from seed	8	7 - 15
1 to 2 inches from seed	15	20 - 40
More than 2 inches from seed	20+	40+

Exploring new ways to apply fertilizer, Dr. Barber at Purdue found that banding of fertilizer at a spacing of 28 in. before plowing increased corn yields compared to both starter and broadcast applications (table 5). This strip placement allows for the application of higher rates of fertilizer while, at the same time, reducing the contact between the soil and fertilizer. The reduced contact decreases the possibility of fixation of P and/or K in soils.

TABLE 5. Effect of fertilizer placement on corn yield. Indiana.

Placement	Yield
Band near the row	115
Broadcast	121
Strip placement	132

Considering the results of the Purdue research as well as the potential stratification of nutrients when broadcast applications are used in conservation tillage systems, some researchers have raised questions about the potential benefit of applying fertilizer in concentrated bands at one or more depths in the root zone. This type of thinking within the fertilizer industry has fostered the use of such terms as "dribble application", "sub-surface bands". "pre-plant bands". To date adequate field research has not been conducted to fully evaluate the effectiveness of band applications of P_2O_5 and K_2O for corn production in either "conventional" or conservation tillage planting systems.

Some information is available from Nebraska which evaluates the effect of depth of phosphate placement on corn production. In one study, broadcast and starter placements were compared with phosphate applied with either a disk or a chisel plow. The use of these tillage implements allowed for placement of phosphate at various depths. With the disk, the fertilizer was placed at a depth of 4 - 6 inches. When applied with the chisel plow, the fertilizer was applied at a depth of 8 - 10 inches. Yields from the 1981 growing season are listed in table 6.

TABLE 6. Effect of method of application of phosphate fertilizer on the yield of non-irrigated corn. Nebraska, 1981.

Method of application*	Yield
	bu./acre
Disk control (no phosphate applied)	134
All phosphate applied with a disk	143
Half applied with a disk; half in a starter	140
Chisel control (no phosphate applied)	127
All phosphate applied with a chisel plow	143
Half applied with a chisel; half in a starter	147
All phosphate applied in a starter	145
All phosphate broadcast	142
Half broadcast; half in a starter	135

*P_2O_5 applied as 10-34-0 at 125 lb./acre

The application of 10-34-0 increased corn production at this site (compare disk and chisel controls to other treatments). Even though the soil P test was in the low range, the placement of all of the P_2O_5 in the starter did not have an adverse effect on yield. Except for the treatment where half the phosphate was broadcast and half applied in a starter fertilizer all methods of application had an equal effect on yield.

Studies have also been conducted in Nebraska to evaluate the effect of phosphate placement on the yield of corn grown on irrigated sandy soils (see table 7).

TABLE 7. Effect of method of application of phosphate fertilizer on the yield of irrigated corn. Nebraska, 1982.

Method of application*	Yield
	bu./acre
Control (no phosphate)	153
All phosphate in a starter	200
All phosphate broadcast	176
Half broadcast; half in a starter	193
All phosphate in deep band below the seed**	174
Half in a deep band**; half in a starter	188
All phosphate sidedressed	164
Half sidedressed; half in a starter	195
All phosphate applied with a disk	190
Half applied in a disk: half in a starter	201

*P_2O_5 applied as 10-34-0 @ 100 lb./acre in all treatments.
**In this treatment, phosphate was placed 6 inches to the side of and 4 inches below the seed.

As would be expected with a low soil P test, there was a substantial yield increase from the use of phosphate fertilizer. Considering the treatments in which no starter fertilizer was used, the disk application produced the highest yield and the sidedress application the lowest. When a starter was used to apply either all or part of the needed phosphate, placement had no real effect on yield. In fact, no placement was superior to the use of 10-34-0 to the side of and below the seed (starter).

The data just presented show that the depth of placement of phosphate fertilizer may not have a meaningful effect on corn yield. As would be expected, the placement of the phosphate fertilizer does affect the absorption of nutrients by young corn plants. In the study just described, corn plants were analyzed for their phosphorous content at several times throughout the growing season. The results are shown in table 8.

Early in the season (3 weeks after emergence) the phosphorus concentration in the plants was highest when the P_2O_5 was applied either in a starter or with a disk. When applied as a sidedress treatment, the phosphate fertilizer was placed at a depth of 8 - 10 inches between reow. Roots of very young plants did not reach this phosphate early in the season (compare sidedress treatment to the control).

The corn tasseled in early August. At this time, the placement used had no influence on the phosphorus content of the corn tissue. Regardless of placement, the corn was adequately supplied with phosphorus at this point in the growing season.

TABLE 8. Effect of placement of phosphate fertilizer on the phosphorus content of corn plants. Nebraska, 1982.

	Stage of Growth	
Placement	3 weeks after emergence	tassel
	P Concentration (%)	
Control	.303	.197
Starter	.393	.240
Broadcast	.360	.249
Deep band	.343	.243
Sidedress	.314	.249
With disk	.405	.243

SUMMARY

In recent years, the placement of phosphate and potash fertilizers has changed from the more traditional starter or broadcast applications. Stimulated by a renewed desire for fertilizer efficiency as well as the popularity of reduced or conservation tillage systems, various other placements of these nutrients are now under study.

Researchers are not yet at the point where they are ready to recommend the best method of placement of phosphate and potash fertilizers. Results of studies conducted to date show that there have been no differences in the way that the placement of these two nutrients affects yields.

There are many questions that still need to be answered. It may be that fertilizer placement will be matched to the tillage system used by an individual grower. In the future, growers will have a broader selection of methods to supply the phosphate and potash needed for corn production.

NITRIFICATION INHIBITORS

Gary L. Malzer
Department of Soil Science
University of Minnesota

Products known as nitrification inhibitors have been available for commercial application in Minnesota for approximately nine years. During this period, a product known as N-Serve (trademark of Dow Chemical) has received a great deal of attention. As the term nitrification inhibitor (NI) implies, products such as N-Serve are designed to inhibit or slow down the nitrification process. The nitrification process is that microbiological reaction in soils which is responsible for the conversion of ammonium nitrogen (NH_4^+-N) to nitrate nitrogen (NO_3^--N).

<u>Should I use a Nitrification Inhibitor?</u>

This question can also be restated to say should I be interested in slowing the natural conversion of NH_4-N to NO_3^--N. To address this question, we must consider nitrogen management recommendations in general. In most situations, if moisture is adequate, and we do not lose any nitrogen from the soil, it would not be necessary to make any fertilizer N recommendations concerning such things as the form of N to use the time to apply (fall vs. spring), or temperature recommendations for fall application let alone the use of a nitrification inhibitor. The reality is that we may frequently lose substantial quantities of our fertilizer N and experience yield reductions. These losses, primarily leaching and denitrification, take place from the NO_3-N form of N. (Fig. 1).

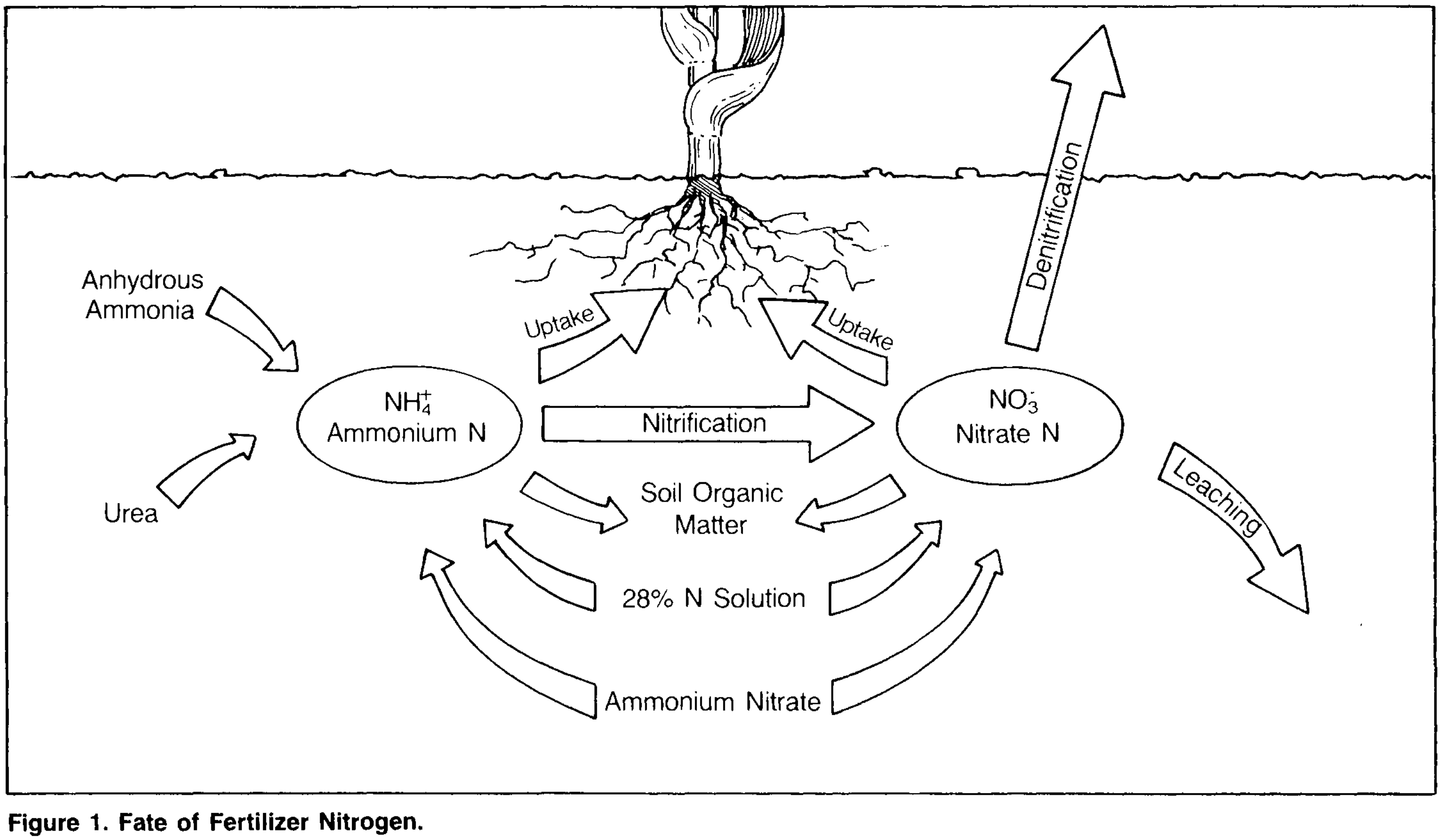


Figure 1. Fate of Fertilizer Nitrogen.

Likewise, many of the recommendations that are frequently made either to reduce nitrification (low temperature reduce nitrification) or are made to reduce the quantity of NO_3-N present in the soil at a given point in time (i.e., avoid NO_3-N applications in the fall--28% N soln. or ammonium nitrate). Recommendations regarding N management as well as the use of a nitrification inhibitor are designed to reduce nitrogen losses through leaching and/or denitrification. The next most obvious question then becomes: How much nitrogen loss do I have?

Nitrogen Loss Potential In Minnesota

In the assessment of N loss, we must be in a position to evaluate both the frequency and the magnitude of N loss. If nitrogen losses are infrequent and relatively small, we need to be less concerned about N management than the producer that might experience more frequent and substantial N losses.

There are many factors to consider when addressing nitrogen loss or attempting to determine nitrogen loss potential. Such things as soil type, time of N application, form of N applied and the rainfall patterns and/or climatic trends must be considered. On a given soil, we would anticipate a higher frequency of occurrence and an increased nagnitude of N loss in the more humid regions.

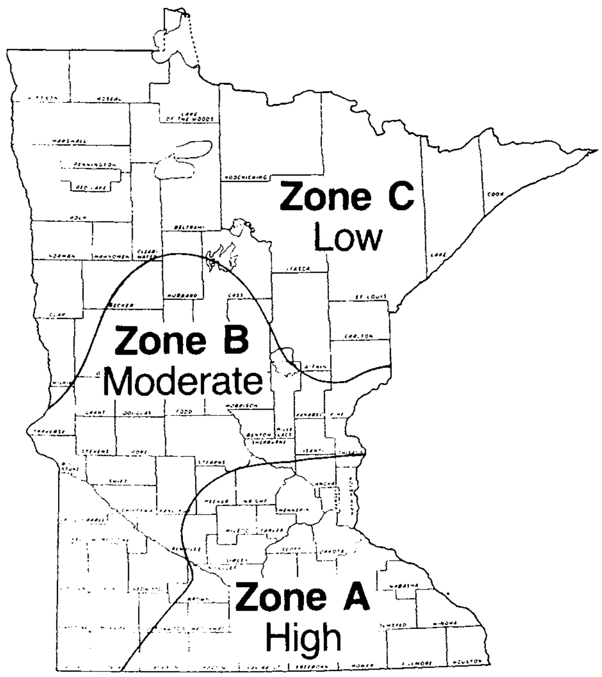


Figure 2. Climatic Zones Affecting Nitrogen Loss Potential.

The map presented in Figure 2 represents those areas of the state that we might expect differential nitrogen loss if climate was the only thing considered. As we stated above, there are a number of factors that need to be considered in addition to climate. Some of there factors are evaluated in Table 1.

Table 1. Nitrogen Loss Potential for Minnesota Soils[1].

	Zone A Soil Texture[2]			Zone B Soil Texture[2]			Zone C Soil Texture[2]		
	Coarse	Medium	Fine	Coarse	Medium	Fine	Coarse	Medium	Fine
Fall Nitrogen Application									
Soil temp. at 4 in. above 50°F	V. High	Mod	Mod	V. High	Low	Low	Mod	Low	Low
Soil temp. at 4 in. below 50°F	V. High	Mod	Mod	V. High	Low	Low	Mod	Low	Low
Spring Nitrogen Application									
Preplant	High	Mod	Mod	High	Low	Low	Low	Low	Low
Sidedressed or split application	Mod[3]	Low	Low	Mod[3]	Low	Low	Low	Low	Low

[1]V. High: probability of substantial nitrogen loss is very high; this practice is not recommended. High: probability for substantial nitrogen loss is greater than 60 percent. Mod: probability for substantial nitrogen loss is 40 to 60 percent. Low: probability for substantial nitrogen loss is 30 percent or less.

[2]Coarse: sand, loamy sand, sandy loam. Medium: silt, silt loam, loam. Fine: clay, clay loam, silty clay, silty clay loam, sandy clay loam, sandy clay. Information concerning soil texture and other soil characteristics is available through detailed soil surveys published by the Soil Conservation Service and the Minnesota Agricultural Experiment Station.

[3]Sidedressed or split applications of nitrogen made after June 15 would have a low nitrogen loss potential.

It sould be stressed that the estimations of nitrogen loss presented in Table 1 represent the estimated frequency of nitrogen loss and not an estimation of quantity. Therefore, if you are on a fine textured soil in Zone A and wish to apply fall applied N, the N loss potential is moderate. In other words, the probability is four to six years out of ten you will experience situations where your yields may be reduced because of this management technique. It can also be reversed to say four to six years out of ten this technique will be as good as any other management. Thus, yield reductions due to nitrogen loss will not occur every year. Likewise, if the nitrogen loss potential has a low rating, the probability may still be up to three years out of ten that yield reductions may be encountered.

Magnitude of N Loss

As was mentioned previously, the information contained in Table 1 deals with the frequency of N loss. It does not reflect the amount of nitrogen that may be lost. Again, the amount lost will depend on a number of factors, some of which we have little control over. As a general rule, the magnitude of nitrogen losses are more dramatic on the coarse textured soils than on the fine textured soils. This is due to the low water holding capacity of these coarse textured soils and the high leaching losses that may occur. An example of how important N management can be on coarse textured irrigated soils is presented in Table 2.

Table 2. Grain Yields as Influenced by N Management. Sand Plains Research Farm, Becker, MN - 1983.

N Treatment	Anhydrous Ammonia	28% N Soln.
	bu/a	
Preplant	107	90
Preplant + N-Serve	129	113
Sidedressed (10-leaf)	148	153

N rate - 150#N/a

In this particular experiment, nitrogen losses due to early application were severe and can be estimated by comparing preplant with sidedressed applications. Improper nitrogen management reduced yields over 40 bu/a when anhydrous ammonia was used and over 60 bu/a when 28% N solution was utilized. The N forms responded differently because 28% N solution contains approximately 25% nitrate-N and this portion would be immediately susceptible for N loss. The use of N-Serve reduced N losses and produced a positive yield response, but as is frequently the case, did not stop N loss. The nitrification inhibitors were therefore a useful tool in reducing N loss but were not a substitute for reasonable N management.

On the fine textured soils, the magnitude of nitrogen loss is much lower than what we observe on coarse textured soils. They can, however, occur and should be considered especially by those producers interested in high yields. A summary of research information from the Southern Experiment Station at Waseca is presented in Tables 3 and 4. The information presented in Table 3 is a summary of yield results over a six-year period (1977-82) comparing fall vs. spring applications at recommended rates of N application (150#N/a).

Table 3. Corn Grain Yields as Influenced by Time of N Application and N-Serve at Waseca, MN (1977-82).

	Fall[1]		Spring[1]	
	-NI	+NI	-NI	+NI
	bu/a			
1977-82[2]	163	168	165	166
Range in yield due to NI	0 + 9		-1 + 6	
Years with NI increase of 5+bu/a	3 of 5		1 of 6	

[1]Fall includes a 5-year average and spring includes a 6-year average.

[2]Applied with 150#N/a as anhydrous ammonia.

Over five years of research, NIs produced an average of 5 bu/a more with fall application and only 1 bu/a with spring application suggesting that N loss in the fall with anhydrous ammonia is of more concern. It sould also be pointed out that we did not get a positive response each year suggesting that N losses are not always a problem. At Waseca,with current prices, it is probably cost effective in the long run to use an NI with anhydrous ammonia with fall application but not spring applications. In situations where nitrogen losses occur, different N fertilizer materials frequently respond differently. Likewise, we might expect the response due to nitrification inhibitors to vary also. Table 4 presents information from a number of experiments conducted at Waseca with different nitrogen forms.

Table 4. Influence of Fertilizer Farm, Timing of N Application and Nitrification Inhibitors on Corn Grain Yield. Waseca, MN (1977-82).

	Urea[1]				28% Soln.[1]			
	Fall[2]		Spring[2]		Fall		Spring	
	-NI	+NI[3]	-NI	+NI[3]	-NI	+NI	-NI	+NI[4]
	bu/a							
1977-82	161	163	162	162				
1980-82					--	--	159	168
Range in yield due to NI	-5 +14		-5 +4				-6 +20	
Years with NI increase of 5+ bu/a	2 of 5		0 of 6				2 of 3	

[1]N rates applied = 150#N/a broadcast and incorporated.

[2]Fall includes a 5-year average and spring includes a 6-year average.

[3]Nitrification inhibitors include Dwell treatments in 1977, 78 and 79 and Dwell + N-Serve in 1980, 81 and 82.

[4]Nitrification inhibitor treatments are N-Serve.

The results presented in Table 4 would suggest that it probably would not be cost effective to utilize a nitrification inhibitor with urea on this type of soil over the long run. Substantial increases were obtained two out of three years when used with 28% N solution suggesting that the use of a nitrification inhibitor would be cost effective. In the comparison of nitrification inhibitor use with different nitrogen forms on coarse textured soils, an NI response can be obtained with all the aforementioned N form but the biggest responses will come with urea followed by 28% N solution followed by anhydrous ammonia.

Comments and Suggestions Regarding the use of Nitrification Inhibitors

The suggestions and/or recommendations will be separated according to location and soil type. If a nitrification inhibitor is utilized, it should be utilized with a substantial quantity of N to be cost effective (80+#N/a). In all situations, it is also recommended that the nitrification inhibitor be incorporated immediately after application.

Coarse Textured Soils - Zones A and B (irrigated)

1. Frequency of nitrogen loss - high
   Magnitude of nitrogen loss - high
2. Major advantage: An insurance policy to minimize nitrogen loss and to add flexibility into the producers N management program.
3. Recommendation: For corn production nitrification inhibitors recommended with any major N application made prior to the 8-10 leaf stage.

Fine Textured Soils - Zone A

1. Frequency of nitrogen loss - moderate
   Magnitude of nitrogen loss - low to moderate
2. Major advantage: An insurance policy against N loss when it occurs. Added flexibility with timing of N applications (especially fall applications).
3. Recommendations:
   a) Producers should adhere to standard N management recommendations
      --delay fall applications until soil temperatures reach 50-55^{o}F
      --avoid NO_3^--N containing fertilizers with fall application
   b) Nitrification inhibitors are probably cost effective when used with anhydrous ammonia in the fall (expecially if soil temperatures are 50-62^{o}F) or used with 28% N solution in the spring.

Fine Textured Soils - Zone B

1. Frequency of nitrogen loss - low
   Magnitude of nitrogen loss - low
2. Major advantage: none
3. Recommendation:
   a) Producers do not need to be as concerned about N management. HOWEVER, the low frequency and magnitude of N loss does not mean no possible loss. Standard recommendations may still be good guidlines.
   b) Use of nitrification inhibitors not recommended.

TRENDS IN CORN IMPROVEMENT

Jon L. Geadelmann
Professor, Agronomy and Plant Genetics
University of Minnesota

Corn improvement, or corn breeding as it's usually called, got its start as a science in the early years of the 20th century. University researchers such as E. M. East, D. F. Jones, and H. K. Hayes conducted basic genetic research in inbreeding and crossing that later developed into the billion-dollar-a-year hybrid seed corn industry. In the paragraphs below, I've attempted to describe my view of some major changes or trends that have occurred during the first 50 years or so of what's now called the "hybrid corn era". Some thoughts about future trends are also included. These trends are listed under three major headings: corn performance, the hybrid seed corn industry, and corn breeding research.

CORN PERFORMANCE

Before 1930, Minnesota corn grain yields averaged about 30 bushels/acre, changing only slightly and mainly due to weather (1). During the 1930's, the first generation of hybrids began to replace open-pollinated varieties such as 'Minnesota 13' which farmers had previously grown, and yields increased by 10 to 20%. Probably as important as yield was the improved standability of the hybrids relative to the o.p. varieties. Hybrids were quickly accepted, since their better performance more than paid for the cost of seed. More than 80% of Minnesota's corn acres were planted with hybrids in the 1940's, and by the 1970's 100% of our corn was hybrid. Crop management practices such as increased use of nitrogen fertilizer and chemical weed control were changing too, and a good summary has been given by Cardwell (1). By 1980, state average yields had reached the 100-bushel mark.

Corn breeders and their colleagues in plant pathology, entomology, etc. continued to develop "new, improved" hybrids throughout this 50-year period. Three recent studies (2,3,4) have compared hybrids from different time periods in replicated small-plot tests to estimate the contribution of improved hybrids alone to improved corn performance in farmers' fields. Each study divided the past 50 years into five 10-year periods or decades, and each included several representative hybrids from each decade in the tests. Results of these three studies are summarized in Table 1.

Grain yield

All three studies showed consistent increases in grain yield over time, with highest yields from the most recent hybrids. About 60% of the increase in corn yield over the past 50 years is due to the development and use of improved hybrids. Putting it another way, corn breeding has contributed about 1.0 bushels/acre/year to corn yield.

Average planting density (plants/acre) has increased from about 12,500 plants/acre in the 1930's to about 20,200 plants/acre in 1979 (1). Modern hybrids yielded much higher at today's higher rates than did older hybrids, and were more resistant to barreness (ears/100 plants in Table 1). Harvest index, or the percentage of grain in total plant weight (except roots) did not change.

Table 1. Changes in corn performance among hybrids from five decades, 1930-1980, grown under modern management practices.

Author and location of study; trait measured	Decade				
	1930's	1940's	1950's	1960's	1970's
Russell, 1974; central Iowa					
Grain yield - bu/a	86	101	101	111	122
Duvick, 1977; central Iowa					
Grain yield - bu/a	82	87	108	118	126
Broken stalks - %	37	32	15	11	7
Root lodged - %	47	40	23	14	10
Ears/100 plants	88	90	92	94	96
Plant health score - 1=good	3.5	2.7	2.8	2.2	2.1
Geadelmann & Marten, 1980; southern Minnesota					
Grain yield - bu/a	80	94	121	123	143
Broken stalks - %	43	45	13	11	4
Root lodged - %	17	10	30	19	10
Ears/100 plants	81	91	92	94	98
Plant health score - 1=good	3.6	4.0	3.0	2.9	2.1
Harvest index[1/] - %	44	44	44	44	44
Grain protein - %	10.8	10.4	10.1	9.7	10.4
Stover ADF[2/] - %	44	45	43	42	42
Stover ADL[3/] - %	4.6	4.8	4.8	4.6	4.7

1/ Percentage of grain in total plant dry weight, except roots.

2/ Acid detergent fiber in stalk + leaves; low = higher digestibility

3/ Acid detergent lignin in stalk + leaves; low = higher digestibility

Defensive traits

Much improvement has also been made in standability, as shown by the trend to fewer stalks broken below the ear and decreased root lodging (Table 1). Plant health score steadily improved also, which indicates higher tolerance to leaf diseases in modern hybrids. There has also been improvement in tolerance to European corn borer (Table 2), as shown by another University of Minnesota study (5). Losses to corn borer in Minnesota this past season made it clear that we still have a lot of room for improvement in this trait.

Table 2. Changes in tolerance to European corn borer among hybrids of six vintages, 1930-1970, grown under high levels of artificially infested borer.

Year	Dropped ears	Stalk damage	Broken stalks
	%	1-5	%
1930	31	3.0	30
1935	29	2.9	25
1945	11	2.8	29
1955	15	2.5	24
1965	14	2.1	8
1970	16	2.0	9

Quality traits

Some people have speculated that although modern hybrids yield more and stand better, they may have lower grain protein and tougher, less-digestible stalks. Our results (Table 1) indicated that grain protein changed little, if at all, in 50 years of corn breeding. We also included five of the formerly-grown open-pollinated varieties in one test, and found similar grain protein percentages here, too. Stover quality, as indicated by ADF and ADL, has remained constant also. In summary, our data show no trend in decreased feeding value. Modern hybrids appear to be equal to older hybrids in quality of grain, silage, and stover, when grown under modern management practices.

Future trends in performance

Corn breeders will continue to make progress, but perhaps at a slower rate than before. Many believe that much of the "easy" gain has been made, and that future improvements will be slower and more expensive (6).

Changes in corn management practices may require additional effort by corn breeders. For example, reduced tillage may require higher levels of defensive traits such as early vigor and pest resistance. If nitrogen fertilizer costs increase greatly, breeders may need to devote more attention to selecting fertilizer-efficient hybrids. Specific hybrid-herbicide or hybrid-growth regulator combinations may be available after several more years.

It has been said that hybrids of 2033, or 50 years in the future, will bear little resemblance to today's hybrids. This seems unlikely to me. I think corn in 2033 will look pretty much like corn in 1983, but future hybrids will be better able to produce under less favorable conditions (weather, pests), will use fertilizer more efficiently, and will be grown at higher plant densities. I doubt that we'll see corn fields in 2033 with nitrogen-fixing nodules on the roots and five ears on each stalk.

THE HYBRID SEED CORN INDUSTRY

The great success of hybrid corn is, of course, not due only to the researchers who develop it nor to the farmers who grow it, but also to the people who produce and distribute the hybrid seed. We tend to take their efforts for granted here in Minnesota and similar areas. However, there are many countries in our world where corn production has not increased at all over the last 50 years, in part due to the lack of a competitive seed industry that reliably provides a high-quality product to the farmer at a reasonable cost.

Current trends

In the earlier years of the hybrid era, there was about one hybrid seed corn producer in every county or two in our major corn-growing areas. The number of producers dropped as the industry matured, but it has not dropped to only a few very large companies as some predicted. In fact, the number of companies registering hybrids in Minnesota increased slightly over the last 10 years (Table 3).

Table 3. Changes in number of hybrid seed corn companies, number and type of hybrids in Minnesota. Source: Minnesota Dept. of Agriculture.

Year	Number of companies	Number of hybrids	Type of hybrid +		
			2X	3X	4X,other
			--- % of total ---		
1972	71	1188	29	26	45
1983	80	1373	64	19	17

+ Comparable figures for the entire U.S. in 1980 were 88% 2X, 11% 3X, and 1% 4X. 2X = single cross, 3X = three-way cross, 4X = double cross, other = blends and multiple crosses.

The number of hybrids registered for sale in our state has also increased, from 1188 in 1972 to 1373 in 1983. The seed corn industry remains very competitive, even though one company (Pioneer Hi-Bred International, Inc.) now has more than 30% of the U.S. seed corn market (7).

Average cost of hybrid seed corn increased from about $15 per 50-lb bag in 1970 to $45 per bag in 1980. However, the yield potential of the 1980 hybrids is about 10 bushels/acre higher and more than pays for the increased cost (for example, 3 acres/bag x 10 bu/a x $3/bu = $90/bag additional gross income).

Part of the increase in yield, etc. and cost of seed is due to the trend toward single cross (2X) hybrids. In Minnesota, we've gone from 29 to 64% single crosses during the past 10 years (Table 3). In both genetic theory and actual practice, the best hybrids will tend to be single crosses, i.e., crosses of two inbred lines (A x B). Although there are good three-way or 3X crosses (AxB/C) and double or 4X crosses (AxB/CxD), principles of quantitative genetics dictate that the best hybrid among any set of inbred parents will probably be a single cross.

All hybrids in the early years of the hybrid era were three-ways or doubles, because the inbred lines then available were too low in performance as lines to allow economic production of single-cross hybrid seed. Corn breeders improved inbreds at about the same rate as hybrids over the years (8) to the point where single crosses were feasible. Singles are still more risky and give lower hybrid seed yields from production fields than three-ways or doubles, but their higher average performance makes them a good investment when grown with good management practices.

Future trends

Many people thought that only a few, very large companies would remain in the hybrid seed corn industry by 1980. This has not happened for at least three reasons:

(1) the determined effort of smaller companies to compete and survive,
(2) continued research by some university and USDA programs that provided useful inbreds and hybrids to anyone wanting to use them,
(3) increased research efforts by private foundation seedstock companies.

I believe it's likely that a fairly large number of companies will remain in business, but that the trend in acquisition and consolidation will continue. For example, Cargill, Inc. now owns PAG and ACCO Seeds, yet has retained the brand-variety designation of each. A number of seed companies now operate under ownership by Agrigenetics, Inc. The recent merger of DeKalb AgResearch and Pfizer Genetics formed one even larger company, DeKalb-Pfizer Genetics, which markets under one brand-variety. Additional acquisitions of seed companies by larger outside companies will probably continue, such as the recent purchase of O's Gold by The Upjohn Company.

The effective number of hybrids may increase to a small degree. Certainly the number of genetically distinct or different hybrids is smaller than the 1,373 brand-varieties registered in 1983 (9), because popular hybrids of public and privated seedstock inbreds are sold under several different brand-variety designations. Regulation of the industry to prevent this would force companies to develop or purchase similar yet legally different versions of popular hybrids, but such action would probably also serve to slow the potential rate of progress in corn breeding. Increased research activity by private industry and decline in publicly-supported applied breeding research (see next section) may also tend to increase the effective number of hybrids.

The average life span of a commercial hybrid is now about 7 years (10). Most breeders believe this will become even shorter in the future.

The trend toward single-cross hybrids will continue. Nearly all hybrids planted in the "heart" of the Corn Belt are single crosses (9). As better inbreds are developed for the "fringe areas" of the Corn Belt, single crosses will become feasible in these areas, too. It is also possible (don't hold your breath) that we may see the equivalent of single cross hybrid seed produced by clonal or asexual propagation techniques in "seed factories" rather than in the usual seed production fields. Much additional research is needed for this to become reality.

Cost of hybrid seed corn will continue to increase. It may increase faster if the number of companies declines greatly, if regulation increases, and if public breeding programs place more emphasis on basic rather than applied research.

CORN BREEDING RESEARCH

Applied corn breeding has three major steps or phases: (1) source population development and improvement, (2) extraction of new inbred lines from superior source populations, and (3) testing hybrids of new lines and identifying superior new hybrids. Basic research in breeding methodology and related areas can lead to improvement in the effectiveness and efficiency of applied breeding.

Private versus public corn breeding

As mentioned earlier, hybrid corn and the seed industry grew out of what was then (ca 1910) regarded as basic research in corn breeding and genetics. For some years afterward, nearly all applied corn breeding was done by public programs - state university experiment stations and ARS-USDA. Private companies produced and sold lines and hybrids developed by public research. As the industry became well-established, several hybrid seed corn companies invested in their own applied research programs to augment public research. More recently, a few private foundation seedstock companies such as Holdens Foundation Seeds and Illinois Foundation Seeds have made substantial investments in applied breeding research. However, the great majority of hybrid seed corn companies have little or no "in-house" research and depend on private seedstock companies and public applied research for new lines and hybrids.

Private industry has been investing about 2.3% of gross hybrid seed corn sales in research, nearly all of which is applied in nature (i.e., variety development). In 1969, about $5 million was spent on private corn breeding research in the U.S.; by 1980, the investment had risen to $26 million - an increase of 520% (7). During the same time period, public investment in U.S. agricultural research (including about $2 million for basic and applied corn breeding) remained at a fairly constant level, and has declined somewhat in the last 2 years (6).

As a result of increased private research and declining public funds, public breeding research has focused on inbred line and source population development plus continuing basic research on breeding methods. Yet as of 1980, about 78% of the hybrids sold in the U.S. still had at least one public line as a parent (9). Minnesota inbreds alone accounted for 16% of the entire annual U.S. hybrid seed corn production, or enough seed to plant 13 million acres each year.

No revenue is derived by our University from the private use of these lines, and few if any companies publicly acknowledge the use of these materials.

Private corn breeding

Private investment in applied research has greatly expanded the extent to which new hybrids are tested before the best are identified and produced for sale. The largest hybrid seed companies and also cooperation between seed-stock companies and smaller hybrid seed companies may today produce data from 1,000 or more replications (plots) spread over several states on which decisions for hybrid release can be based. Such testing means that companies are making faster, better, and more reliable decisions on which new hybrids to produce and sell to farmers.

Mechanization (planters, combines) and use of modern computers in applied research have facilitated extensive testing programs. These testing efforts will probably continue in the future. As more farmers acquire small but powerful computers, hybrid seed corn companies may provide a means for farmers to "tap in" to a company's performance data files. A farmer may, in the future, be able to make meaningful comparisons of a company's hybrids much more rapidly and reliably through the use of computers.

Most of the many private breeders today are following procedures similar to those of 50 years ago to develop inbred lines for testing. This is not meant to be a negative statement. Today's procedures have been greatly refined and streamlined by basic research and by experience. It's analogous to comparing automobiles of 1933 versus 1983 - both function on the same basic principles (internal combustion engine, four wheels, etc.) but the 1983 models usually run a lot smoother and faster. They're also more complex, and there are a lot more of them.

Very little of private corn breeding research has been devoted to source population improvement and basic research. However, some of the largest companies have expanded their sales and research to international levels, and the amount of new germplasm flowing into the U.S. programs appears to be increasing. Coupled with continued public research in using exotic germplasm plus the large number of existing inbred lines (10), there appears to be little present or future danger of "genetic vulnerability" having a lasting effect on our corn crop.

Public corn breeding

Like most public programs, the Minnesota corn breeding project has three main objectives: (1) basic research in breeding methods and related areas, (2) development of improved source populations and inbred lines, and (3) training of graduate students in plant breeding. We do a lot of hybrid testing around the state, but nearly all is for evaluating experimental, unreleased inbred lines and source populations plus basic research.

The most significant trends in public corn breeding have been (1) the shift in emphasis from hybrid testing to population improvement, (2) the continued wide use of public inbred lines, (3) the increased demand from private industry and foreign countries for well-trained corn breeders, and (4) decreased funding. Recent changes in federal funding priorities will force even greater emphasis on basic research in public programs (6.7), and less emphasis will be given to inbred line development.

Future research in public programs will probably tend to emphasize basic genetic research, "genetic engineering" and the use of exotic germplasm, and long-term population improvement. These areas of research have a very high potential return on investment, but will probably require many years to achieve practical application, i.e., to get the payoff into farmers' fields. Research teams - breeder, geneticist, pathologist, physiologist, etc. - are needed for successful research in these areas, and Minnesota emphasizes the team approach. Most public programs, including Minnesota's, will maintain relatively small but hopefully effective inbred line development programs for at least three reasons: (1) training, (2) production of lines for fringe areas, and (3) evaluation of new breeding methods and materials.

SUMMARY

1. Corn performance has improved steadily over the past 50 years. Since 1930, corn breeding research has contributed an average of one additional bushel on each acre in every year. Future improvement will continue but at a slower rate.
2. Hybrid seed corn has become a highly competitive billion-dollar industry, producing mostly single-cross hybrids. Acquisitions, mergers, and failures will reduce the number of companies somewhat. The number of genetically different hybrids available to the farmer may increase, and the life of hybrids will decrease.
3. Most of the investment in applied corn breeding research is now made by private industry, although public inbred lines remain widely used to produce commercial hybrids. Public programs will emphasize basic research in genetics and related areas plus graduate-level training in plant breeding, but will maintain some inbred line development activity.

LITERATURE CITED

1. Cardwell, V.B. 1982. Fifty years of Minnesota corn production: sources of yield increase. Agron. J. 74:984-990.
2. Russell, W.A. 1974. Comparative performance for maize hybrids representing different eras of maize breeding. Proc. Annual Corn & Sorghum Res. Conf. 29:81-101.
3. Duvick, D.N. 1977. Genetic rates of gain in hybrid maize yields during the past 40 years. Maydica 22:187-196.
4. Geadelmann, J.L. and G.C. Marten. 1980. Unpublished data.
5. Windels, M.B., H.C. Chiang, and R.H. Peterson. 1974. Improvement of resistance level of Minnesota field corn to the European corn borer during the last 40 years. Proc. North Central Branch E.S.A. 29:131-135.
6. Anonymous. 1982. Executive summary of the 1982 plant breeding research forum. Pioneer Hi-Bred International, Inc., Des Moines, Iowa.
7. Sundquist, W.B., K.M. Menz, and C.F. Neumeyer. 1982. A technology assessment of commercial corn production in the United States. Stn. Bull. 546, Univ. of Minnesota Agricultural Experiment Station, St. Paul.
8. Duvick, D.N. 1980. Recent advances in maize breeding with a view to raising yield and quality. U.N. Economic Commission for Europe Symposium, Belgrade, Yugoslavia.

9. Zuber, M.S. and L.L. Darrah. 1980. The 1979 U.S. corn germplasm base. Proc. Annual Corn & Sorghum Res. Conf. 35:234-249.
10. Duvick, D.N. 1981. Genetic diversity in major farm crops on the farm and in reserve. 13th International Botanical Congress, Sydney, Australia.

WHAT'S NEW IN CORN AND SOYBEAN MANAGEMENT

William E. Luèschen, Agronomist
Southern Experiment Station
University of Minnesota

Corn growers are always seeking ways to add new technologies into their corn production programs. Over the past several years planting dates have been moved early, planting rates have increased and new efficiencies have been gained in the areas of weed control and fertilizer efficiency. Planting equipment has changed dramatically to allow farmers to plant corn at a more uniform depth and to space plants more uniformly. All of these factors have contributed to improved yields. As producers strive to improve crop yields in the future, they will continue to look for refinements in their crop management programs and adapt those practices that not only improve yields but also increase efficiency.

Recently there has been a lot of publicity about planting crops in twin rows rather than in normal single row culture. This concept evolves around a planter that plants two rows (twin rows) 7 inches apart with a 23-inch spacing between the pairs of twin rows. This system would allow a grower to harvest with conventional 30-inch row equipment. The planter that has been developed for this system uses two planting units that are mounted side-by-side and are 7 inches apart. Each pair of twin row planting mechanisms use the same seed hopper. The planting units (Kinze) are connected so the seeds are dropped in·the twin rows so the plants are offset rather than side-by-side. The theory is that since this type of planting pattern will give a more uniform distribution of plants which will allow them to more efficiently exploit the environment, higher yields will result.

A study was conducted at Waseca in 1983 to evaluate the effects of plant population and planting pattern on performance of two corn hybrids. Two planters were used in this study. The 30-inch rows were planted with a John Deere 'Max Emerge' planter while the twin rows were planted with a modified Kinze planter. The Kinze twin row planter was constructed as described above.

In this study we planted Pioneer Brand '3732' and '3906' single cross corn at plant populations of 28-, 34- and 40,000 plants/A with both planters. These were our target populations; actual population deviated slightly from this. This study was planted on May 16, 1983. Plot size was 10 x 125 feet and data was collected on the two center rows of 30-inch rows and two center pairs of twin rows. Harvest was done with a combine with a corn head for 30-inch rows. This study was designed as a randomized complete block with four replications.

All plots received an application of Lasso (3 lb/A) + atrazine (1½ lb/A) + Bladex (1½ lb/A) preemergence plus hand-weeding to remove escaped weeds. Soil test levels for both phosphorus and potassium were very high. No starter fertilizer was used in this study. Anhydrous ammonia was applied at the rate of 150 lb N/A in the fall of 1982 following soybean harvest. Two replications received an additional 75 lb/A of N as anhydrous ammonia sidedressed on July 13.

The data collected on this study is given in Table 1. Grain yields for all treatments are relatively low because of the extended period of dry, hot weather in July and August. Highly significant yield differences were observed between the two hybrids--Pioneer 3906 averaged 102 bu/A while Pioneer 3732 averaged 95 bu/A. There were also significant effects of plant population. When averaged over both hybrids and both planting patterns, yields of 103, 100, and 92 bu/A were observed for final stands of 26,700; 31,700; and 36,800 plants/A, respectively. The effects of planting pattern were not significant. The interactions between planting pattern and hybrid or planting pattern and population were not significant for grain yield.

Grain moisture was not affected by planting pattern but was influenced by hybrid and plant population. As population increased grain moisture increased from 20.1% for the low population to 20.6% for the highest population. Pioneer 3906 averaged 2.3 percentage points lower than Pioneer 3732.

In all plots the number of barren plants were counted. This data is expressed as a percentage of the total number of plants in a plot. As plant population increased the percentage of barren plants increased from 1.5% for the low population to 6.3% for the high population, averaged over hybrids and planting pattern. There was a significant hybrid x plant population interaction. Barrenness for Pioneer 3732 increased from about 1.5% at the lowest population to about 10% for the highest population. With Pioneer 3906 the percent change in barrenness was very small as plant population increased. Planting pattern had no affect on barrenness

Table 1. Effect of planting pattern and plant population on corn performance at Waseca in 1983.

Hybrid	Actual Population 1000's	Planting Pattern	% Barren Plants	bu/A	% Grain H_2O
Pioneer 3732	25.9	30"	1.6	103	20.5
	31.6	30"	5.4	94	21.8
	35.2	30"	8.4	93	21.8
	27.2	Twin	1.7	101	21.1
	30.9	Twin	5.0	97	21.7
	35.2	Twin	10.8	86	21.8
Pioneer 3906	26.6	30"	1.6	104	19.3
	32.0	30"	2.2	105	19.1
	35.9	30"	3.4	97	19.4
	27.0	Twin	1.2	104	19.3
	32.4	Twin	2.4	105	18.7
	40.6	Twin	2.6	94	19.4
Treatment averages:	Hybrid	3732	5.5	95	21.5
		3906	2.2	102	19.2
	Pattern	30"	3.8	99	20.3
		Twin	4.0	98	20.3
	Population	Low	1.5	103	20.1
		Med	3.8	100	20.3
		High	6.3	93	20.6
Significance Level(%)	Hybrid		99	99	99
	Pattern		28	61	4
BLSD(.05)	Population		1.4	4.2	0.40

The twin row system was compared to 10-, 20- and 30-inch rows with soybeans. The data are presented in Table 2. The 10-, 20-, and 30-inches were all planted with the same planter. Seed for these planting systems were packaged before planting so an exact seeding rate could be established. The twin row plots were established with the aforementioned planter which was calibrated for the various populations since the planting mechanism did not allow us to count seeds for planting an exact area. 'Hardin' soybeans were planted on June 1, 1983. Target seeding rates were: 120,000; 160,000; 200,000; and 240,000 seeds per acre for all four planting patterns. This study was designed as a randomized complete block with four replications and a plant size of 10 x 55 feet.

Soybean yield was significantly increased by narrowing the row space (Table 2). The highest yields were obtained with 10-inch rows (52.3 bu/A), followed in order by 20-inch rows (49.0 bu/A), twin rows (48.5 bu/A), and 30-inch rows (45.8 bu/A). Plant population also influenced yield. The lowest population generally resulted in lowest yields with little difference in yield among the other populations (Table 2). There were no significant interaction between population and planting pattern for yield. Population for the twin row system was lower than for the other planting systems.

Seed weights were influenced by planting pattern but not by plant population (Table 2). There was no interaction between plant population and planting pattern for seed weight.

Soybean canopy closure was influenced by both plant population and planting pattern (Table 2). As one would expect, the narrowest rows (10-inch) formed a complete canopy over the ground first, followed in order by the 20-inch, twin, and 30-inch rows. The 10-inch rows only required 59 days from planting to form a complete canopy while the 30-inch rows required 79 days. The lower plant population required three to five days longer to close the canopy than the two high populations.

Soybean plant height was similar for most planting patterns with some minor differences (Table 2). There were only small height differences among the plant populations evaluated.

Based on this one-year study, there does not appear to be any significant advantage of the twin row concept over other planting patterns. There was no yield difference between 30-inch rows and twin rows for corn. With soybeans, yields of twin rows were higher than 30-inch rows, but the twin rows were significantly lower in yield than the 10-inch rows but equal to 20-inch rows.

Table 2. Effect of planting pattern and plant population on performance of 'Hardin' soybeans at Waseca, 1983.

Planting Pattern	Actual Population	Height	Canopy[1/] Closed	Yield	Seed wt.
	1000's	inches	days	bu/A	gm/100 seeds
10"	101	33	20	51.0	14.6
	120	32	18	52.4	14.0
	166	37	18	52.8	13.9
	166	35	18	53.2	14.1
20"	106	34	34	48.5	14.4
	147	38	31	50.7	14.1
	174	38	30	50.7	14.4
	208	35	29	46.3	14.5
30"	87	35	55	43.8	15.1
	106	37	50	46.7	14.9
	137	38	47	46.4	14.4
	172	36	44	46.4	14.9
Twin	69	35	44	45.8	14.7
	73	33	46	49.2	15.0
	97	34	43	51.0	14.2
	126	36	42	48.0	14.5
Treatment Averages:					
Patterns 10"	138	34	19	52.3	14.1
20"	159	36	31	49.0	14.4
30"	126	36	49	45.8	14.8
Twin	91	35	44	48.5	14.6
Population 1.	91	34	38	47.3	14.7
2.	111	35	36	49.7	14.5
3.	144	37	34	50.2	14.2
4.	167	35	33	48.5	14.5
BLSD.05: Patterns		2.4	1.8	2.0	0.5
Population		2.4	2.0	2.3	NS

1/ Days past June 30, 1983

THE PHYSIOLOGY OF CORN MATURITY

R. Kent Crookston, Professor
Department of Agronomy
University of Minnesota

Proper adaptation of a corn hybrid to its environment is essential if the hybrid is to succeed. Although there are many aspects of adaptability, the appropriate maturity of a hybrid for the region in which it is to be grown is usually most important. Top-yielding cultivars will almost always be found among those that are rated as "full-season", or those that take advantage of most of the growing season, yet mature before the first killing frost. If an earlier-maturing "short-season" hybrid is grown, it can be expected to yield less than a full-season selection simply because it matures, or stops gaining weight, early in the season. If a late-maturing hybrid is grown, yields sometimes exceed those of full-season hybrids, but planting late-season material is not recommended. Just about the time two or three years of extended favorable fall weather have enticed a farmer to plant a late-maturing hybrid to take advantage of the extended growing season, an early frost will occur, leaving that farmer with immature (soft or wet) grain.

It is quite easy for a farmer to select--from among all the hybrids that are available on the market--one new hybrid which he knows will be maturity-adapted to his farm. It is not as easy, however, for a plant breeder to produce a new hybrid that he knows will be maturity adapted to that same farm, or even to a particular maturity zone. The maturity response of corn is an elusive and often unpredictable thing. For example, two hybrids planted on the same day on an Iowa farm may differ in ear moisture at harvest by only 5%. The same two hybrids planted on the same day on a Minnesota farm could differ in ear moisture at harvest by 15%. The primary reason for this type of response is the photoperiodic sensitivity of corn. Photoperiod sensitivity in fact severely limits the successful exchange of corn germplasm between breeding programs in different states or countries of different latitudes.

CORN NEEDS A LONG ENOUGH NIGHT

In its response to photoperiod, corn is classified as a short-day plant. This means that it can flower only when the days are short enough. Many would prefer to call corn a long-night plant, because it is the length of the night that is critical. In other words, corn will flower only if the nights are long enough to permit the flower-induction process to occur (see figure 1).

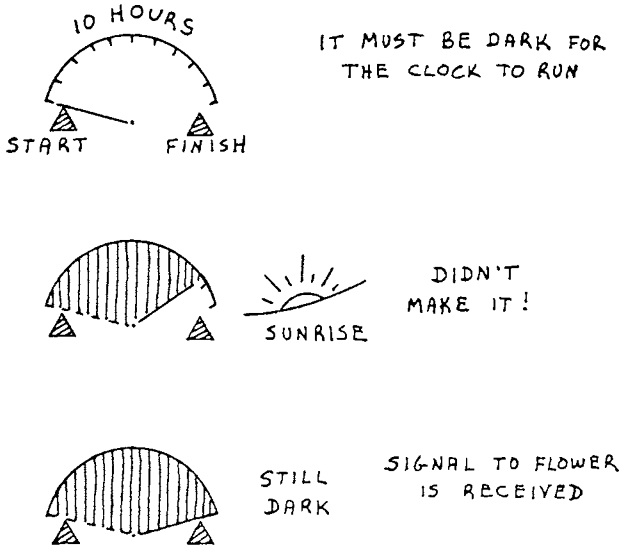


Figure 1. A diagramatic portrayal of the photo-timing process in short-day plants. In this example, the plant requires a 10-hour night to flower.

The flower-induction stimulus is received by the leaves of corn. A bluish-green, light-sensitive pigment called phytochrome is present in corn leaves in extremely small amounts and is responsible for receiving the stimulus. Phytochrome is a peculiar pigment in that it can exist in either of 2 forms, and in nature is continually changing from one form to the other. A biologically-active form exists in the light. The other form develops only under darkness and is apparantly inactive. As long as the pigment is exposed to sunlight, it absorbs out of the red part of the spectrum (660 nm wavelength) and stays in the active form. When darkness falls, or when the red wave-lengths of sunlight weaken and disappear, the pigment absorbs only from the infra-red range (730 nm), and slowly converts to the inactive form. If the darkness is of long enough duration, most of the active form will disappear. If, before the conversion is completed however, the leaves are subjected to just a brief exposure of light--the phytochrome will absorb red energy and jump back to the active form. It will then have to start the slow conversion to inactivity all over again.

Scientists do not yet understand just how a corn plant is induced to flower. It is clear that a night period of adequate length is needed so that corn-leaf phytochrome can be inactivated. Some signal (apparantly a hormone) then moves from the leaf to the shoot apex where leaf formation is terminated and tassel initiation begins (see figure 2).

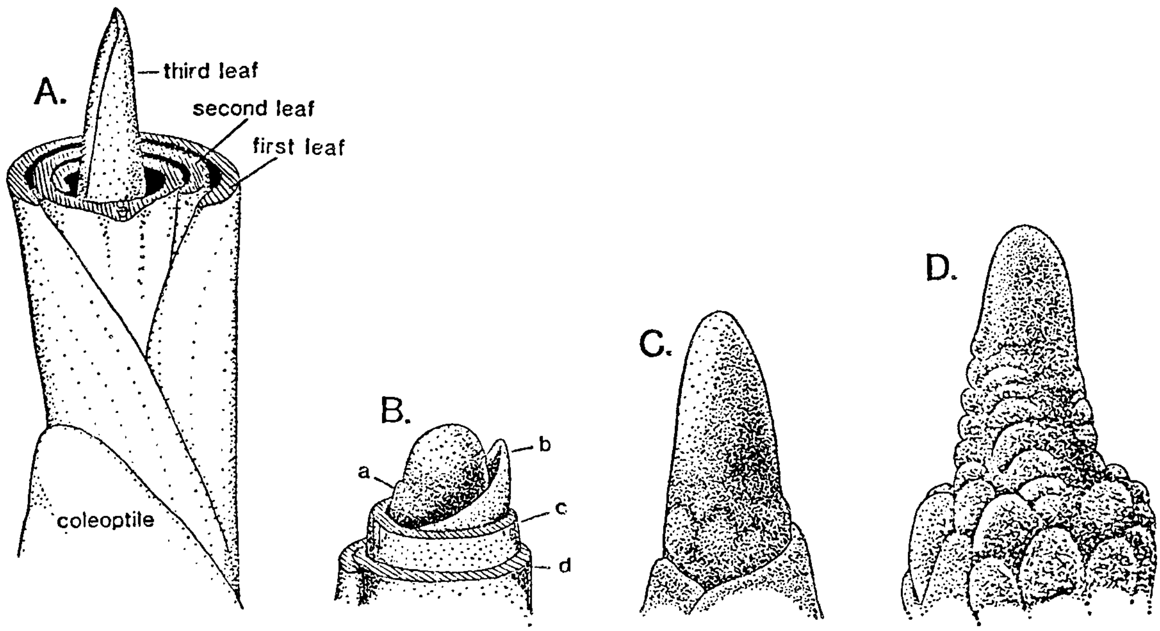


Figure 2. Growing point of corn in various stages of development. If the proper photoperiod is detected by the leaves, the apex will cease to form leaves and will begin to differentiate into a tassel. If the proper photoperiod is not detected, the apex will continue to form leaf, after leaf, after leaf, and flowering will be delayed.

A. Foliar shoot with leaf one and two removed. The third leaf is still rolled into a cone. The rest of the leaves are rolled inside of this foliar cone x 5.
B. Stem apex of corn showing the differentiation of new leaves. Leaf a is the newest, and consists of a clump of cells. Leaf b has begun to rise alongside the apex dome and will soon surround it. Leaf c and d have been removed x 50.
C. Stem apex of corn which has elongated and begun to differentiate into tassel tissue x 50.
D. Stem apex of corn 2 days older than in c. Tassel-branch initials have appeared x 50.

The reason that corn cannot be easily transferred north or south of its native maturity zone is simply because this introduces it to a change in the length of day (see table 1). For example, corn that is adapted to flower in the tropics is accustomed to a night period of nearly 12 hours. When that corn is planted in Minnesota, it experiences a night period of only 8 hours (actually less because of the twilight effect, see table 1). It therefore never receives a night period long enough to completely inactivate its tropical-programmed phytochrome, and so it just continues to develop leaves and to grow vegetatively. It may eventually develop a tassel which emerges sometime in August or September, but it will not produce grain.

Table 1. Length of the night period, or hours from sunset to sunrise at different latitudes in North America. Some corn is photo-stimulated by a light intensity of only 1 to 2 foot candles. Hours that are free of twilight = 2 foot candles or less, are therefore also given (in brackets).

Latitude	May	June	July	August	September
	22nd day of				
	hours:minutes				
50°N (Winnipeg)	8:14(7:24)	7:38(6:43)	8:18(7:29)	9:51(9:08)	11:50(11:11)
40°N (Indianapolis)	9:23(8:44)	8:59(8:19)	9:26(8:48)	10:28(9:53)	11:53(11:19)
30°N (New Orleans)	10:11(9:38)	9:55(9:22)	10:13(9:41)	10:56(10:25)	11:53(11:23)
20°N (Mexico City)	10:49(10:20)	10:40(10:10)	10:51(10:22)	11:17(10:49)	11:53(11:26)
10°N (Costa Rica)	11:22(10:55)	11:18(10:50)	11:23(10:55)	11:36(11:09)	11:53(11:28)
0° (Equator)	11:53(11:26)	11:53(11:25)	11:53(11:26)	11:53(11:28)	11:53(11:29)

When Minnesota-adapted corn is moved to the tropics, it is induced to flower prematurely--apparently because the nights are so long that the plants phytochrome is completely inactivated every night right from the start. Not only does the northern corn flower prematurely in the tropics, but it usually senesces prematurely also, and consequently fails to produce much grain.

TEMPERATURE IS INVOLVED TOO

For the first 3 to 4 weeks after emergence, most corn plants in their native habitat cannot be induced to flower regardless of the day-length. These non photo-responsive plants are classified as "juvenile" and their growth is temperature-controlled and strictly vegetative. They soon outgrow the juvenile phase however, and are then able to respond to the photoperiod if the appropriate one is provided.

For a long while after flowering has been triggered in corn, the plant is once again virtually unaffected by changes in daylength. From flower induction to silking, corn growth is controlled primarily by temperature (grows faster when it is warm). After pollination, most corn plants again begin to show a response to the daylength. Natural senescence, or shut-down of the plant's physiology is hastened as the days of autumn grow progressively shorter. The senescence response to daylength is usually less dramatic than is flowering however.

In most corn there is an interaction between daylength and temp-erature. Low temperatures can slow down the conversion of phytochrome from the active to the inactive form. Within the tropics, where day-lengths are essentially constant, corn is adapted to the altitude at which it is grown. Night temperatures at high altitudes are cool, and corn from a low (warm-night) elevation will often fail to flower when planted at higher altitudes. The phytochrome conversion in a plant accustomed to warm nights is delayed in the cool-night environment of the mountains. High-altitude corn flowers and senesces prematurely when grown in the lowlands.

SOME CORN IGNORES PHOTOPERIOD

Some corn appears to be completely insensitive to either photoperiod, or temperature within the normal range. Gaspé, and Peace River corn from Canada are examples. These varieties begin to develop tassels about 5 days after emergence, no matter what the daylength is, as long as the temperature is adequate for growth. It appears that the signal to flower is already present in the embryo of the seed of these plants, and they have no juvenile phase. At maturity, these plants are less than two feet tall, and they complete their life cycle in just two months.

Several southern and tropical varieties also show a degree of photoperiod insensitivity (see table 2). Plant breeders are very interested in such insensitivity. Incorporation of photo- and/or temperature-insensitivity into improved varieties would allow the exchange of these varieties from one latitude or altitude to another more easily. Although, as a species, maize is widely adapted, the exchange of any one particular germplasm is usually severely limited.

Table 2. Days from emergence to tassel differentiation in maize as effected by the length of the day. The study was conducted in Columbia, South America.

	Daylength		
	13 hours	17 hours	
genotype	normal day	lights on 1:00 a.m.	difference
	days to flower		
Sensitive			
D.H. 205	13	39	26
D.V. 351	14	36	22
ETO	14	39	25
Insensitive			
U.S.A. 342	13	20	7
L.E. Synthetic	13	18	5
Trojan DX-02	12	13	1

MATURITY RATING OF HYBRIDS

It is clear that the genetics of adaptation in corn is complex. It is easy to understand why two hybrids that differ in ear moisture at harvest by only 5% when grown in Iowa may differ by 15% when grown in Minnesota. Their photo and temperature responsiveness could be altered dramatically by a move of only a few hundred miles. And, in addition to photo and temperature responsiveness, some hybrids are physically capable of rapid ear-moisture loss (post-maturity dry down) whereas others, with tightly-bound and less moisture-permeable husks dry down slowly.

Although the corn breeder must concern himself with the complex problems of photo and temperature sensitivity, as well as the rate of post-maturity dry down, the Minnesota farmer need not. The current Minnesota maturity-rating system (see fact sheet No. 27) assures farmers that the hybrids they plant will mature according to their rating. The farmer will most likely never know the problems his plant breeder went through to introduce an important genetic characteristic from an exotic, or unadapted source. He only knows that he is planting seed, which, for one reason or another, will produce a plant that is maturity-adapted to his environment, and therefore will serve him well.

AGRICULTURAL EXTENSION SERVICE
UNIVERSITY OF MINNESOTA

AGRONOMY NO. 27–1973

R.H. PETERSON AND D.R. HICKS

Minnesota Relative Maturity Rating Of Corn Hybrids

It's important to select corn hybrids for local conditions. Maximum yields are obtained with "full-season" hybrids. To harvest maximum yields of dry shelled corn, you should select hybrids which reach maximum dry weight (physiological maturity) before the first killing frost. To aid farmers, Minnesota law requires that seed corn must be registered and designated with "the day classification and zone of adaptation . . . . , as declared by the owner or originator." This fact sheet describes the Minnesota Relative Maturity Rating System.

In 1939, the Minnesota Legislature established relative maturity zones and classifications. The Minnesota Agricultural Experiment Station grew hybrids in the zones of adaptation. Kernel moisture percentages were compared to the averages of experiment station hybrids which were used as standards. The test hybrids were evaluated for 3 years before they were classified.

The law was revised in 1961. Presently it establishes classifications in increments of 5 days for the five zones of adaptation (figure 1). Also, owners now assign maturity ratings after evaluating their hybrids in the zones of adaptation and comparing them with standard hybrids. Owners are allowed 4 percentage points moisture above or below the average of three designated standard hybrids. The Minnesota Department of Agriculture commissions the Minnesota Agricultural Experiment Station to periodically check ratings. The Minnesota Department of Agriculture uses these data to determine if the hybrids are correctly rated. The owner is required to change the rating if a discrepancy exists.

For example, if a company thinks it has a hybrid of 105-day relative maturity (RM), it tests the hybrid in replicated trials in the south central zone in comparison to the three 105-day RM standard hybrids. If the new hybrid tests 27.5 percent kernel moisture at normal harvest compared with 23.0 percent for the standard hybrids, the new hybrid would not be within the 4 percentage points. It would not qualify for a 105-day RM rating. However, the standard hybrid's average could be as low as 23.5 percent. Then the new hybrid would qualify for a 105-day RM. This explains why some 105-day RM hybrids may not differ much in kernel moisture percentage at harvest from some hybrids rated 110-day RM. This can happen in all maturity ratings yet the hybrids are correctly labeled according to law.

The Minnesota Relative Maturity Rating System categorizes corn hybrids into maturity groups. It should not be associated with absolute days, even though hybrids are referred to as "110-day" or "115-day" hybrids. To illustrate this point, Table 1 gives two hybrids' time length from planting and emergence to 30 percent ear moisture when grown in their adaptation zone. Calendar days associated with growth stages do not correspond to the relative maturity designations. However, when there are 5 days difference between ratings, the earlier hybrid should reach physiological maturity about 5 days before the later hybrid.

The state is divided into five corn-growing zones (figure 1) with suggested maximum relative maturities. When using the Minnesota Relative Maturity Rating System, you should first identify your area's full-season rating. Then you should select hybrids with that maturity rating to obtain maximum yields. If hybrids are rated correctly and planting occurs at normal dates (May 1 - May 20), kernels should reach physiological maturity before the date of the average first killing frost. If planting is delayed or if you desire to harvest at an earlier date, you should select a hybrid with an earlier maturity rating. If your corn is not reaching expected maturity, use hybrids with earlier ratings.

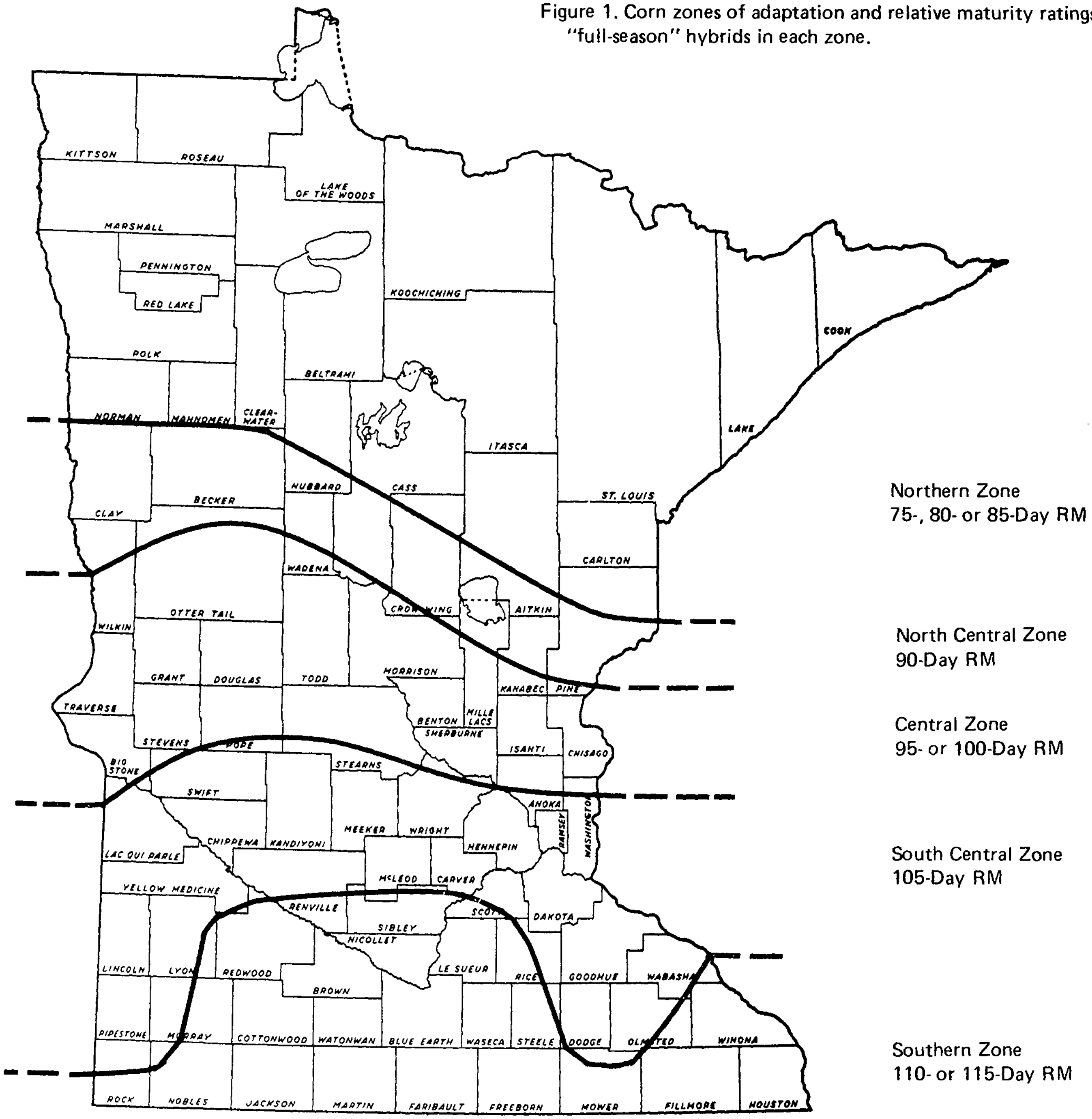
For more information regarding maturity regulations, see the State of Minnesota Agricultural Seed Laws issued by the Department of Agriculture.

Table 1. Calendar days from planting and emergence to 30 percent ear moisture for hybrids of adapted maturity at Lamberton and Morris

Location and hybrid maturity	Planting date	Calendar days to 30% moisture: From planting	From emergence
Lamberton–110-day relative maturity	April 25	154	130
	May 4	146	127
	May 17	145	133
	May 31	*	*
Morris–95-day relative maturity	April 27	153	126
	May 9	144	129
	May 17	144	132
	June 1	*	*

* These full-season hybrids did not reach 30% moisture before frost when planted at the last date.

Figure 1. Corn zones of adaptation and relative maturity ratings for "full-season" hybrids in each zone.



Issued in furtherance of cooperative extension work in agriculture and home economics, acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture. Roland H. Abraham, Director of Agricultural Extension Service, University of Minnesota, St. Paul, Minnesota 55101. We offer our programs and facilities to all people without regard to race, creed, color, sex, or national origin.

WATER MANAGEMENT IN CORN PRODUCTION

Fred G. Bergsrud, Professor and Head
Jerry A. Wright, Area Extension Irrigation Engineer
Darnell R. Lundstrom. Graduate Research Assistant
Agricultural Engineering Department
University of Minnesota

Water management is a critical factor in attaining high yields in either dryland or irrigated corn production. This paper discusses the water requirements of a corn crop, the sources of water to satisfy crop requirements, the effects of moisture deficiencies or excesses on yields, and some management ideas for consideration in optimizing water benefits.

WATER REQUIREMENTS IN CORN PRODUCTION

The total quantity of water required for corn production consists of that transpired through the plants plus that evaporated from the soil. This combination of transpiration and evaporation is referred to as evapotranspiration, E_t, or consumptive use. Optimum crop production is dependent on the soil moisture being at high enough levels to readily satisfy the crops E_t requirements. A soil moisture level near field capacity may be necessary to prevent yield reductions under certain climatic conditions. Maintaining that level is not possible except in irrigated production so in dryland production the goal must be to make optimum use of what is provided. Soil moisture levels above field capacity are seldom beneficial and if allowed to remain for any substantial period of time will reduce yields.

The seasonal E_t requirements for corn depend primarily on the relative maturity used and the climatic factors. To a lesser extent other cultural factors affect the total seasonal water requirements. In Minnesota, E_t may range from 18 inches to 30 inches per year. A more normal range is 20 to 25 inches. The normal May to September rainfall ranges from 14 to 20 inches. Some of this rainfall is normally lost to runoff or deep percolation. Even if all of this was useful to the crop, some of the crop requirement would need to be satisfied from stored soil moisture.

The variation in rate of water use with stage of growth and climatic factors and how that crop demand matches with rainfall distribution is of more concern than the total seasonal use. Moisture excesses are common in Minnesota in the spring and moisture deficiencies are common in July and August.

SOURCES OF WATER TO SATISFY CROP REQUIREMENTS

In dryland corn production there are three potential sources of water to meet the crop requirements. These are rainfall, water stored in the root zone of the crop, and water brought into the root zone by capillary rise. Irrigated crop production also has the additional water supplied by irrigation to meet the crop requirements.

Rainfall amounts will, of course, be fixed in a specific location in a given year. The utilization of that rainfall will vary with the soil and crop management practices used.

The capability of a soil to store soil moisture is also a fixed value based on the soils texture. Some variability will occur with organic matter content and with structure but in most soils the total storage or available water holding capacity, AWHC, can be considered to be a fixed value. The range in AWHCs as reported by the Soil Conservation Service in the Irrigation Guide for Minnesota is from about 2 inches for the shallow, sandy soils to around 13 inches for a silt loam soil (both values based on a 5-foot depth).

A 5-foot rooting depth is considered normal for corn when grown on soils without any special limiting characteristics. Any condition, such as inadequate internal drainage, that restricts the depth of root development will reduce the amount of water potentially used from soil storage.

The preceding discussion is on the variation in capacities of different soils. The utilization of management techniques to make maximum use of that storage capability are discussed in the last section of this paper.

Capillary rise is a known contributor to crop water use. The magnitude of contribution is difficult to determine and in most cases will be small. The potential benefit due to capillary rise is increased by controlling the water table at a specific level such as may be accomplished in some subsurface drainage systems.

The quantity of irrigation water required will vary with the soil AWHC, the relative maturity of the crop and the climatic area of the state. Using a simplified computer model, Bergsrud et al. (1982) determined the net irrigation requirements for 90-day R.M. corn grown in the Morris area of West Central Minnesota. All values are for a system design capacity of 0.25 inches net per day and an irrigation strategy based on 40% depletion of the AWHC between irrigations. The values determined for the different AWHC soils are as follows:

AWHC in Inches	Net Seasonal Irrigation in Inches
2.0	11.65
4.0	9.52
6.0	8.37
8.0	7.48

These irrigation amounts are consistent with reports from irrigators and from research and demonstration results in the area.

EFFECTS OF SOIL MOISTURE DEFICIENCIES OR EXCESSES

The effects of soil moisture deficiencies or excesses on crop yields are known in general but are difficult to quantify. Some of the factors that make the effects difficult to quantify are discussed in the following paragraphs.

The yield loss expected as a result of insufficient moisture to satisfy crop requirements varies with the stage of growth of the plants. The effect on corn yield of four days of visible wilting is shown in Figure 1. The interval from tasseling to the dough stage shows the most serious yield reducing effects.

Stegman and Aflatouni (1978) reporting on field research in North Dakota referred to three growth periods: planting to 12 leaf; 12 leaf to blister kernel; and blister kernel to physiological maturity. They reported the following yield reductions for each percent reduction in evapotranspiration.

Growth Period	Yield Reduction for Each 1 Percent Reduction in Evapotranspiration
P-12L	1.6 percent
12L-BK	2.7 percent
BK-PM	1.7 percent

The maximum yields in these tests using adequate fertility, weed control, and moisture were 180 bushels per acre. The average yield reductions caused by a one-inch decrease in E_t was 15 bushels in the planting to 12 leaf and blister kernel to physiological maturity periods. The average yield reduction in the critical reproductive stage, 12 leaf to blister kernel, was 25 bushels per acre.

Moisture excesses like deficiencies have varying effects with the crop growth stage. Early season excesses can delay planting, delay soil warming, and restrict root development. The latter effect may result in a moisture deficiency later in the season. Moisture excesses later in the season can restrict the oxygen in the root zone reducing plant respiration.

Crop susceptibility factors for excessive soil moisture conditions have been reported based on unpublished work done by Hiler (see Hardjoamidjojo reference). For corn, these are as follows:

Stage of Growth	Growing Period, Days	Crop Susceptibility Factor
Vegetative	0-42	0.51
Silking and tasseling to soft dough	42-80	0.33
After soft dough	80 to maturity	0.02

Although these factors show a very small yield effect due to excess water late in the growing season, there may be a decrease in harvested yields due to wet field conditions.

A method of measuring stress caused by fluctuating water tables was reported by Wesseling (1974). This method quantifies the excess moisture in the top 30 centimeters (about 1 foot) of soil and refers to them as the SEW_{30}. If the top 30 centimeters is completely saturated for one day, the result would be an SEW_{30} of 30 centimeter days. If an average of 15 centimeters are saturated for 3 days, the SEW_{30} would be 45 centimeter days for that period.

These values can be combined with the crop susceptibility factor for stage of growth to arrive at a stress day index, SDI. For example, the 45 centimeter days calculated as an SEW_{30} if it occurred in the vegetative stage would be multiplied by 0.51 to arrive at (45 x 0.51) a stress day index, SDI, of 23.

Using the results of long-term field experiments at Ohio State University, Hardjoamidjojo et al. (1982) developed a relationship between relative corn yield and stress day index. The results of their work are shown in the following table and in Figure 2. If a 180 bushel per acre potential yield is assumed, the yield loss for a stress day index of 50 would be about 27 bushels per acre. Considering the many cultural and climatic factors that affect corn yields these results indicate a very well defined relationship.

Table 1. Relative Yield (YR) and the Stress Day Index (SDI) For Excessive Soil Water Conditions, Ohio Experiments

	Treatment							
	No drainage		Surface drainage		Tile drainage		Tile + surface drainage	
Year	SDI	YR	SDI	YR	SDI	YR	SDI	YR
1962	111.1	45	60.7	92	23.6	100	22.5	99
1963	87.9	58	50.6	81	25.5	95	26.8	99
1964	94.5	54	46.2	78	26.4	93	28.7	95
1967	132.8	46	63.1	76	36.0	86	35.7	91
1968	209.4	40			66.8	89	64.0	94
1969			143.1	27	84.9	60	67.0	68
1970			106.7	31	53.5	70	52.5	79
1971			130.1	48	32.6	88	32.5	100
1976			125.8	74	47.0	83	43.3	88
1977			108.1	61	48.2	84	46.4	91
1978			53.5	81	31.5	95	16.5	100
1979			63.3	56	32.4	85	22.8	89

Note: SDI and YR are in cm days and percent, respectively.

MANAGEMENT IDEAS FOR OPTIMIZING WATER BENEFITS

Several management ideas for optimizing water benefits can be made. Basically they all center around the concept of banking off-season soil moisture, retaining that moisture for later crop use and keeping all needed rainfall in the place where it falls until it infiltrates into the soil for later use by the crop.

Good internal soil drainage to allow spring field work including planting to be accomplished early is essential. Adequate drainage is also important to promoting a deep rooted crop which is desirable in meeting the crop water needs later in the summer.

A minimum tillage program that fits the soil and cropping program provides several advantages. It increases the stored soil moisture at the beginning of the season by decreasing water losses in the spring. Estimates place the losses with each tillage operation generally in the range of 0.25 to 0.50 inch. Residues on the surface enhance infiltration, keep losses from the surface down and reduce crusting in the period before the crop canopy protects the surface. Fewer tillage operations also reduce the chance of compaction which has adverse effects on water infiltration and percolation.

Farming on the contour and other farming practices like ridge tillage or basin tillage that assist in holding water, even from high intensity rainfalls, in place until they have time to infiltrate can be very beneficial.

The use of recommended cultural practices is necessary to provide an environment for efficient crop growth. Included are practices like proper fertility, effective weed control, elimination of stress due to insects or diseases, etc.

If irrigating, good water management to predict when irrigations are required is a necessity. The program should include some type of soil moisture measurement as well as a method to predict crop water use. This type of program is necessary to avoid either over or under irrigating.

LITERATURE CITED

Bergsrud, F. G., J. A. Wright, H. D. Werner and G. J. Spoden. 1982. Irrigation system design capacities for West Central Minnesota as related to the available water holding capacity and irrigation management. ASAE Paper No. NCR 82-101.

Hardjoamidjojo, S., R. W. Skaggs, and G. O. Schwab. 1982. Corn yield response to excessive soil water conditions. ASAE Transactions Vol. 25, pp. 922-927.

Stegman, E. C. and M. Aflatouni. 1978. Corn yield responses to water stress management. ASAE Paper No. 78-2558.

Wesseling, J. 1974. Crop growth and wet soils. In: Drainage for Agriculture, J. Van Schilegaarde (ed). ASAE Monograph No. 17.

Figure 2. Corn relative yield-stress day index relationship for Ohio experiments. Each point represents two to four replications.

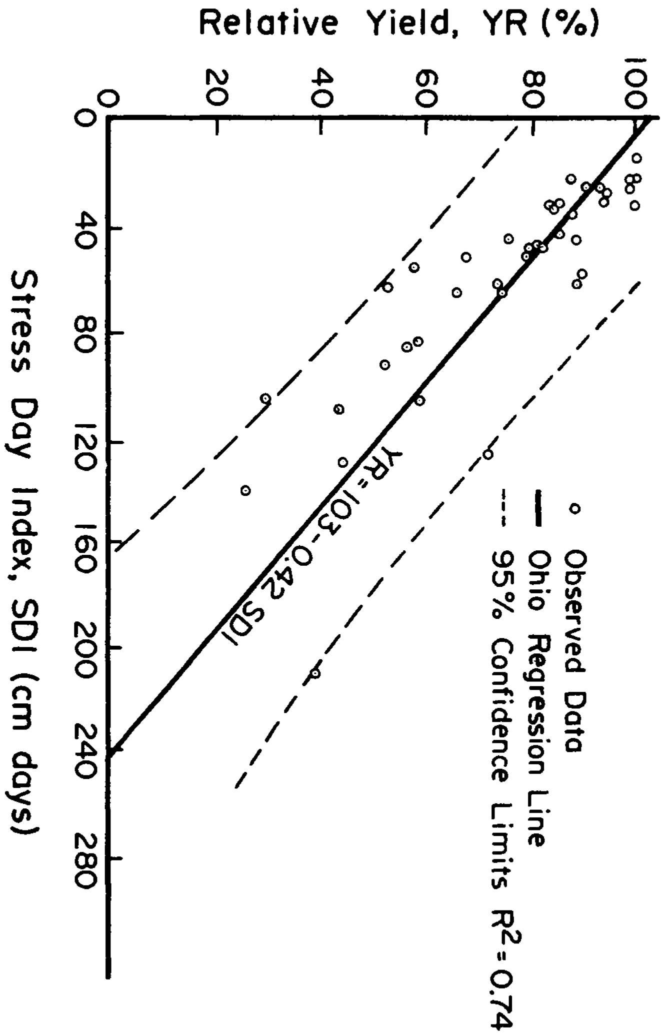
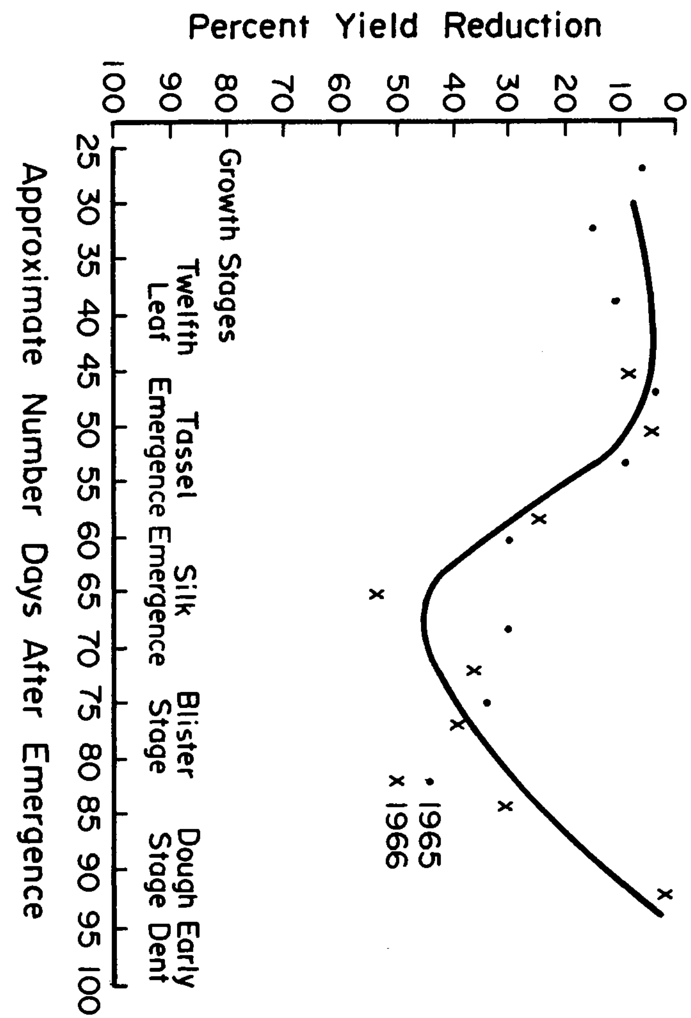


Figure 1. Effect of 4 days of visible wilting on corn yield (From Claassen, M. M. and R. H. Shaw. 1970. Water Deficit Effects on Corn. II Grain Components. Agron. J. 62:562-655).



GRAIN SHRINK CALCULATIONS

Harold A. Cloud
Extension Agricultural Engineer
Department of Agricultural Engineering
University of Minnesota

When the moisture content of grain is reduced there is a weight loss, commonly referred to as "shrink." The shrink is usually expressed as a percentage of the original quantity in bushels, pounds, or tons. There are several procedures used to "pencil shrink" grain to determine the quantity of grain remaining after drying. There is considerable confusion and lack of understanding of those calculations and the results obtained through their use.

WATER SHRINK

The major weight loss or shrink incurred in grain drying is due to the removal of water. An ideal drying process would be where the only weight loss was the water removed. This situation can be readily analyzed through standard calculations since the weight of "dry matter" before and after drying will be the same.

Example:

a) Assume 100 bushels (5,600 pounds) of corn at 25% moisture content is reduced to 14% by ideally removing only water.

b) Initially, the corn contains 1,400 pounds of water (25% of 5,600) and 4,200 pounds of "dry matter" (75% of 5,600).

c) Since only water is removed (in this ideal situation), 4,200 pounds of "dry matter" remains after the moisture content is reduced to 14% (dry matter is 86%).

d) As a result, 86% of the final weight must be 4,200 pounds. The final weight at 14% is obtained by dividing 4,200 pounds (weight of dry matter) by 0.86, giving 4,883.72 pounds or 87.21 bushels.

e) The calculations can be checked by calculating the weight of "dry matter" at the initial and final moisture content.
Initial - 5,600 pounds x 0.75 = 4,200 pounds
Final - 4,883.72 pounds x 0.86 = 4,200 pounds

In the above ideal example, 716.28 pounds of water was removed from 5,600 pounds of corn, giving a "water shrink" of 12.79 percent (716.28 divided by 5,600). Since we started with 100 bushels, the loss in weight is equivalent to 12.79 bushels, leaving 87.21 bushels at 14 percent. The same result is obtained by dividing the final weight of 4,883.72 pounds by 56 pounds per bushel.

In the above example, a weight loss or "water shrink" of 12.79 percent occurs when shelled corn is dried from 25 percent to 14 percent moisture content by ideally removing only water. It is clear that shrink <u>cannot</u> be calculated by using the difference between initial and final moisture contents. In this case the "water shrink" is 12.79 percent with a moisture reduction of 11 percent (from 25 percent to 14 percent) or a weight loss of 1.163 percent per point of moisture removed. If the same calculation is made starting with shelled corn at 30 percent and drying to 14 percent, the "water shrink" is 18.60 percent or the same 1.163 percent per point of moisture removed.

WATER SHRINK FACTOR

The "water shrink" per point of moisture removed is constant for any given final moisture content. Therefore, the ideal water shrink can be calculated by use of a "water shrink factor" which varies with the final moisture content. The "water shrink factor" can be calculated for any final moisture content by dividing the final dry matter content (in decimal form) into one.

Example:

a) In the previous example a "water shrink factor" of 1.1673% per point of moisture was obtained when shelled corn was dried to 14% moisture content.

b) For a final moisture content of 14%, the final dry matter content in decimal form is 0.86.

c) One divided by 0.86 equals 1.1628% (rounded off to 1.163) per point of moisture.

Table 1 gives the "water shrink factor" which can be used to determine the ideal water shrink when grain is reduced to various final moisture contents.

Table 1. Water Shrink Factors

Final Moisture Content Percent	Water Shrink Factor % shrink per point
15.5	1.1834
15	1.1765
14	1.1628
13	1.1494
12	1.1364
11	1.1263
10	1.1111
9	1.0989
8	1.0870
0	1.0000

Example: Calculate the water shrink when shelled corn is dried from 25% to 12% moisture content.

a) Water shrink factor from Table 1 is 1.1364% per point.

b) Points of moisture is 25% - 12% = 13 points.

c) Water shrink = 1.1364% per point x 13 points = 14.773%.

The calculation can be checked by determining the pounds of dry matter in a given initial weight (for simplicity, assume 1,000 lbs.) of shelled corn before and after drying.

a) Since the water shrink is 14.773%, 147.73 pounds are lost from an initial weight of 1,000 pounds, leaving a final weight of 852.27 pounds.

b) Weight of dry matter before drying = 1,000 pounds x 0.75 = 750 pounds.

c) Weight of dry matter after drying = 852.27 pounds x 0.86 = 750 pounds.

Since the weight of dry matter after drying is the same before and after drying, only water was removed (147.73 pounds) in this ideal drying situation.

HANDLING LOSS OR INVISIBLE SHRINK

In addition to the water shrink incurred in drying there will be some other losses which are commonly referred to as "invisible shrink." Probably a better term for this additional loss is "handling loss." These losses will normally be quite small when compared to the water shrink. Some drying tables have been constructed in which a constant "invisible shrink" or "handling loss" is added to the calculated water shrink to give the total shrink. Most of these tables use a handling loss of 0.5 percent.

Example: Using 0.5% handling loss, calculate the total shrink when drying shelled corn from 28% to 15.5% moisture content.

a) "Water shrink factor" (from Table 1) = 1.1834% per point.

b) Points of moisture removed = 28% - 15.5% = 12.5 points.

c) Water shrink = 12.5% x 1.1834% per point = 14.79%.

d) Total shrink = 14.79% + 0.5% = 15.29%.

SHRINK FACTOR

Another procedure commonly used to "pencil shrink" grain during drying is to use a "shrink factor." The total shrink is determined by multiplying the moisture content reduction by the "shrink factor." Commonly used "shrink factors" vary from 1.25 percent per point to 1.5 percent per point.

Example: Compare the total shrink calculated with a shrink factor of 1.4% per point to the water shrink when drying shelled corn from 25.5% to 15.5% moisture content.

a) Moisture content reduction = 25.5 - 15.5 = 10 points.

b) Total shrink (calculated by use of shrink factor) = 1.40% per point x 10 points = 14.00%.

c) Water shrink factor from Table 1 = 1.1834% per point.

d) Water shrink = 1.1834% per point x 10 points = 11.83%.

In this example the total calculated shrink is 14.00 percent and the water shrink is 11.83 percent. The difference of 2.17 percent is a handling loss or invisible shrink built into the total shrink by using a 1.4 percent shrink factor when drying from 25.5% to 15.5% moisture content.

RESEARCH ON HANDLING LOSSES DURING DRYING

Research at Iowa State University has shown handling losses of 0.22 percent to 1.71 percent over several years in both commercial and on-farm drying operations. The handling losses for six on-farm low temperature drying tests over a three year period ranged from 0.22 percent to 1.71 percent with an average of 0.78 percent. Handling losses for four on-farm high temperature drying tests ranged from 0.54 percent to 1.25 percent with an average of 0.87 percent. One test on an intermediate temperature dryer in 1979 gave a handling loss of 0.40 percent. The same year one test on a high temperature dryer had a handling loss of 0.65 percent.

Three years of tests on commercial drying facilities yielded handling losses ranging from 0.64 percent to 1.33 percent with an average of 0.88 percent. The handling losses did not appear to depend on initial moisture content. In the 1979 commercial test a handling loss of 0.64 percent occurred when drying from 27 percent to 15.5 percent, whereas in 1980 a handling loss of 1.33 percent occurred when drying from 19.5 percent to 14.5 percent.

HANDLING LOSSES INCLUDED IN SHRINK CALCULATIONS

It is to everyone's best interest to understand shrink calculations when buying and selling grain at various moisture contents. The difference between the water shrink and the total shrink, calculated by any procedure, is the assumed handling loss. It is necessary to recognize the handling loss built in to any shrink calculation.

Table 2 gives the handling loss built into the total shrink calculated by various shrink factors when drying shelled corn to 15.5 percent moisture content.

Table 2. Handling Loss Contained in a Total Shrink Calculated from a Shrink Factor

INITIAL MOISTURE CONTENT %	SHRINK FACTOR						
	1.20	1.25	1.30	1.35	1.40	1.45	1.50
	handling loss (%)						
32	0.27	1.10	1.92	2.75	3.57	4.40	5.22
30	0.24	0.97	1.69	2.42	3.14	3.87	4.59
28	0.21	0.83	1.46	2.08	2.71	3.33	3.96
26	0.17	0.70	1.22	1.75	2.27	2.80	3.32
24	0.14	0.57	0.99	1.42	1.84	2.27	2.69
22	0.11	0.43	0.76	1.08	1.41	1.73	2.06
20	0.07	0.30	0.52	0.75	0.97	1.20	1.42
18	0.04	0.17	0.29	0.42	0.54	0.67	0.79

(Drying to 15.5 percent moisture content)

Table 3 gives the shrink factors necessary to yield a 0.5 percent, 1 percent, and 1.5 percent handling loss when drying to 15.5 percent.

Table 3. Shrink Factors Required to Yield Specific Handling Losses when Drying to 15.5%

Initial Moisture Content (Percent)	Handling Loss		
	0.5%	1%	1.5%
	Necessary Shrink Factors		
32	1.214	1.244	1.274
30	1.218	1.252	1.287
28	1.223	1.263	1.303
26	1.231	1.279	1.326
24	1.242	1.301	1.360
22	1.260	1.337	1.414
20	1.295	1.406	1.517
18	1.383	1.583	1.783

CONCLUSIONS

It is clearly evident from Tables 2 and 3 that grain shrink calculations based on a shrink factor (percent shrink per point of moisture) builds in a variable handling loss which depends on the initial moisture content. The research at Iowa State University indicates the handling loss is not dependent on initial moisture content. If a handling loss of 1 percent to 1.5 percent is assumed reasonable based on that research, a shrink factor of 1.5 percent per point is reasonable for low initial moisture contents (18 percent to 20 percent). However, if a 1.5 percent per point shrink factor is applied to initial moisture contents of 25 percent to 30 percent a handling loss of 3 percent to 4.5 percent is built in. This would seem to be somewhat unreasonable based on the Iowa State research.

It is assumed that handling losses during drying are not dependent on initial moisture content. The use of a constant shrink factor throughout the entire range is not correct. A shrink factor that varies with moisture content or the addition of a constant handling loss to the water shrink may be more appropriate. Regardless of the procedure used to "pencil shrink" grain during the drying process it is vital that all parties affected by the calculations understand the procedure and the results obtained from it. This should be a high priority for anyone buying or selling grain in which a shrink calculation is involved.

LITERATURE CITED

Hurburgh, Charles R., Jr., Carl J. Bean, W. F. Wilcke, and M. E. 1982. Shrinkage and corn quality changes in on-farm handling operations. ASAE Paper 82-3550. American Society of Agricultural Engineers, St. Joseph, MI.

Hurburgh, Charles R., Jr. and Bruce W. Moechnig. 1982. Corn quality changes in commercial elevator operations. ASAE Paper 82-3547. American Society of Agricultural Engineers, St. Joseph, MI.

INSECT CONCERNS

CONTENTS:

Typical life history of the European corn borer in southern Minnesota

Typical life history of the European corn borer in northern Minnesota

European corn borer fall populations-An historical perspective

Summary of insecticide performance against European corn borer in University of Minnesota trials (1981-1983)

Corn hybrid evaluations for first generation European corn borer resistance

Making control decisions for first generation corn borer in Minnesota

European corn borer control (Fact sheet revision)

Corn rootworm adult survey

1983 corn rootworm damage surveys of first year corn

Minnesota corn rootworm trials-1983
- Lamberton
- Rosemount
- Morris
- Waseca

Consistency of root protection by registered corn rootworm insecticides -Minnesota experience 1977-83

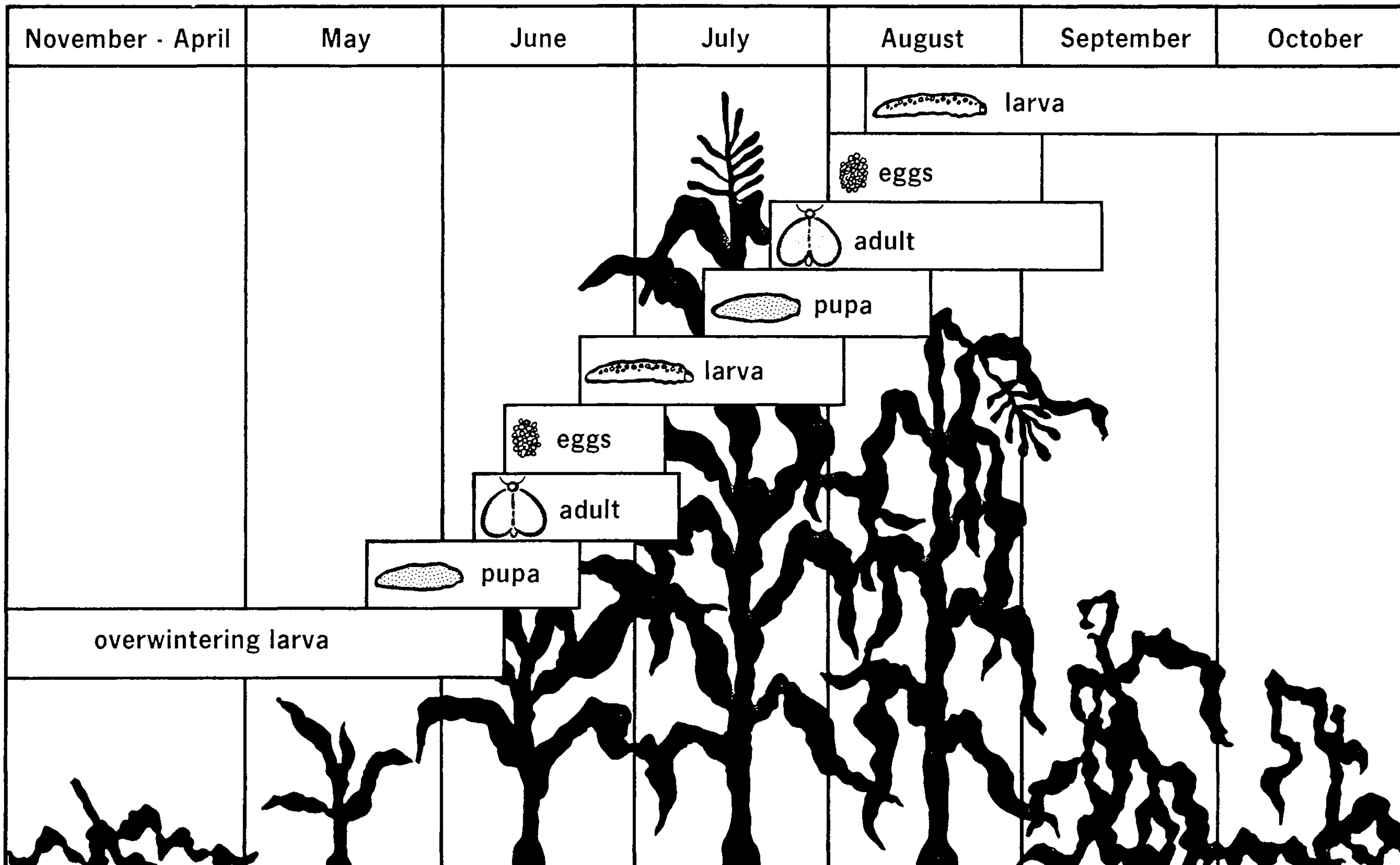
Soybean insect control (New fact sheet)

Outlook-Possible insect problems in corn following idled P.I.K. land

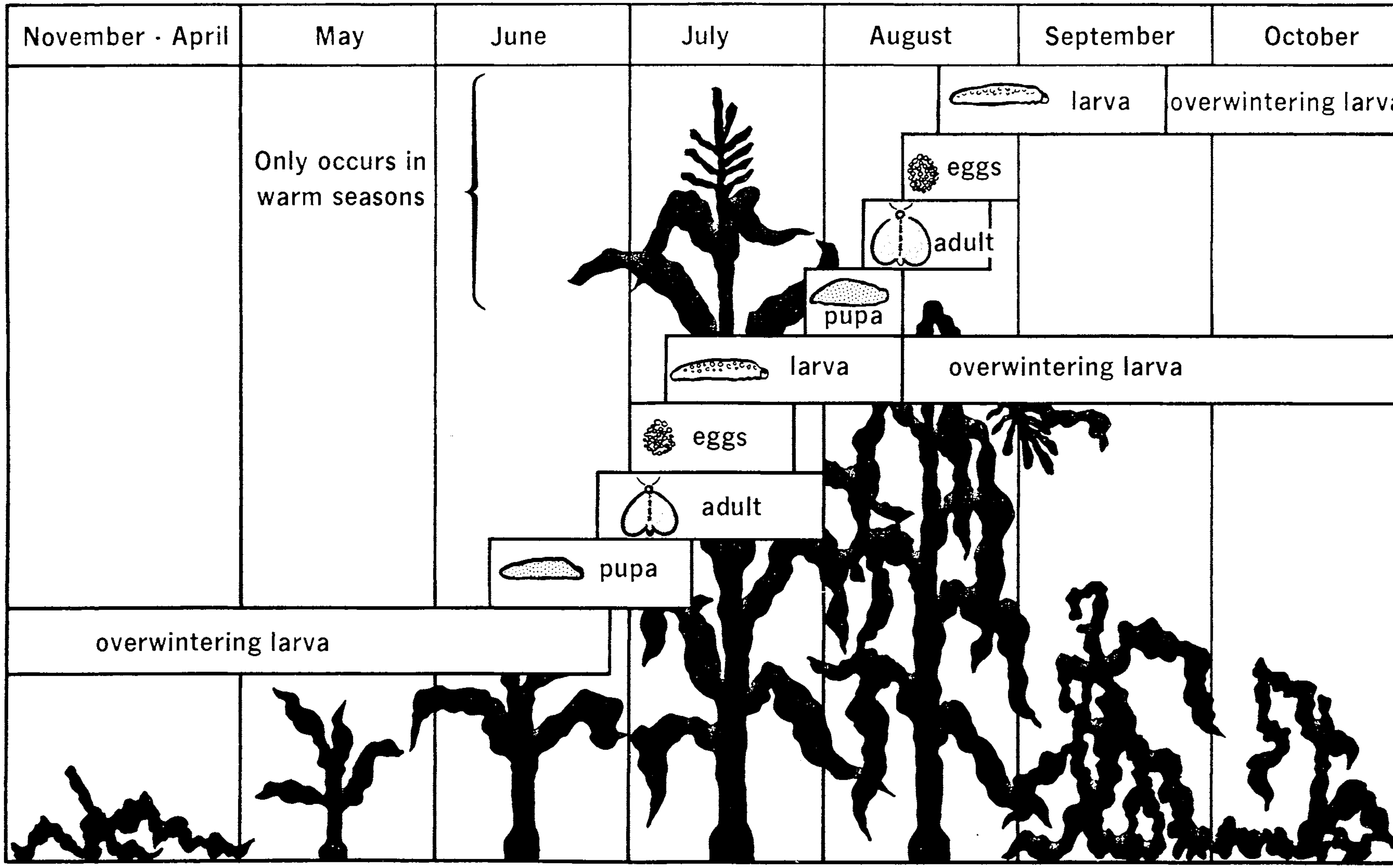
Compiled by:

Whitney S. Cranshaw

Typical life history of the European corn borer in southern Minnesota



Typical life history of the European corn borer in northern Minnesota



EUROPEAN CORN BORER - FALL POPULATIONS
AN HISTORICAL PERSPECTIVE

Whitney S. Cranshaw
Department of Entomology
University of Minnesota

The question has come up repeatedly regarding how well correlated are corn borer problems in Minnesota from one year to the next. In other words "since we had it so bad this year, can we predict next year's problems?"

Unfortunately, the answer is "no" as the following figures clearly indicate. Far too many environmental influences come into effect between one season and the next. The primary "bottlenecks" in corn borer biology include overwintering survival success, egg production by the first generation moths, survival of the first generation larvae, egg production by the second generation moths, and, finally, survival of the second generation corn borer larvae.

The Minnesota Department of Agriculture conducts annual surveys of Fall corn borer populations. Their figures for number of larvae per 100 plants is the basis for this review. The years 1967-1983 are reviewed.

<u>How populations fluctuate</u>

In the past 16 years Fall corn borer populations have increased from one year to the next 40% of the time, decreased 30%, and stayed the same (± 33%) 30% (Table 1). This kind of variation appears to be entirely random, as would be expected, particularly since 1984 populations are likely to be substantially lower than our current near record levels. Yearly end-of-the season populations are outlined in Figure 1.

Table 1. Between season second generation European corn borer population changes, 1967-1983. Based on Minnesota Department of Agriculture Fall Corn Borer Surveys.

District	Year-to-year population change		
	Increased	Stayed the same (± 33%)	Decreased
WC	5	6	5
C	6	5	5
EC	5	5	6
SW	8	3	5
SC	7	5	4
SE	8	5	3

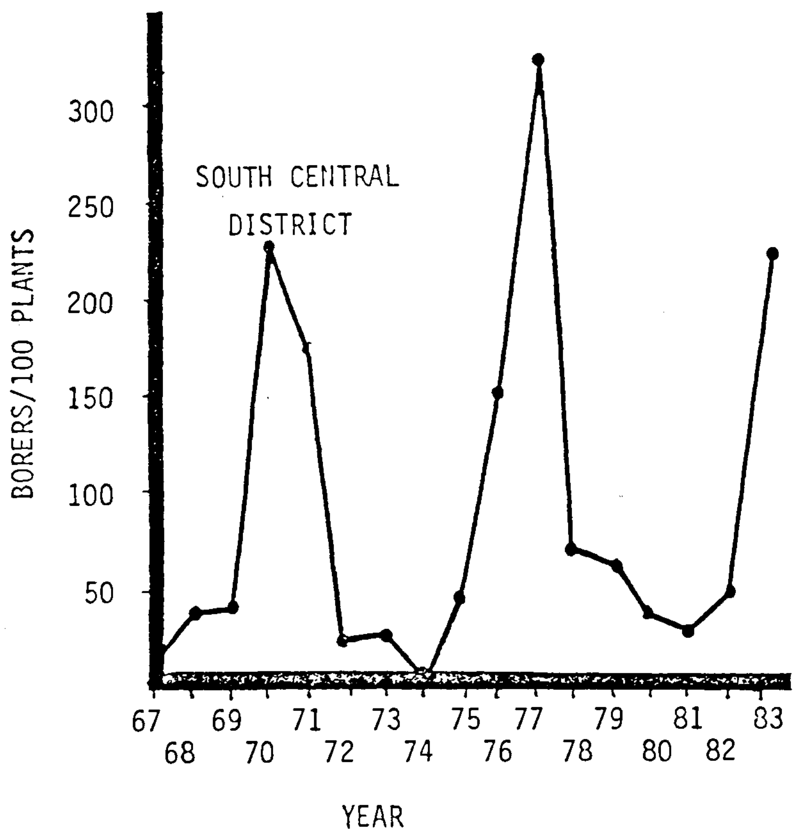
Do high years follow each other?

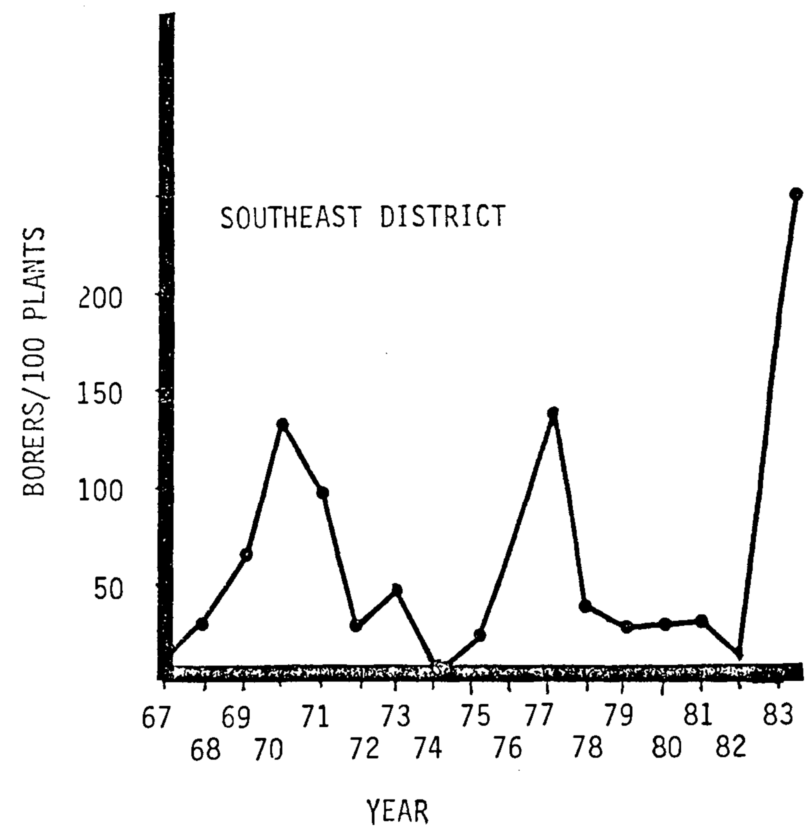
High infestations of second generation corn borers (in excess of 1 per plant average) have occurred in 2 consecutive seasons 8.3% of the time (Table 2). They have not occurred back to back in the SE, C, or EC areas since at least 1967. High populations have been followed by low populations 11.5% of the time. Low populations have been followed by high populations 16.7% of the time, including 1982-1983. Consecutive low seasons are the norm, 64.6%

Table 2. Year-to-year Fall corn borer population changes categorized by infestation severity. From Minnesota Department of Agriculture Fall Corn Borer Surveys, 1967-1983.

District	Number of occurrences year one - year two[a]			
	High-High	High-Low	Low-High	Low-Low
WC	3 (70-71, 71-72, 77-78)	2 (72-73, 78-79)	3 (69-70, 76-77, 82-83)	8
C	0	1 (77-78)	2 (76-77, 82-83)	13
EC	0	1 (77-78)	2 (76-77, 82-83)	13
SW	3 (69-70, 70-71, 77-78)	2 (71-72, 78-79)	3 (68-69, 76-77, 82-83)	8
SC	2 (70-71, 76-77)	2 (71-72, 77-78)	3 (69-70, 75-76, 82-83)	9
SE	0	2 (70-71, 77-78)	3 (69-70, 76-77, 82-83)	11

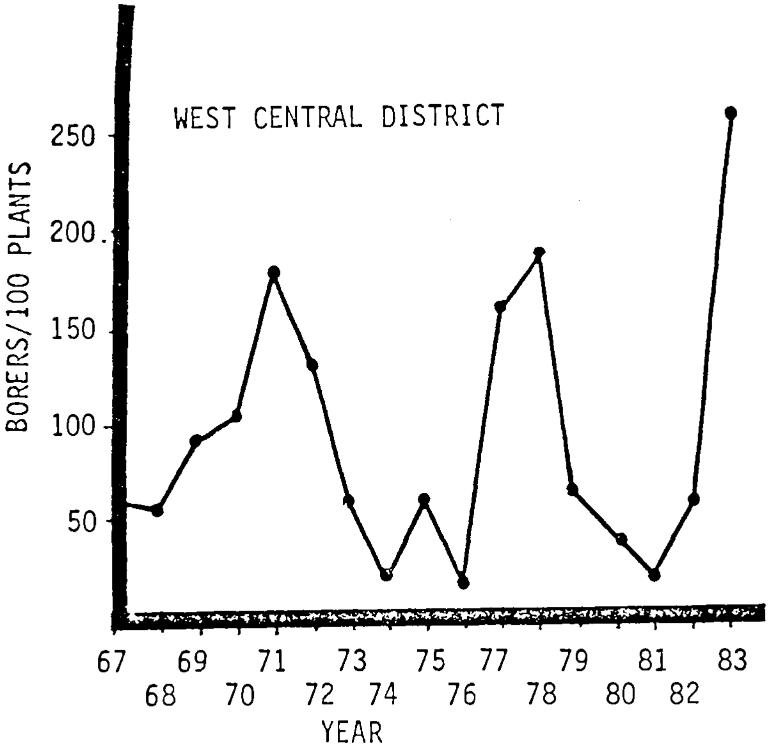
[a] Specific years are indicated in parentheses.

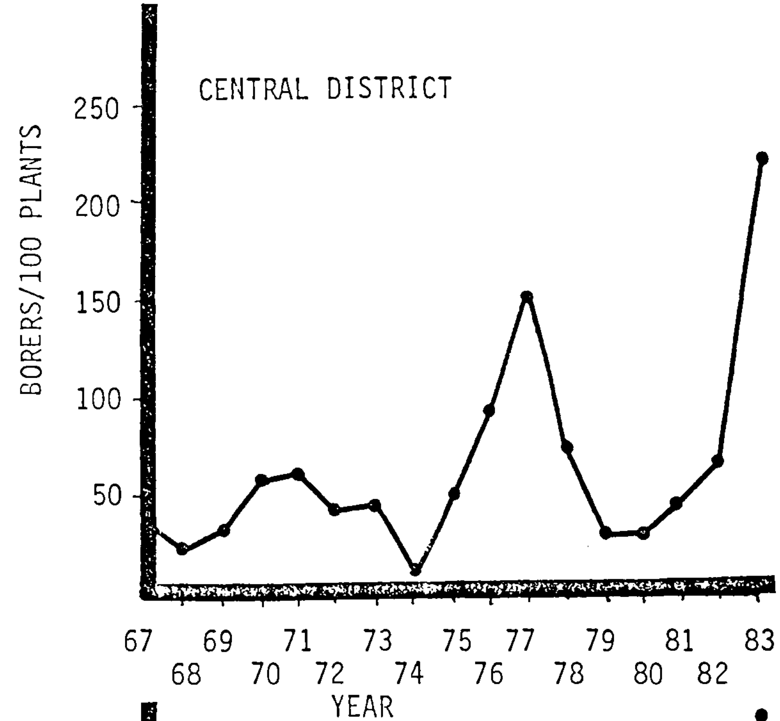


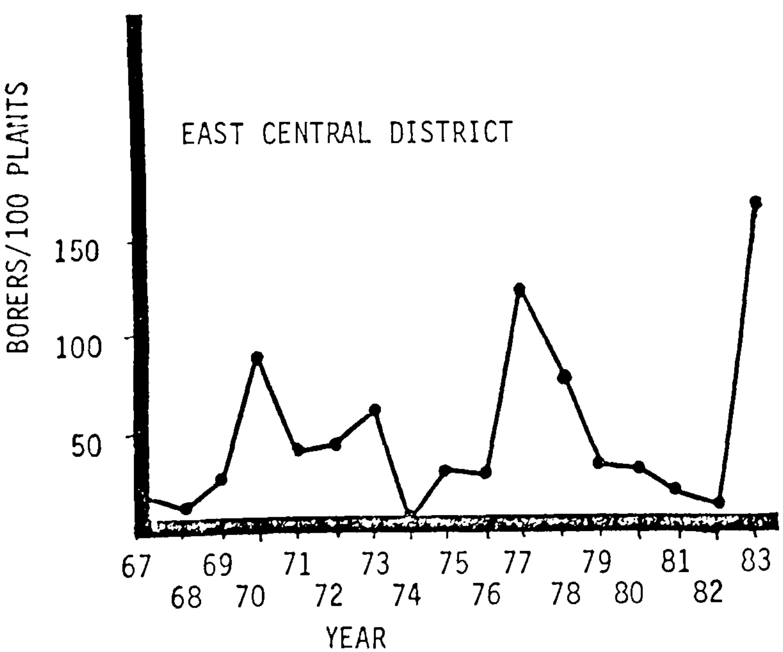


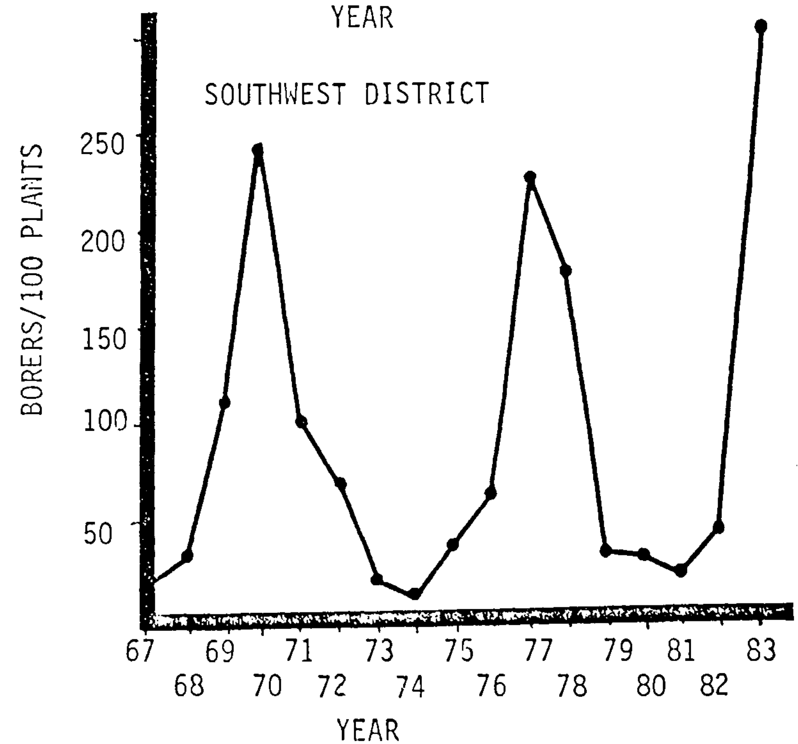
<u>EUROPEAN</u> <u>CORN</u> <u>BORER</u>

MINNESOTA DEPARTMENT OF AGRICULTURE FALL SURVEYS, 1967-1983


WEST CENTRAL DISTRICT
BORERS/100 PLANTS
250
200
150
100
50
67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83
YEAR


CENTRAL DISTRICT
BORERS/100 PLANTS
250
200
150
100
50
67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83
YEAR


EAST CENTRAL DISTRICT
BORERS/100 PLANTS
150
100
50
67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83
YEAR


SOUTHWEST DISTRICT
BORERS/100 PLANTS
250
200
150
100
50
67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83
YEAR

SUMMARY OF INSECTICIDE PERFORMANCE AGAINST EUROPEAN CORN BORER
IN UNIVERSITY OF MINNESOTA TRIALS (1981-1983)

Treatment and Rate	Field Corn 1983 1st Brood (Leaf damage rating 1-9)[a]	Field Corn 1982 1st Brood (Leaf damage rating 1-9)[a]	Sweet Corn 1983 2nd Brood[b] (% control)	Snap Bean 1982 Artificial Infestation (% control)	Snap Bean 1981 Artificial Infestation (% damage control)
Ambush 2E 0.05		1.6			94
Ambush 2E 0.1					94
Ammo 2.5E 0.04		1.3	58	66	97
Cymbush 3E 0.04		1.3			
Cymbush 3E 0.06		1.7			
Dyfonate 20G 1.0		2.2			
Furadan 15G 1.0		1.4			
Furadan 4F 0.5	2.0		65		
Lannate 1.8L 0.45					73
Lannate 1.8L 0.9			42		
Larvin 500 0.5		1.5			
Lorsban 4E 0.5	3.3				
Lorsban 15G 1.0		1.5			
Orthene 70S 0.5				89	97
Pay-Off 0.04		1.8	0	72	
Pay-Off 0.02		2.0			
Penncap-M 0.5	2.3	1.4	31	86	
Pounce 0.05	1.7	1.6			
Pounce 0.1		1.6	42		
Pydrin 2.4E 0.05	3.0	2.1			48
Pydrin 2.4E 0.1		2.3	23	40	
Sevin 80S 2.0				31	
Sevin 80S 1.5			31		
Sevin 80S 1.0	4.3	1.8			
Sevin XLR 0.8					91
Thimet 20G 1.0		1.9			
Thuricide HPC 1 qt					58
Untreated check	6.0	3.4	0	0	0

[a] No pinhole feeding wounds--1; most leaves with long lesions--9.

[b] Two applications; all others had single application.

CORN HYBRID EVALUATIONS FOR FIRST GENERATION
EUROPEAN CORN BORER RESISTANCE

Whitney S. Cranshaw and Jon L. Geadelmann

Replicated varietal trials at the Lamberton and Morris experiment stations were evaluated in 1983 for resistance to leaf feeding injury by first generation European corn borer (ECB). Heavy natural ECB infestations occurred at both locations approaching 100% of the plants at Lamberton; 50% at Morris.

A 9-point leaf damage scale was used as the basis for the Lamberton plot evaluations:

1) No visible leaf injury or a small amount of pin or fine shot-hole type of injury on a few leaves.
2) Small amount of shot-hole type lesions on a few leaves.
3) Shot-hole injury common on several leaves.
4) Several leaves with shot-hole and elongated lesions.
5) Several leaves with elongated lesions.
6) Several leaves with elongated lesions (about 1 inch).
7) Long lesions common on about one-half of the leaves.
8) Long lesions common on about two-thirds of the leaves.
9) Most of the leaves with long lesions.

At Morris, the same guidelines served as the basis for plot evaluations. However, due to the lower ECB infestation the rating scale was "stretched" so that the most heavily infested plot received a 9 rating. There was also greater variability between plots at Morris because of the lower infestation.

Plots were evaluated July 25 (Lamberton) and July 29 (Morris). Richard Gauger assisted with the Morris evaluations. Plot design was a randomized complete block with 3 replications.

Table 1. Leaf damage ratings for 76 corn hybrids infested with European corn borer, Lamberton, MN 1983.

Hybrid	Leaf damage rating*	Hybrid	Leaf damage rating*
A619 x H99/B87	2.7 a	Stauffer S4402	5.7 defghi
Pioneer 3707	3.0 ab	Asgrow RX610	5.7 defghi
Pioneer X0146	3.3 abc	Payco WX5060	5.7 defghi
Pioneer 3906	3.3 abc	Northrup King X2921	5.7 defghi
Northrup King X2242	3.3 abc	Kussmaul KS105	5.7 defghi
A671 x A634	3.7 abcd	Dekalb-Pfizer EW550	5.7 defghi
A671 x A672	3.7 abcd	Dekalb-Pfizer DK556	5.7 defghi
Keltger KS-1020	3.7 abcd	Crows SL25	5.7 defghi
Northrup King X2262	3.7 abcd	Supercrost 1940	6.0 efghij
Dekalb-Pfizer EW320	3.7 abcd	Stauffer S5340	6.0 efghij
A665 x A634/A671	4.0 abcde	Funks G4342	6.0 efghij
Pioneer X0165	4.0 abcde	Dekalb-Pfizer DK484	6.0 efghij
Pioneer 3747	4.0 abcde	Crows 431	6.0 efghij
Cargill 867	4.3 abcdef	MO17 x A672	6.3 fghij
Cargill 872	4.3 abcdef	W135R x A671/A672	6.3 fghij
A671 x A632	4.3 abcdef	A634 x MO17	6.3 fghij
Keltger KS-95	4.3 abcdef	Stauffer X4880	6.3 fghij
Cargill 836	4.3 abcdef	Paymaster 2890	6.3 fghij
Payco SX 599	4.3 abcdef	Payco SX788	6.3 fghij
Funks 3012X	4.3 abcdef	Payco SX722	6.3 fghij
Crows 201	4.3 abcdef	Golden Harvest H2440	6.3 fghij
A671 x B84	4.7 bcdefg	Dekalb-Pfizer T1100	6.3 fghij
Cargill 861	4.7 bcdefg	Dekalb-Pfizer P1000	6.3 fghij
A665 x MO17	4.7 bcdefg	Asgrow RX418	6.3 fghij
A619 x A632	4.7 bcdefg		
Payco SX 619	4.7 bcdefg	Stauffer S5602	6.7 ghij
Dekalb-Pfizer XL55A	4.7 bcdefg	Asgrow RX622	6.7 ghij
A659 x A658/A632	5.0 cdefgh	Paymaster 2990	6.7 ghij
A665 x A634/MO17	5.0 cdefgh	Asgrow RX532	6.7 ghij
Northrup King PX9353	5.0 cdefgh	Golden Harvest H2300	6.7 ghij
Kussmaul KS108	5.0 cdefgh	Dekalb-Pfizer T950	6.7 ghij
Pioneer 3732	5.3 defghi	A554 x A654/A672	7.0 hij
Paymaster 2960	5.3 defghi	Thorobred 400	7.0 hij
Paymaster 1990	5.3 defghi	Asgrow RX420	7.0 hij
Funks 1011	5.3 defghi	Stauffer S2202	7.3 ij
Crows 199	5.3 defghi	Supercrost 3030	7.7 j
Cargill 891	5.3 defghi		
A671 x B73	5.7 defghi		
A619 x H99/A672	5.7 defghi		
Supercrost 2410	5.7 defghi		

* Numbers followed by the same letter are not significantly different (P=0.05) by Duncan's MRT.

Table 2. Leaf damage ratings for 45 corn hybrids infested with European corn borer, Morris, MN 1983.

Hybrid	Leaf damage rating*	Hybrid	Leaf damage rating*
A641 x W1828	1.0 a	Cargill SX222	4.3 bcde
Cenex 2098	1.3 ab	Customaize 2004	4.3 bcde
Dekalb XL6	2.3 abc	Pioneer 3906	4.3 bcde
Pioneer 3950	2.3 abc	Cargill 810	4.3 bcde
Jacques JX32	2.3 abc	A554 x A654/A672	4.7 cde
Cenex 2093	2.7 abcd	Sokota 222	4.7 cde
A654 x A672	2.7 abcd	Pride X902	4.7 cde
Customaize 3601	2.7 abcd	Cargill 832	4.7 cde
Customaize W1000	2.7 abcd	Jacques JX47	4.7 cde
Tracy T2941	2.7 abcd	W155R x A671/A672	5.0 cde
Pride 1169	2.7 abcd	A671 x A672	5.0 cde
Dekalb XL12	3.0 abcd	Tracy T205 SX1	5.0 cde
Sigco 0902	3.0 abcd	A661 x A654	5.3 cde
Pride X952	3.0 abcd	W117 x A672	5.3 cde
Sigco 1392	3.3 abcde	(A239/B9A) A632	5.3 cde
Tracy T2001	3.3 abcde	Pride 1142	5.3 cde
Sakota 474	3.3 abcde	Cargill 834	5.7 de
Dekalb XL13	3.3 abcde	Dakalb T950	5.7 de
Dekalb XL8	3.7 abcde	Dekalb TX599A	5.7 de
W153R x A672	3.7 abcde	Funks G4256	6.3 e
Pioneer 3978	3.7 abcde		
Dekalb T891	3.7 abcde		
A665 x A634/A671	4.0 abcde		
Customaize 2301	4.0 abcde		
Pioneer 3901	4.0 abcde		

* Numbers followed by the same letter are not significantly different (P=0.05) by Duncan's MRT.

MAKING CONTROL DECISIONS FOR FIRST GENERATION CORN BORER IN MINNESOTA FIELD CORN

Whitney S. Cranshaw
Department of Zoology and Entomology
Colorado State University
Ft. Collins, Co 80523

Several factors must be considered to produce an optimal return with corn borer control. A procedure is outlined below which will allow calculation of the corn borer infestation severity at which a prompt insecticidal application will produce economic benefit. This is the economic threshold (ET) expressed as a percentage of infested plants.

Key Factors

Economic Injury Level (EIL)

The number of borers per plant which will cause a yield loss equal in value to the control cost (Economic Injury Level) is outlined in Table 1. Required inputs are expected yield, anticipated corn price, control costs, and the average percent yield reduction per borer per plant. For this latter figure, research suggests that lower values are more appropriate when the plants are infested during the early whorl stages. Such a situation would tend to occur most frequently on late planted corn. Higher values are suggested if egg hatch coincides with early tasseling.

Borers per infested Plant (BP)

The number of borers per infested plant will vary due to weather, planting date, resistance of the hybrid, and other natural controls. A rough estimate can be made if the whorl leaves of infested ('shotholed') plants are examined and an average number of borers/plant is determined. However, this estimate is likely to be high since some natural mortality will continue after the survey. One factor to take into account is the resistance of the hybrid since survival will generally be better in more susceptible hybrids.

Research in other states has suggested that a value of about 4-5 borers per infested plant (20%survival rate) is appropriate. However, observations in Minnesota indicate that the range is usually 0.5-3.0 borers/infested plant. One borer per infested plant is close to the average.

Expected Control (EC)

The expected control will vary due to the choice of insecticide, application method, and the timing of the application. Maximal control rarely exceeds 0.90 (90%). Applications made after borers have moved into the plants will result in lower percentage control

Formula

$$\frac{100}{BP} \times EIL \div EC = ET$$

Example

Assumptions:

EIL = 0.8 ($12 application cost, $2.75 bu corn price, 100 bu/acre expected yield, 5.5% yield loss /borer)

BP = 2.0 (2 borers/infested plant)

EC = 0.85 (85% control)

$$\frac{100}{2.0} \times 0.8 \div 0.85 = 47$$

Answer: Infestations exceeding 47% infested plants would benefit from an insecticide treatment.

Table 1. Economic Injury levels (EIL) for first generation European corn borer. Figures indicate point where borers/plant is expected to cause a yield loss equivalent in value to the insecticide and application costs (assumes $12/acre control cost[a]).

Expected yield (bu)	60			80			100			120			140			160		
% yield loss/ borer/plant	4.5	5.5	6.5	4.5	5.5	6.5	4.5	5.5	6.5	4.5	5.5	6.5	4.5	5.5	6.5	4.5	5.5	6.5
Market price ($/bu)																		
$2.25	2.0	1.6	1.4	1.5	1.2	1.0	1.2	1.0	0.8	1.0	0.8	0.7	0.8	0.7	0.6	0.7	0.6	0.5
$2.75	1.6	1.3	1.1	1.2	1.0	0.8	1.0	0.8	0.7	0.8	0.7	0.6	0.7	0.6	0.5	0.6	0.5	0.4
$3.25	1.4	1.1	0.9	1.0	0.8	0.7	0.8	0.7	0.6	0.7	0.6	0.5	0.6	0.5	0.4	0.5	0.4	0.4

[a] If control costs differ, change figures proportionately. For example, where application costs are only $6/acre, figures would be reduced by one-half (6/12=1/2).

EUROPEAN CORN BORER CONTROL IN FIELD CORN

Entomology Fact Sheet No. 40
Revised 1984 - Whitney S. Cranshaw

Since its appearance in Minnesota in 1943, the European corn borer has been one of the most damaging insect pests of field corn in the state. Infestations and damage may vary greatly from year to year but great damage to the corn crop can occur in any season where conditions favor corn borer survival and reproduction. Damage results from larvae feeding on leaves, in stalks, in ears, or in ear shanks. This injury can result in reduced yields, stalk breakage, and dropped ears. Infested plants may also be more infected with stalk rot since corn borer wounds may allow entry of disease organisms.

First generation corn borer infestations primarily cause direct yield reductions by affecting the vigor of the corn plants. Actual losses will vary depending on crop yields with an estimated loss of 4.5 - 6.5% per borer per plant at this time. Early season tunneling primarily occurs above the developing ear zone but limited lower stalk tunneling does happen. Breakage of tassels and the upper stalk may commonly result from first generation corn borer injury.

Second generation corn borers tend to affect yields primarily by increasing harvest losses due to stalk breakage and ear droppage. In the absence of harvest losses, late season corn borers directly reduce yields little.

Life Cycle

European corn borers overwinter as full grown larvae in old stalks, corn cobs, weed stems, or in other protected areas such as webbed together leaves or husks. As the weather warms up in spring the borers become active and form a brown cigar-shaped pupa. After a few weeks, the adult moths begin to emerge, mate, and lay eggs. Egg laying generally occurs during late June - early July and is dependent on temperature. Egg laying tends to occur earlier in southern parts of the state and during years when temperatures are above average.

The female moths are most attracted to the tallest, most vigorously growing plants for egg laying. The eggs are usually laid near the mid-rib on the leaf underside. Eggs are laid in groups of 15-30, as a flat cluster overlapping like fish scales or shingles. Just prior to hatching the dark heads of the young borers can be seen through the egg shells. This is called the 'blackhead' stage of development.

Following egg hatch, the larvae feed on the leaves and move into the plant whorls. As the whorl leaves expand, small 'shothole' feeding wounds can be easily observed. As the larvae get older, usually within a week to 10 days after egg hatch, they begin to tunnel into the leaf mid-ribs and the stalk. Larvae cease feeding 3-5 weeks after egg hatch and, depending on the season and location in the state, may either prepare for overwintering ('diapause') or pupate to produce a second generation.

In southern Minnesota a second generation usually occurs. Eggs tend to be laid on leaves near the ear zone during August and the larvae burrow into the plant at leaf axils, the ear shank, or into the ears after feeding for a brief period on pollen and leaf tissue.

In the northern Minnesota corn growing areas, a single generation of corn borers predominates in most seasons. Usually much of the initial egg hatch will coincide with late whorl or tassel emergence so 'shothole' feeding may not be observed. A partial second generation can occur in August and September during warm seasons.

Control

Naturally Occurring Controls

Weather has a very great effect on the survival and reproduction of corn borers. Free water, in the form of rain or dew, must be available to the female moths or egg production will be severely reduced. Heavy rains following egg hatch can dislodge many of the young larvae from the plants and drown others in the whorls or leaf axils where water collects. Conversely, very hot temperatures can be extremely stressful to the young larvae if conditions are dry. Leaf curling associated with drought stressed plants can also cause egg masses to fall from the plants.

There are several biological control organisms which can suppress corn borer populations. Predatory insects such as ladybird beetles, lacewings, and minute pirate bugs are often abundant on corn plants and may feed on corn borers. Sap beetles may also occasionally kill some borers. Various species of parasitic flies and wasps are present in Minnesota which may kill corn borer larvae. Corn borers may also suffer from fungus or protozoan diseases. However, biological controls do not usually provide a high or consistent level of corn borer control.

Selection of Varieties

There are differences in the susceptibility of various hybrids to European corn borer. Early season infestations can largely be avoided by planting varieties which cause corn borer larvae not to survive well in the plants. Unfortunately these resistant hybrids are not currently grown over much of the acreage because they do not yield as well as susceptible varieties when corn borers are not present. Further development and distribution of corn borer resistant varieties could, ultimately, provide the best method for corn borer management.

Late season corn borers cannot currently be well controlled by resistant hybrids. However, plants which hold ears well and resist stalk breakage can better tolerate injury. Fertility and cultural practices which promote stalk strength may also help reduce breakage related losses.

Planting Dates

Early planted corn in highly fertilized fields is the most attractive to the first generation corn borer moths. Therefore, if you use a variety which is susceptible to corn borers and plant early for the area, you should often expect heavy infestation. However, even fields planted in late May can be infested on occasion so these should also be monitored. Fields with an extended leaf height of 16 inches or less during egg hatch will avoid first generation corn borer problems.

Second generation corn borers can infest both early and late planted fields. Infestations tend to be greater in later plantings since the higher amount of fresh pollen in the leaf axils allows for better survival by the larvae.

Destruction of Overwintering Borers

Theoretically, it would be possible to reduce the number of borers from year to year by handling the crop residues so that overwintering larvae are killed. However, corn borer moths are strong fliers and disperse widely. Consequently, there is no relationship between the number of borers which overwinter in a field and the level of infestation the following season. On a regional basis, there have also been historically few instances where two consecutive seasons of heavy infestation have occurred.

Harvest practice can have a great effect on corn borer survival. Combine harvest kills a greater percentage of corn borers in the field than does a corn picker. In addition, picked corn that is cribbed may also harbor a large number of corn borer larvae within the ear. Stalk choppers, by themselves, do not cause a great reduction in corn borer survival. Feeding infested plants as silage or fodder to livestock will destroy a high percentage of the borers.

Tillage can also affect the survival of overwintering corn borers. Plowing which turns crop and weed residues under completely before moth emergence in the spring is an effective method for reducing the number of overwintering borers in a field. However, clean plowing will not kill all of the borers and is not be appropriate for some operations.

None of these cultural practices can be relied on to control borers. If these practices fit your particular farming operations, they may help to reduce the number of overwintering borers locally. However, weather conditions during winter and the growing season are far more important in their effect on corn borer infestations.

Weed Control

Dense weedy areas serve as concentrations of corn borer moths during the day. Most mating occurs in weed patches where dew is present which the moths drink. If weeds can be largely eliminated within a field and if grassy field edges are mowed, corn borer infestations may be lessened in a field.

Early Harvest

Early harvest should be considered fundamental to management of late season corn borer infestations in Minnesota. In fields where high numbers of corn borers (greater than an average of one per plant) are found in the ear shank or in the stalk below the ear early harvest should be considered. In these high risk cases, potential harvest losses following wind storms can greatly exceed the additional drying costs.

Use of Insecticides - First Generation

A number of insecticides are capable of well controlling first generation European corn borers. However, these treatments must be timed correctly and should only be applied if the severity of the infestation warrants the control costs.

In southern Minnesota use shotholing of the infested plants as an indicator of when egg hatch begins. At the same time confirm that living larvae are still present in the plants. This latter check is important since severe weather, predators, or host plant resistance may kill most of the larvae shortly after they begin feeding.

To survey first generation corn borer select at least 10 consecutive plants in each of 5 field locations for evidence of leaf feeding ('shotholes') and for egg masses. Conduct this survey just after peak egg hatch. If the percentage of plants infested with larvae in the whorls or fresh egg masses exceeds 50%, an insecticide application is economically justified. Fields of extremely high yield potential or valuable seed fields may benefit from treatment at lower levels of infestation, 25-35%. Irrigators who can put insecticides through their irrigation equipment may particularly get benefit because of low application costs.

First generation corn borer insecticide applications should be directed into the whorl. In general, granular insecticide formulations perform better than do sprays against early season borers because of better penetration into the whorl. Rainfall will have little influence on performance of these early season treatments since much of the insecticide will be flushed into the whorl rather than off the plants.

In extreme northern Minnesota shotholing may not be a reliable indicator of early infestation. Instead, scouting for eggs and young larvae in leaf axils will be needed. The timing for this survey would be in mid-July in most seasons. If 1/3 - 1/2 of the plants are found to be infested, insecticide treatment may be of benefit.

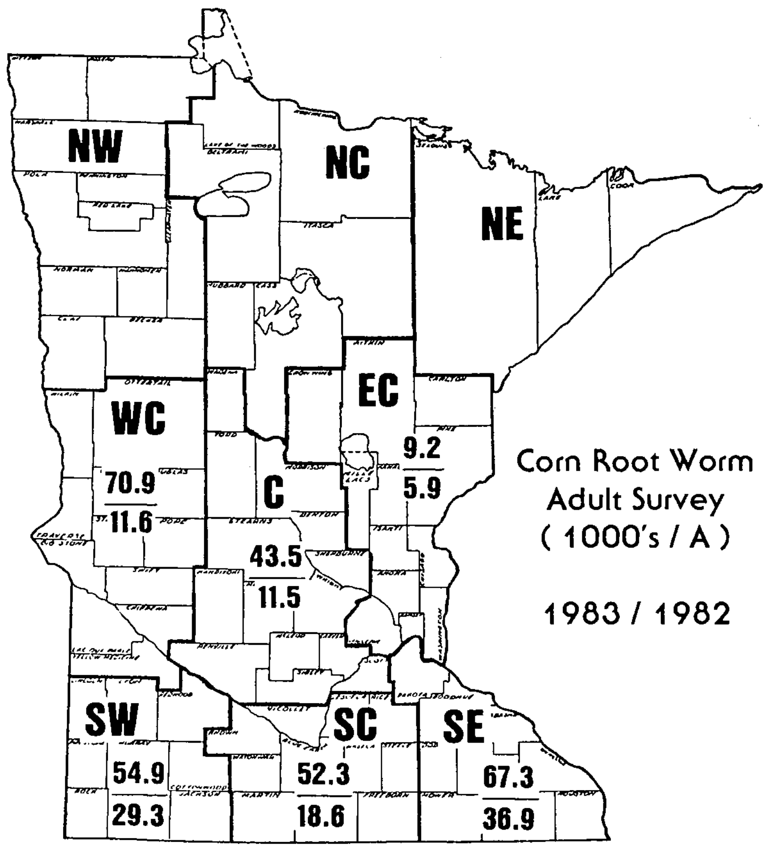
Use of Insecticides - Second Generation

Treatment of second generation corn borer is rarely economically justified in field corn. Egg laying and egg hatch of this later generation is extended over a period of several weeks and single applications do not persist adequately. Furthermore, coverage of the plant is difficult late in the season so the potential control is decreased. Treatment may be of benefit if egg masses or living larvae are found on 50% of the plants. In seasons of high infestation levels, 2 or more applications may be needed for second generation corn borer control.

If infestation warrants, use one of the following;

Material	Amount per acre (actual toxicant)	Limitation, days before harvest
carbaryl (Sevin)	1-2 lbs.	None. Granules or spray.
carbofuran (Furadan)	1 lb.	Do not apply if used at planting. Granules.
chlorpyrifos (Lorsban)	1 lb.	As spray or granules
diazinon	1 lb.	None. Granules.
fonofos (Dyfonate)	1 lb.	45 days. Granules. First brood.
fenvalerate (Pydrin)	0.1-0.2 lbs.	Restricted Use Compound
methyl parathion	0.5-1.0 lb.	Do not apply during pollen shed or when flowering weeds are present. Restricted Use Compound
phorate (Thimet)	1 lb.	None. Granules.

Observe all safety precautions and restrictions given on pesticide labels. Seed production fields that are to be hand detasseled should not be treated with Furadan, Dyfonate, or Thimet.



Northern: Western = 91:9

Source: Minnesota Dept. of Agriculture

1983 CORN ROOTWORM DAMAGE SURVEYS OF FIRST YEAR CORN

Whitney S. Cranshaw
Department of Entomology
University of Minnesota

Each season a few reports are received of apparent corn rootworm injury to first year corn. On examination, much of the reported injury is found to result from root rots or other environmental stresses. Where corn rootworms are involved, most, but not all, cases can be explained on high populations of volunteer corn or pollinating weeds in the previous season's crop. However, it was thought that a recent survey in the absence of injury reports was important to determine the extent of corn rootworm injury to first year corn.

Procedure - During early August, 33 first year corn fields were evaluated for corn rootworm larval injury to the plants. Root injury was assessed using the Iowa 1-6 root damage scale.

Results - None of the fields were observed to have root damage ratings in excess of 3.0, the generally recognized economic threshold. These results confirm that first year corn injury by corn rootworms is very rare in Minnesota and that the practice of routine insecticide treatment to these fields would not be economically justified.

Table 1. Corn rootworm root damage ratings of 33 first year Minnesota corn fields, 1983.

Region	No. of fields	Average root damage rating (1-6 scale)
WC[a]	10	2.1 (1.9 - 2.3)
SW[b]	10	1.5 (1.2 - 2.0)
SC-SE[c]	13	1.9 (1.1 - 2.2)

[a] Evaluated by Rick Gauger.

[b] Evaluated by Lee French.

[c] Assisted by John Craig, John Skoglund, Arney Imholt, and James Gill.

MINNESOTA CORN ROOTWORM INSECTICIDE TRIALS

LAMBERTON - 1983

Whitney Cranshaw and Harlan Ford

Planting date - May 18

Plot design - Randomized complete block, 4 replications. 2-row plots.

Hybrid - Pioneer 3732

Application - 7" band ahead of presswheel unless otherwise indicated

Root damage evaluation date - July 25

Harvest date - October 11

Treatment	Rate (oz/1000 row ft)	Average root damage rating (1-6)*	Average yield (Bu/A)*
Amaze 20G	6.0	2.2 abc	68.6 a
Broot 15G	8.0	2.3 bcde	67.2 a
Counter 15G	8.0	2.4 bcde	65.1 a
Counter 15G	6.0	2.4 bcde	68.0 a
Dyfonate 20G	6.0	2.3 abcde	71.6 a
Dyfonate 20G	4.5	2.5 cd	67.0 a
Furadan 10G	12.0	2.7 de	77.7 a
Lorsban 15G	8.0	2.8 ef	60.6 a
Mocap 15G	8.0	2.2 abc	70.3 a
Mocap 20G	6.0	2.1 ab	67.4 a
Thimet 20G	6.0	2.1 ab	73.5 a
BAS 263 20G	6.0	2.2 abc	72.0 a
BAS 263 20G(in furrow)	6.0	2.8 ef	64.5 a
BAS 263 20G	4.5	1.8 a	61.4 a
CGA 12223 20G	4.5	2.0 ab	77.0 a
CGA 12223 20G	3.0	2.2 abc	67.2 a
CGA 12223 20G	1.8	2.0 ab	75.0 a
Untreated check		3.1 f	69.6 a

* Numbers followed by the same letter are not significantly different (P=0.05) by Duncan's MRT.

MINNESOTA CORN ROOTWORM INSECTICIDE TRIALS

ROSEMOUNT - 1983

Whitney Cranshaw

Planting date - May 17

Plot design - Randomized complete block, 4 replications. Single-row plots.

Hybrid - Funks G 4507

Application - Banded May 20 and lightly incorporated

Root damage evaluation date - August 6

Treatment	Rate (oz/1000 row ft)	Average root damage rating (1-6)*
Amaze 20G	6.0	3.3 b
BAS 263 20G	4.5	2.4 a
BAS 263 200g/liter	4.5	4.9 d
Broot 15G	8.0	2.6 ab
CGA 12223 20G	4.5	3.0 b
CGA 12223 20G	3.0	2.9 ab
CGA 73102 20g/kg		3.3 b
CGA 73102 15g/kg		4.0 c
CGA 73102 10g/kg		4.5 cd
Counter 15G	8.0	2.8 ab
Furadan 15G	8.0	3.3 b
Untreated check		4.9 d

* Numbers followed by the same letter are not significantly different (P=0.05) by Duncan's MRT.

MINNESOTA CORN ROOTWORM INSECTICIDE TRIALS

MORRIS - 1983

Whitney Cranshaw and Dennis Warnes

Planting date - May 18

Plot design - Randomized complete block, 4 replications. 2-row plots.

Hybrid - Pioneer 3901

Application - 7" band ahead of presswheel

Root damage evaluation date - July 28

Harvest date - September 26

Treatment	Rate (oz/1000 row ft)	Average root damage rating (1-6)*	Average yield (Bu/A)*
Amaze 20G	6.0	2.6 ab	142.5 a
Broot 15G	8.0	2.9 b	136.0 ab
CGA 12223 20G	4.5	3.6 c	126.7 bc
CGA 12223 20G	3.0	4.0 c	134.4 ab
CGA 12223 20G	1.8	3.8 c	139.3 a
Counter 15G	8.0	2.3 a	135.8 ab
Dyfonate 20G	6.0	3.8 c	135.5 ab
Furadan 15G	8.0	2.4 ab	144.7 a
BAS 263 20G	6.0	2.4 ab	140.7 a
BAS 263 20G	4.5	2.4 ab	137.3 ab
Lorsban 15G	8.0	4.6 d	121.2 c
Mocap 15G	8.0	3.9 c	139.1 a
Thimet 20G	6.0	2.5 ab	136.3 ab
Untreated check		4.6 d	123.5 c

* Numbers followed by the same letter are not significantly different (P=0.05) by Duncan's MRT.

MINNESOTA CORN ROOTWORM INSECTICIDE TRIALS

WASECA - 1983

Whitney Cranshaw and Bill Lueschen

Planting date - May 11

Plot design - Randomized complete block, 4 replications. 2-row plots.

Hybrid - Pioneer 3732

Application - 7" band behind presswheel unless otherwise indicated

Root damage evaluation date - July 27

Harvest date - September 27 and 29

Treatment	Rate (oz/1000 row ft)	Average stand (plants/ 110 row ft)	Average root damage rating (1-6)*	Average yield Bu/A)*
Amaze 20G	6.0	148	2.6 bc	118.7 a
Broot 15G	8.0	148	2.2 ab	112.0 a
Counter 15G	8.0	151	2.1 a	111.6 a
Dyfonate 20G	6.0	148	2.5 abc	116.3 a
Furadan 15G	8.0	150	2.4 abc	119.2 a
Lorsban 15G	8.0	149	2.6 bc	113.0 a
Lorsban 15G (ahead of presswheel)	8.0	154	2.4 abc	108.2 a
Mocap 15G	8.0	152	2.8 cd	111.2 a
Mocap 20G	6.0	151	2.5 abc	108.6 a
Thimet 20G	6.0	148	2.4 abc	109.0 a
BAS 263 20G	6.0	147	2.1 a	118.1 a
BAS 263 20G	4.5	150	2.1 a	116.4 a
CGA 12223 20G	4.5	149	2.1 a	122.9 a
Untreated check		142	3.1 d	99.6 a

* Numbers followed by the same letter are not significantly different (P=0.05) by Duncan's MRT.

CONSISTENCY OF ROOT PROTECTION BY REGISTERED CORN ROOTWORM INSECTICIDES - MINNESOTA EXPERIENCE 1977-83

Whitney S. Cranshaw

Corn rootworm insecticides have been routinely tested in Minnesota at the various Branch Experiment Stations. This work was done by John Lofgren prior to his retirement in 1981 and by myself in 1982-1983.

A review of root protection performance is given below for trials conducted since 1977. Two comparisons are made. The first summarizes performance against the registered product with the lowest average root damage rating (Iowa 1-6 scale). The statistical analyses used involved L.S.D. (P=0.05) prior to 1982 and Duncan's MRT (P=0.05). Summary statistics are not available for 1980 and at the Lamberton location in 1978. A listing is made of whether treatments resulted in root damage ratings significantly equal to the best (lowest damage rating) registered product in the trial (Table 1).

The second comparison is of how often a treatment was able to maintain the root damage rating below the 3.0 level which is generally considered to be the economic threshold (Table 2). Note that in 4 trials listed, the untreated check also failed to exceed a 3.0 root damage rating.

Only granular planting time applications applied as a 7" banded were compared. Where multiple formulations of the same active ingredient were tested, the more concentrated formulation was selected (with the exception of Mocap 15 G versus Mocap 20 G comparisons where the 15 G was chosen). Isofenphos applications listed as oftanol are included as are trimethacarb applications listed as Landrin or UC27867. At least 4 or more registered materials had to be included in a test to be included in this comparison.

Table 1. Performance of corn rootworm insecticides in Minnesota trials, 1977-1982. Number of times root damage rating did not significantly differ from best performing registered insecticide.

Insecticide	Insecticide Trial Location: Waseca	Morris	Lamberton	Other*	Total
Amaze	5/6	4/4	1/1	2/2	12/13
Broot	4/4	2/3	1/1	2/2	9/10
Counter	6/6	3/4	1/1	2/2	12/13
Dyfonate	5/6	1/4	1/1	1/1	8/12
Furadan	5/6	2/4	0/1	2/2	9/13
Lorsban	2/6	1/4	0/1	1/1	4/12
Mocap	4/6	1/4	1/1	0/1	6/12
Thimet	6/6	4/4	1/1	0/1	11/12
Untreated	1/6	0/4	0/1	1/2	2/13

*Trials at Janesville in 1982 and Rosemount in 1983.

Table 2. Performance of corn rootworm insecticides in Minnesota trials, 1977-1983. Number of times treatments maintained root damage rating below 3.0.

Insecticide	Insecticide Trial Location: Waseca	Morris	Lamberton	Other*	Total
Amaze	6/7	4/4	3/3	1/2	14/16
Broot	5/5	4/4	3/3	2/2	14/14
Counter	6/7	5/5	3/3	2/2	16/17
Dyfonate	7/7	3/5	3/3	0/1	13/16
Furadan	6/7	3/5	3/3	1/2	13/17
Lorsban	4/7	2/5	3/3	1/1	8/16
Mocap	7/7	1/5	3/3	0/1	11/16
Thimet	7/7	5/5	3/3	0/1	15/16
Untreated	0/7	1/5	2/3	0/2	3/17

*Trials at Janesville in 1982 and Rosemount in 1983.

SOYBEAN INSECT CONTROL

Entomology Fact Sheet No.
1984 - David W. Ragsdale and Whitney S. Cranshaw

Several insects can be found infesting Minnesota soybeans throughout the season. Rarely do these pests cause economic loss to the crop. However, severe outbreaks occasionally occur and may need to be controlled.

Seed Injury--Seed corn maggot is the most serious insect pest of germinating soybeans. The larvae of this common, gray colored fly feed on the seeds after planting and can kill the plants. Less injured soybeans may emerge with two stunted growing points ('baldheads' or 'snakeheads') caused by destruction of the original growing point.

Injury is often most severe where animal manures or large amounts of green manure have been recently applied. In addition, soybeans grown on soils with high levels of organic matter content may frequently be seriously infested by seed corn maggot. In seasons where cool wet weather occurs after planting seed corn maggot development is favored and injury intensifies.

Injury can be reduced by planting the crop in a manner that allows rapid germination and growth. In some fields, where a history of serious seed corn maggot injury has occurred, use of an insecticide seed treatment can be used to avoid injury.

Seedling Injury--The primary seedling pests of Minnesota soybean are the various cutworm species. Fortunately, economic cutworm damage is extremely rare in soybeans. The crop is grown with high plant populations and has great ability to compensate for missing plants. In fields where heavy infestations will depress plant populations below recommended levels, insecticides may be of benefit.

Bean leaf beetles may also be found infesting seedling plants with earliest plantings most heavily infested. However, seedling beans can sustain considerable defoliation losses, in excess of 40%, without yield loss.

Foliage Injury--Several caterpillars can be found in soybeans which will chew on the foliage. Most common is the green cloverworm. During some seasons, yellow woollybears and thistle caterpillars will become abundant. All of these caterpillars only rarely cause economic losses because their damage is well tolerated by the plants and the pests or usually brought under control by fungus diseases and parasitic insects.

Bean leaf beetles begin to emerge during late July with peak emergence in late August. The beetles continue their emergence until soybeans are mature. Bean leaf beetles rarely cause economic damage, with early planted soybeans being most susceptible.

Research on the impact of insect defoliation to soybean yield indicates that the pod development (R3-R5) stages of growth are the most sensitive to this insect injury. At this time soybean will tolerate only a 20% leaf area loss before a yield reduction occurs equal in value to an insecticide treatment (economic injury level). Economic injury levels for both vegetative growth (VC-R1) and seed maturation (R6-R8) stages are in excess of 40% defoliation.

Potato leafhopper may commonly be found feeding on soybeans. However, soybean is not a preferred host plant for this insect and the crop apparently is more tolerant of potato leafhopper than are many other crops. In addition, potato leafhoppers reproduce poorly on the hairy leaved soybean varieties which are grown in Minnesota. Consequently, damage to soybeans by this insect is extremely unlikely.

Spider mites may infest soybeans following extended period of hot, dry weather. Infested leaves become discolored and may sense prematurely. Since spider mite outbreaks can be rapidly terminated by biological controls following rains, there are few instances where a pesticide application may be of benefit.

Pod Injury--Grasshoppers and bean leaf beetles may feed on developing pods as well as soybean foliage. This pod feeding injury can directly cause reduced seed number and can reduce seed quality. Determinations of the need for treatment should take this additional injury into account as well as the defoliation economic injury levels described in the discussion of defoliating caterpillars.

Grasshopper infestations tend to be concentrated next to the grassy field edges where eggs are laid. Movement into soybeans increases as the grasses dry and the grasshoppers become full grown in mid-summer. Outbreaks usually occur in dry seasons. Most infestations are limited to relatively small areas of the field so spot treatments are often all that is economically warranted.

When the plant has pods with full sized green beans (R6), foliage is too old for the bean leaf beetle and the beetles begin to feed on pods. The outer layer of pod tissue (pericarp) is removed and the bean directly beneath the feeding scar is often attacked by fungi, reducing seed quality. If more than 10% of the pods show feeding injury and bean leaf beetles are present, an insecticide treatment is recommended.

If infestation warrants, use one of the following:

Insect	Insecticide	Amount per acre (Actual toxicant)	Limitations, pre-harvest intervals, remarks
Seed corn maggot	diazinon	1 oz per bu	Seed treatment only
Cutworms	carbaryl (Sevin)	1.5 lbs	No limitations
	chlorpyrifos (Lorsban 4E)	0.5-1 lb	28 days
Bean leaf beetle	acephate (Orthene)	0.50 lb	14 days
	azinphosmethyl (Guthion)	0.25 lb	45 days, do not graze or feed foliage
	carbaryl	0.50 lb	No limitations
	chlorpyrifos	0.50 lb	28 days
	fenvalerate (Pydrin)	0.10 lb	21 days, effective against cutworms, Restricted Use Compound
	methyl parathion (Penncap-M)	0.50 lb	20 days, hazardous to bees Restricted Use Compound
Green cloverworm	acephate	0.50 lb	14 days
	<u>Bacillus thuringiensis</u> Dipel, Thuricide, Sok Bt, Bactospeine)		As labeled
	carbaryl	1.0 lb	No limitations
	carbophenthion (Trithion)	0.50 lb	7 days, do not feed treated foliage
	chlorpyrifos	0.50 lb	28 days, effective against yellow woollybears
	fenvalerate	0.05 lb	21 days, effective against yellow woolly-bears, Restricted Use Compound
	malathion	1.00 lb	7 days
	permethrin (Pounce, Ambush)	0.05 lb	60 days, effective against yellow woollybears, Restricted Use Compound
Grasshoppers	acephate	0.25 lb	14 days. Do not feed forage
	carbaryl	1.50 lb	No limitations
	chlorpyrifos	0.50 lb	28 days
	dimethoate (Cygon, Defend)	0.50 lb	7 days
Spider mites	dimethoate	0.50 lb	7 days
	carbophenthion (Trithion)	0.50 lb	7 days, do not feed treated foliage
Potato leafhopper	carbaryl	1.00 lb	No limitations
	fenvalerate	0.05 lb	21 days, Restricted Use Compound

Outlook - Possible insect problems in corn following idled P.I.K. land

Whitney Cranshaw
Assistant Professor
Department of Zoology and Entomology
Colorado State University
Fort Collins, CO 80523

During 1983, wide variation marked the management practices of idled Minnesota P.I.K. acres. Prediction of insect pest problems is always difficult, but few changes are expected in corn grown on previously idled land. However, certain cropping practices may cause a higher incidence of some pests, and an increased need for scouting is probable on corn following P.I.K. acres. Insect problems to watch and prepare for include:

Seed corn maggots. Seed corn maggots are the larvae of a common small, grey fly. Maggots attack germinating seeds and can cause stand losses or a reduction in seedling vigor. Soybeans are more frequently injured but corn may also be attacked. Patterns of increased seed corn maggot injury occur following heavy applications of fresh organic matter, such as green or animal manures. Injury intensifies in cool, wet soils and when germination is retarded.

Seed corn maggot problems may increase in corn which follows a lushly growing sorghum-sudan grass cover crop or other high organic matter cover. Particular problems might be expected with earliest planted corn on the cooler soils. In these situations, a seed treatment containing an insecticide such as Lorsban or diazinon is a recommended low cost method for preventing seed corn maggot injury. Such treatments are unnecessary if planting-time corn rootworm insecticides are applied.

Wireworms, white grubs. Both wireworms and white grubs are extremely rare problems in Minnesota field corn and a single year of acreage idling is not expected to impact on these pests. Moreover, since most wireworms and white grubs have a long life cycle extending three or more years, insignificant damage would be expected in 1984, the first year of the life cycle after the P.I.K. program.

Cutworms. The most damaging cutworm to Minnesota corn is the black cutworm. Since this insect does not overwinter in the state, 1983 cropping practices will not affect the probability of 1984 problems. Black cutworm outbreaks are entirely dependent on the occurrence of heavy, adult moth flights into Minnesota which originate in the southern U.S. during mid-spring. These moth flights were very low during the past two years.

Cutworms which overwinter in Minnesota, such as dingy cutworms or dark-sided cutworms may or may not be affected by P.I.K. croppings. However, these cutworms have not been as damaging to corn as black cutworms since they generally confine most feeding on corn to the leaves and have little effect on yield.

Regardless of previous cropping practices, the most effective way to handle corn cutworms in Minnesota is to take the "wait and see" approach. Better insect control is achieved at lower cost if sprays are applied after detecting a cutworm problem than routinely applying a planting time "insurance" treatment. Recommended cutworm sprays include Pydrin and Lorsban.

Common stalk borers. The overwintering eggs of the common stalk borer hatch throughout May and the young larvae immediately tunnel into nearby plants. Usually these larvae first feed within a small stemmed plant, such as a grassy weed, and are later forced to move to a larger plant as the stalk borers become older.

Stalk borer eggs are laid on grassy weeds after the first week in September. Normally, stalk borer infestations are limited to the outside rows of corn fields which are adjacent to weedy field edges. However, many idled fields supported high weed populations in September and the potential exists for some field-wide stalk borer problems in 1984. Fields which were mowed before egg laying should have had a reduced attraction to the moths.

Stalk borers can not be controlled with insecticides while they are within a corn plant. Also, the period during which borers initiate attacks on the plants is spread over weeks. Unfortunately, no insecticide program, sprays or granules, have yet showed a high level of consistent, cost effective control of common stalk borers.

If the potential for serious stalk borer problems exists, fields should be planted at the full recommended seeding rate so that occasional missing plants can be better tolerated. Stalk borers do not cause significant damage to soybeans or other crops.

Corn rootworm larvae. Economic damage to first year cover by corn rootworms is extremely rare in Minnesota. This was again established during 1983 by surveys of 33 first year fields at which time no fields were found to have root damage exceeding a level at which a yield response occurs (2.5^{+} on the Iowa 1-6 scale).

Corn rootworm egg surveys were conducted in 39 south central and southeastern Minnesota P.I.K. fields and 19 nearby corn fields. Corn rootworm eggs were detected in 36% of the P.I.K. fields. However, when found, they were at a much lower average population than in neighboring corn fields. Consequently, corn rootworm problems following P.I.K. are possible but unlikely and are probably at nearly the same risk as is first year corn following soybeans or small grains. Corn rootworm egg laying is most likely to occur in P.I.K. fields which were producing large amounts of pollen during late August and September from a grassy ~~corn~~ cover crop.

European corn borer. Previous crop history has little or no effect on subsequent infestation by the first generation of European corn borer. First generation corn borer problems tend to be greatest on earliest planted corn and require proper environmental conditions for high egg production and larval survival. All corn, every year, should be scouted during late June and early July for evidence of developing corn borer problems. Insecticide applications applied into the whorl shortly after egg hatch can provide excellent control of early season corn borer.

Armyworms. Armyworms do not overwinter in Minnesota and problems are dependent upon the arrival of large numbers of migrant moths from southern states. In corn, serious armyworm problems are generally limited to fields with grassy weed problems during the period when eggs are being laid. Where 1984 grass problems exist, watch for developing armyworm problems during July.