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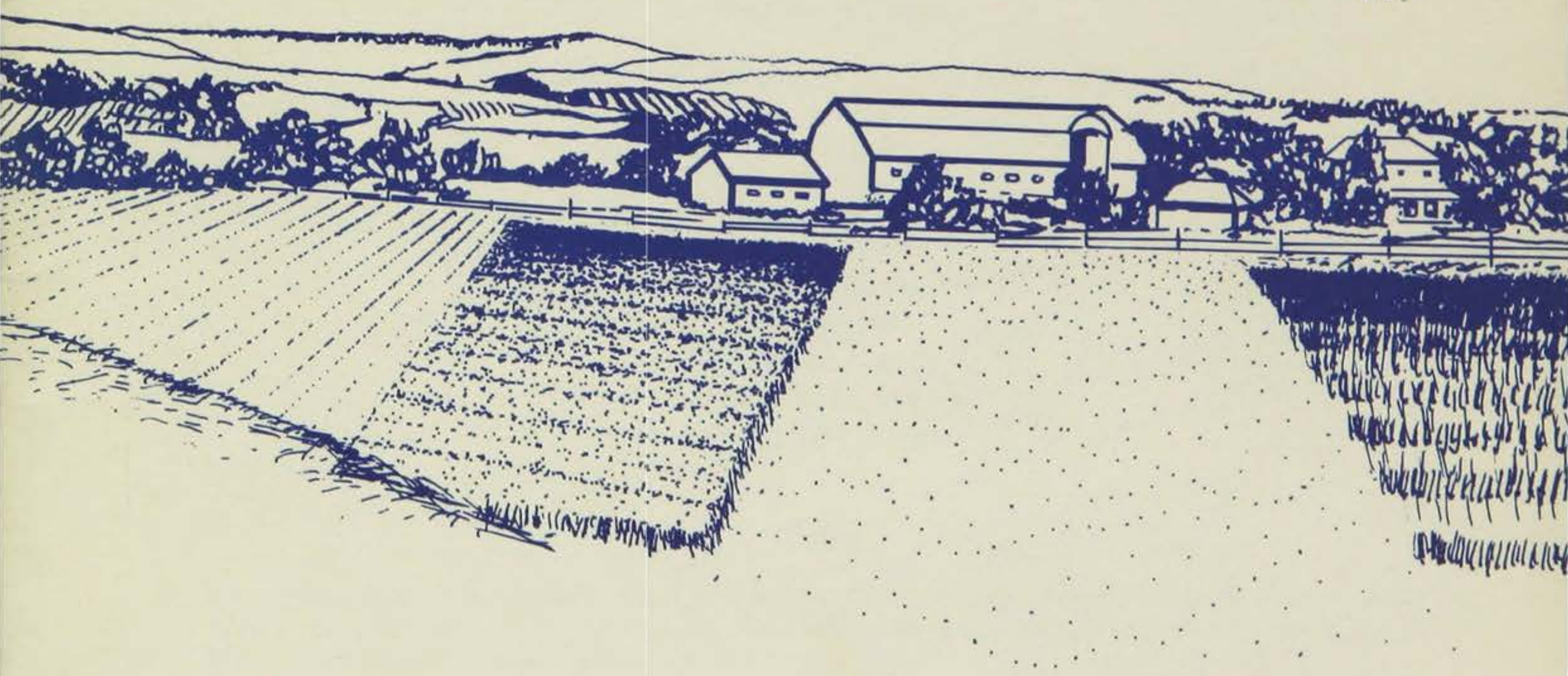
AGRICULTURE

Soils, Fertilizer and Agricultural Pesticides Short Course

December 15-16, 1993

Minneapolis Convention Center



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PROCEEDINGS

SOILS, FERTILIZER AND AGRICULTURAL PESTICIDES SHORT COURSE AND EXPOSITION

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STRATEGIES FOR FERTILIZING IN 1994

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The unusually wet weather for the past two growing seasons has been cause for concern. The negative impact on yield has been well documented. As the 1994 growing season approaches, there are, obviously, some questions about potential changes that might be needed for a fertilizer program for corn production.

Based on the evidence that we have on hand, it is possible to make some suggestions that might reduce risk. If we could accurately predict the weather for next year, we could provide more precise advice. However, we all realize that accurate weather prediction for next year's growing season is not possible.

In discussing potential changes in fertilizer management, it's important to discuss the mobile nutrients (nitrogen) separately from the immobile ones (phosphorus, potassium).

Changes To Consider In The Use Of Phosphate and Potash Fertilizer:

Agronomic Factors

Special consideration for these two nutrients might be affected by some facts that we know going into the 1994 season which are:

- Both 1992 and 1993 yields were lower than normal. Therefore, uptake of both P and K would be less than normal.

- For many counties, large acreages of corn were destroyed to qualify for the 0/92 program. The P and K in the grain were returned to the soil rather than removed in the harvested crop.

- For many low areas in fields, standing water prevented the growth of any plants. These flooded areas were essentially fallow for the entire growing season.

- Because of the currently high soil moisture contents, there is a high probability that soils will be cool and wet at planting time next year.

There is no accurate method for predicting what effect these four factors might have on the supply of P and K available for the 1994 crop. A large amount of uncertainty about nutrient availability can be eliminated by using the fundamental management practice of collecting accurate and representative soil samples. There is no substitute for basing fertilizer recommendations on the results of the analysis of soil samples.

Special consideration should be given to those areas in the field that were fallow during 1993. From past experiences, we know that early corn growth on these areas could be severely restricted. The stunted plants show phosphorus deficiency symptoms even though the soil test for phosphorus might be in the medium to high range.

This condition has been described as the "fallow syndrome." The cure is not complicated. A banded application of phosphate usually with some zinc at planting is adequate. High rates are not needed. A rate of 20 lb. P_2O_5 with 1 lb. Zn per acre in a starter would be adequate for fields with a medium or high soil test for phosphorus. The recommended rate of phosphate for starter fertilizer use would be appropriate for fields having low or very low levels of soil test phosphorus. Past experience has shown that the broadcast application of phosphate at rates that are economical will not correct the "fallow syndrome."

Economic Factors

There's no doubt that adequate cash flow could be a major problem for many Minnesota farmers in 1994. For these situations, a close look at input costs is imperative. Looking ahead to 1994, fertilizer costs can be minimized by substituting banded placement of phosphate, potash, and zinc for broadcast applications. In general, recommended rates can be reduced by one-half if banded placement is used. This substitution can result in substantial savings in the money spent for fertilizer. The effect of banded and broadcast applications of phosphate and potash fertilizer is illustrated in Table 1. These yields illustrate and confirm the efficiency of banded application of immobile nutrients.

Table 1. The effect of rate and placement of phosphate and potash on corn yield.

Rate Applied			Location and Year		
			Goodhue County		Lamberton
K_2O	P_2O_5	Placement	1992	1993	1992
- lb./acre -			- - - - - - bu./acre - - - - - -		
0	-	-	114.0	117.0	-
40	-	starter	142.5	126.2	-
100	-	broadcast	135.5	120.9	-
200	-	broadcast	140.4	123.7	-
-	0	-	-	-	122.2
-	40	starter	-	-	146.3
-	100	broadcast	-	-	148.1
-	200	broadcast	-	-	158.3

Soil Test P - Lamberton (92) = 6 ppm (low)
Soil Test K - Goodhue County (92) = 77 ppm (low)
Soil Test K - Goodhue County (93) = 63 ppm (low)

If soils are cool and wet, use of a starter fertilizer has a high potential for increasing early plant growth. This enhanced early growth has a strong potential for increasing grain yields.

Considerations For Nitrogen Fertilizers:

Responses to Supplemental Sidedress N

Since substantial amounts of anhydrous ammonia were applied this fall in many parts of Minnesota, some may feel that it is inappropriate to discuss potential changes in the management of nitrogen fertilizer at this time. However, it's important to recognize that the soil in the root zone is at or near field capacity. If snowfall is normal, we face saturated soils in the spring of 1994 with a potential for delayed planting. There is also a potential for loss for fall-applied N to denitrification. Although we can't make accurate long-range weather forecasts, we can anticipate that there is the potential for some N loss and be prepared. Supplemental N may be needed during the 1994 growing season. A score sheet that can be used as a decision aid is provided. This score sheet should be used on a field by field basis.

The response of corn grown in excessively wet soil conditions to supplemental sidedress nitrogen has been researched in other states where the problem occurs more frequently. The results from research in Illinois illustrate the type of response that might be expected (Table 2). For this study, researchers applied various rates of nitrogen; then they saturated the soil. After the soil was saturated, they applied additional water. nitrogen and more water. In one situation, they added an additional 4 inches of water over a period of 3 days. The second situation involved the application of an additional 6 inches of water over a period of 8 days. As a result of the application of excessive water, conditions were very favorable for denitrification. After the water treatments were finished, they split each plot giving half the plots an additional 50 lb. N/acre and the other half nothing.

Table 2. The influence of supplemental sidedress nitrogen on corn yields grown in excessively wet conditions.

Initial N Applied	None	Additional Water Added (in.) 4 in. in 3 days: 0 added N	4 in. in 3 days: +50 lb.N/A	6 in. in 8 days: 0 added N	6 in. in 8 days: +50 lb N/A
lb./acre		bu./acre			
0	72.5	71.8	94.4	63.0	90.4
100	130.3	119.8	132.2	117.6	116.9
150	132.5	123.1	129.3	122.9	132.1
200	138.1	130.8	136.2	131.4	128.2

Source: University of Illinois, 1985-1987

Score Sheet: A decision aid to assist in determining whether sidedressed, supplemental fertilizer N should be recommended for corn.

Instructions: For each field, evaluate the situation in terms of the three listed factors and assign the appropriate score.

Factor 1: When was the fertilizer N applied?

	Fall	Early Spring	Late Spring
Score:	4	3	2

Factor 2: What has been the predominate soil moisture status in the field?

	Standing Water/Saturated	Wet	Normal
Score:	4	3	1

Factor 3: What is the crop's current condition?

	Chlorotic/ >16" Tall	Chlorotic/ <16" Tall	Green/ <16" Tall	Green/ >16" Tall
Score	5	3	2	1

Now: Total the score for the 3 factors and use the following guidelines.

Less than 7	8-9	10 or more
No supplemental N is recommended	Re-evaluate in one week	Add an additional 40-70 lb. N/acre

Without supplemental sidedress nitrogen, corn yields decreased as the amount of excess water applied increased. When 4 inches of excess water was applied, the use of 50 lb. of N per acre increased yields compared to those that were produced with the initial level of soil moisture that was established. This observation was also true if the initial level of applied N was 150 lb. per acre and the added water used was 6 inches applied over 8 days. For this moisture, the lack of response to sidedress N when the initial rate of applied N was either 100 or 200 lb./acre cannot be explained at this time. The results of this research project, however, do indicate that a supplemental sidedress application of 50 lb. N per acre should be satisfactory for corn production in excessively wet situations.

Minnesota Observations

Because of the excessively wet conditions that persisted throughout June in southern Minnesota, there were numerous questions about the need for supplemental sidedress N.

Twelve fields were selected for this project. Each had been fertilized with either anhydrous ammonia in the fall of 1992 or urea in the spring of 1993. Soil samples (0-12 inches, 12-24 inches) were collected from uniform areas in late June. These were dried, ground and analyzed for NO_3-N. After sampling was complete, ammonium nitrate was applied to 3 plots and another 3 plots were left as controls. A 150 lb. N per acre rate was used which was higher than the rate that would have been recommended. However, this rate was chosen to assure that adequate fertilizer N had been applied.

Soil samples were collected from each plot at each site in early September. If the corn was not destroyed for the 0/92 program requirements, grain yields were measured in October.

The amounts of NO_3-N measured in these fields in late June are summarized in Table 3. The average amount found was higher when spring urea had been used as the N source and most of the NO_3-N was found in the surface foot. The NO_3-N was nearly uniformly distributed in each depth in fields fertilized with anhydrous ammonia in the fall of 1992. These results indicate that there was loss of N when this N management system was used. There is no way to determine the mechanism for the loss, but denitrification could have taken place in June.

Table 3. Average amounts of soil NO_3-N measured in late June in selected corn fields in southern Minnesota.

N Management System	Depth (feet) 0-1	1-2	0-2
	- - NO_3-N, ppm	- - -	lb. NO_3-N/acre
fall anhydrous ammonia	12	15	108
spring urea (preplant)	32	15	188

The rate of preplant fertilizer N applied by the farmer to each field averaged 145 lb. N per acre with a range of 110 to 235 lb. N per acre. Similar rates were applied with fall or spring applications.

The amounts of NO_3-N measured in September in plots that had not received supplemental nitrogen were small (Table 4). These values were slightly higher in fields where preplant urea had been used. As might be expected, there was a substantial increase in the amounts of NO_3-N measured when supplemental sidedress N had been used. These values are higher than levels that are desired. However, the 150 lb. N/acre that was applied is much higher than the rate suggested for this purpose (40-70 lb. N/acre).

Table 4. Average amounts of soil NO_3-N measured in early September in selected corn fields in southern Minnesota.

N Management System	Sidedress N Rate	Soil Depth (feet) 0-1	1-2	0-2
	lb./acre	NO_3-N, ppm		lb. NO_3-N/acre
fall anhydrous ammonia	0	3	2	20
	150	10	8	72
spring urea (preplant)	0	4	7	44
	150	17	13	120

Of the twelve original sites, approximately one-third were destroyed to meet the requirements of the 0/92 program. The use of supplemental sidedress N produced a yield increase in one-half of the remainder. This yield averaged <u>138</u> bu./acre when the added N was used. Average yields were <u>119</u> bu./acre when no supplemental N was used. The yield increases ranged from 5 to 66 bu./acre. The average yield was <u>105</u> bu./acre for fields where the supplemental sidedress N did not increase yields. This suggests that there may be instances where yields are limited by factors other than nitrogen. There was no correlation between yield response and the amount of NO_3-N measured in the top foot in late June. The observed movement of NO_3-N into the 1-2 foot depth is a primary contributing factor for this lack of correlation.

Applying Supplemental Fertilizer N

The grower has several choices if faced with the need to apply supplemental N. Many prefer the use of anhydrous ammonia for sidedress applications. This is an acceptable practice if soil moisture conditions will allow for retention. In 1993, soil conditions were frequently too wet and it was difficult, if not impossible, to get a satisfactory seal to prevent the loss of the anhydrous.

The broadcast application of urea for sidedress application was a popular practice in 1993. There was little, if any, volatilization from this practice in 1993 because of either satisfactory cultivation or frequent rains. There is a common perception that broadcast urea may injure the corn crop. Although some minor burning could occur when urea granules get down into the whorl, this has no effect on either growth or yield.

Liquid N can also be easily used in sidedress applications. If soil conditions permit, it is easy to knife in. If corn is tall and N is needed, it can be dribbled on the soil surface with high clearance equipment. Application on leaf tissue should be avoided.

Using Nitrogen Fertilizer Next Year

It's obvious that all of the nitrogen needed for the 1994 crop was not applied in the fall of 1993. For those fields that will be fertilized with nitrogen next spring, major changes in nitrogen management plans are not needed.

For western Minnesota, use the soil nitrate test. Soil samples analyzed to date indicate that residual or carryover NO_3-N is lower than normal and an upward adjustment in nitrogen rates would be justified.

For the remainder of Minnesota, base N fertilizer needs on yield goal, soil organic matter content, and previous crop history. Be sure to give accurate credit for any legumes and manure used in the rotation. If, for some reason, a substantial carryover of NO_3-N is expected, take soil samples to 2 feet at or near planting time and use the suggested rate of N as a sidedress treatment.

Summary:

The unusually wet and cold weather of 1993 should not cause substantial and widespread changes in fertilizer management for 1994. The use of well established management practices is still recommended. Some suggestions are summarized below.

- Use soil testing as a basis for making recommendations for the use of phosphate and potash fertilizer.

- Apply some phosphate and possibly zinc in a starter fertilizer if corn is to be planted on areas that were fallow in 1993. Base rates on the results of soil test.

- Plan on using a starter fertilizer if the option is available. There is a good chance that soils will be cool and wetter than normal at planting time.

- If there is substantial rainfall next spring, be prepared to consider supplemental sidedress N.

- If nitrogen fertilizer was not applied in the fall, use Best Management Practices (soil nitrate testing, credits for legumes and manures, etc.) to guide N recommendations.

HERBICIDE RESISTANT WEEDS - AN UPDATE

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Resistance of weeds to herbicides is not a unique phenomenon. In fact, resistance to pesticides is a world-wide problem that is not confined to any single pest category. The first report of insects resistant to insecticides was in 1908, of plant pathogens resistant to fungicides was in 1940, and of weeds resistant to herbicides (triazines) was in 1968. By 1991, 120 weed biotypes that were resistant to triazine herbicides and 15 other herbicide families were documented throughout the world. Results of a 1992 North Central Weed Science Society survey of the north central United States and Canada reflect a world-wide trend of increasing appearance of herbicide resistance. Twelve states or provinces reported biotypes of 19 weed species resistant to triazine herbicides. Five states or provinces reported biotypes of three weed species resistant to lipid biosynthesis inhibitors, 10 states or provinces reported biotypes of four weed species resistant to amino acid biosynthesis inhibitors, four states or provinces reported biotypes of two weed species as resistant to dinitroaniline herbicides, and Manitoba reported resistance of a wild mustard biotype to growth regulator herbicides. Indeed, pests have proven to be ecologically and biochemically adaptable to agrichemicals.

Herbicide Resistant Weeds in Minnesota

There are currently three weed biotypes that have developed resistance to herbicides in Minnesota. They are: common lambsquarters and redroot pigweed to the trazine herbicides and wild oats to the lipid biosynthesis inhibitor herbicides.

Why Worry About Herbicide Resistance?

In corn, soybean, and small grains there are many herbicide options. Why then should a crop producer be concerned whether a weed biotype is resistant to a particular herbicide? There are several reasons. Many herbicide options could quickly be lost for several crops if a weed biotype is resistant to more than one herbicide (i.e. cross resistance). Obviously, a loss of herbicide options could have important economic and environmental consequences to agriculture. Also, in an era of high reregistration costs for older herbicides and high development costs for new herbicides, the possibility for replacement of the herbicides lost due to resistance diminishes. Finally, in most cases, it will not be easy nor inexpensive to assess resistant weed biotypes. Due to cross resistance, many resistance problems may have to be solved by trial and error, which could be quite expensive to the crop producer.

The herbicide resistance issue does have solutions and perhaps the best place to start is to consider herbicides as a resource that needs to be preserved. Strategies for resistance prevention follow from there.

How Does Selection of Resistant Weed Biotypes Occur?

Selection for change in weed populations begins when a small number of plants (a biotype) within a weed species have a genetic makeup that enables them to survive a particular herbicide application. Where this difference in genetic makeup originated is not clear. However, herbicides are not known to directly cause the genetic change (i.e. mutation) that allows resistance. The resistant biotype, therefore, is present in low numbers in natural populations and when a herbicide is applied, most of the susceptible weeds die but the few resistant weeds survive, mature, and produce seed. If the same herbicide continues to be applied and, the resistant weeds reproduce, the percentage of the weed population that is resistant will increase.

It is difficult to predict exactly which weed species will have biotypes resistant to a given herbicide. However, we have learned from previous pesticide resistance problems that the occurrence of herbicide resistant weeds is linked directly to the herbicide program used, the weed species present, and the crop management practices employed.

Selection Intensity - The Key to Prevention

Selection intensity acts, in a sense, like a filter that can screen out susceptible weed biotypes while leaving resistant biotypes. Herbicides by definition are effective weed killers, therefore, they have the potential to exert heavy selection intensity on weeds. The more susceptible a weed species is to a given herbicide (i.e. the greater the weed control) the greater the selection intensity. As a result, the rate of selection for resistance can be quite rapid if the same herbicide or herbicides with the same site of action are repeatedly used in a particular field.

With such highly effective herbicides, one would think that the increase in the number of herbicide resistant biotypes would be readily observable. This is not the case. Resistant biotypes generally are only detectable when they make up about 30% of the population. During the first several years of a weed control program that relies on only one herbicide, the proportion of resistant biotypes is very low (less than 1% of the population). As long as the application of this herbicide continues and the resistant biotypes reproduces, the proportion of the population that is resistant will increase. It is very common to go from excellent control of a particular weed species to very poor control within one growing season. A gradual decline in performance is seldom seen. Figure 4 illustrates the predicted rapid increase in the proportion of a kochia population that is resistant following repeated annual applications of the sulfonylurea herbicide Glean. In field situations, resistance to sulfonylurea herbicides has been reported to occur after 3 to 5 years of repeated use. With triazine herbicides, resistance has generally appeared after seven or more years of repeated use. Therefore, depending upon the proportion of the population that was initially resistant to a herbicide, repeated use of a product for more than two years could develop a herbicide resistance problem.

Herbicide Factors that Increase Selection Intensity

The herbicide characteristics that affect herbicide resistance are as follows.

1. Herbicides that act on a single site of action.
2. Herbicides that are applied multiple times during the growing season.
3. Herbicides used for several consecutive growing seasons or repeated application of herbicides with the same site of action to the same or different crops.
4. Herbicides used without other weed control options (e.g. cultivation) and are considered "stand alone" weed control programs.

Weed Characteristics That Favor Resistance

Weeds, by their nature, have a diverse genetic background that gives them the ability to adapt to many different environments. For example, the repeated mowing of a lawn selects for low growing plants that avoid or are not affected by repeated cutting. Therefore, it should not be surprising that weeds can adapt to certain herbicide programs. Weeds with a diverse genetic background may have a resistant biotype that has a 1 in 1 million chance of occurring within a weed population. Although these odds sound remote, a 1 in 1 million chance of occurrence can translate into a high probability of selecting for a herbicide resistant weed biotype unless proper methods to reduce selection intensity are used.

As a herbicide resistant biotype becomes more predominant in the weed population two factors increase in importance:

1. Weed reproductive capability.
2. Weed seed dispersal mechanisms.

The greater the reproductive success of the resistant biotype, the greater its potential to spread and become a dominant part of the population. Due to the extended viability of most weed seeds, once established, a herbicide resistant biotype will be difficult to eliminate from the population, even if extensive remedial weed control measures are used. Weeds such as kochia, can tumble for miles spreading seed onto previously uninfested land. As a result of the diverse seed dispersal mechanisms of weeds, it is apparent that a farm manager must always use good herbicide resistance management strategies to prevent resistant biotypes from developing on their land and prohibit the establishment of resistant weed biotypes spreading from adjacent lands or from custom harvesting equipment and other machinery.

Diagnosing Herbicide Resistant Weeds

Before assuming that any weeds surviving a herbicide application are resistant, rule out other factors that might have affected herbicide performance. Several factors would be misapplication, unfavorable weather conditions, improper timing of herbicide application, and weed flushes after application of a non-residual herbicide. If resistance appears to be a likely possibility, check for the following:

1. Are other weeds listed on the product label controlled satisfactorily? Chances are only one weed species will show herbicide resistance in any given field situation. Therefore, if several normally susceptible weed species are present, reconsider factors other than herbicide resistance as the cause of the lack of weed control.

2. Did the same herbicide or herbicide with the same site of action fail in the same area of the field in the previous year?

3. Do field histories indicate extensive use of the same herbicide or herbicide site of action year after year?

If one or more of these three situations apply, it is possible that the weeds are resistant to the herbicide. If resistance is suspected, control the weeds with a labeled herbicide having another site of action or use appropriate nonchemical weed control methods to prevent the weeds from going to seed. Next, contact your local crop consultant or extension agent, state weed specialist, and the appropriate chemical company to develop a comprehensive weed control program to manage the problem.

Herbicide Resistant Crops

Recent research efforts have been directed at breeding herbicide resistance into crops. For minor-use crops it may be more economical to breed herbicide resistance into a crop than to develop new selective herbicides for current crop varieties. For major-use crops such as corn, soybeans, and wheat, herbicide resistant crops may be useful where difficult to control weeds or environmental conditions dictate the use of specific herbicides to which the crop is normally susceptible.

The use of herbicide resistant crops could enhance the potential for selecting for herbicide resistant weeds unless careful management practices are followed. The key, once again, is selection intensity. Misuse of herbicide resistant crops could encourage the use of a single herbicide or herbicide family over several crop rotations; thereby enhancing the selection intensity for herbicide resistant weeds.

Herbicide resistant crop varieties or hybrids need to be carefully evaluated for other performance characteristics (e.g. yield) and these characteristics should be compared to all other suitable hybrids or varieties in the marketplace, whether they have herbicide resistance or not. This will ensure that crop producers are getting the best overall agronomic value for their money. It will also be very important that accurate records be kept of the exact planting location of the herbicide resistant crops to avoid herbicide misapplication.

Management Strategies for Avoiding and Managing Herbicide Resistant Weeds

The North Central Weed Science Society (NCWSS) Herbicide Resistance Committee has developed a list of strategies for avoiding and managing problems with herbicide resistant weed biotypes. Keep in mind that reliance upon any one strategy is not likely to be effective. The crop producer must use the following strategies in carefully selected combinations if herbicide resistant weed problems are to be avoided or properly managed.

1. Use herbicides only when necessary. Where available, herbicide applications should be based on economic thresholds. Continued development of effective economic threshold models should be helpful.

2. Rotate herbicides (sites of action). Do not make more than two consecutive applications of herbicides with the same site of action to the same field unless other effective control practices are also included in the management system. Two consecutive applications could be single annual applications for two years, or two split applications in one year.

3. Apply herbicides in tank-mixed, prepackaged, or sequential mixtures which include multiple sites of action. Both herbicides, however, must have substantial activity against potentially resistant weeds for this strategy to be effective. Remember that in the past, weeds which were selected for herbicide resistance often were not the primary target species. It may be expensive to apply herbicide combinations which duplicate a wide-spectrum of weed control activity. Many of the more economical herbicide combinations may not be adequate. Table 10 is a cross reference list of package mixtures and their corresponding sites of action.

4. Rotate crops, particularly those with different life cycles (e.g. winter annual such as winter wheat, perennial such as alfalfa, summer annual such as corn or soybeans). At the same time, remember not to use herbicides with the same site of action in these different crops against the same weed unless other effective control practices are also included in the management system.

5. Planting new herbicide resistant crop varieties should not result in more than two consecutive applications of herbicides with the same site of action against the same weed unless other effective control practices are also included in the management system.

6. Where feasible, combine mechanical weed control practices such as rotary hoeing and cultivation with herbicide treatments.

7. Where soil erosion potential is minimal, include primary tillage as a component of the weed management program.

8. Scout fields regularly and identify weeds present. Respond quickly to changes in weed populations to restrict spread of weeds which may have been selected for resistance.

9. Clean tillage and harvest equipment before moving from fields infested with

resistant weeds to those which are not.

10. Railroads, public utilities, highway departments and similar organizations which use total vegetation control programs should be encouraged to use vegetation management systems which do not lead to selection of herbicide resistant weeds. Resistant weeds from total vegetation control areas frequently spread to cropland. Chemical companies, state and federal agencies, and farm organizations can all help in this effort.

CLIMATOLOGY: WHAT WILL THE '94 WEATHER BE?

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INTRODUCTION

There is no question that the climates of the crop growing seasons in recent years have had tremendous impact on production systems. Disconcerting recollections of 1988, 1991, 1992, and now 1993 are vivid to many producers and consultants. The climate anomalies experienced during these years were of extreme magnitude and distinctly different in their seasonal pattern and impact: drought coupled with persistent high temperatures were the major features of 1988; extremely wet conditions prevailed in 1991, with many Minnesota counties reporting 35 to 45 inches of precipitation; very cool summer temperature conditions were persistent in 1992, with late spring and even summer frosts (frost on the summer solstice had not occurred since last century); and finally the combination of cool growing conditions and widespread flooding in 1993 produced one of the worst growing seasons ever for the state, with over 50 counties filing disaster declarations.

Many climatologists believe that year to year climatic variability has increased in recent years. Climatic fluctuations, once thought to be cyclical or even static, are increasingly regarded as highly variable with patterns which might be linked to the frequency of other atmospheric perturbations brought about by volcanic activity or changing sea surface temperature anomalies (El Nino, La Nina), among others (see Changnon, 1987). But regardless of scientific explanations and theories about climatic teleconnections, climate should be regarded as a natural resource like soil and water, and any production adjustments to conditions should be made in the context of consideration of risk and probability. The purpose of this paper is to present a discussion of climatic variability as evidenced in Minnesota records; to illustrate the spatial, temporal and conditional probabilities which need to be considered in any crop production management system; and to consider some of the conditional probabilities and indications about what type of weather might be expected in the spring of 1994.

EVIDENCE FOR INCREASED VARIABILITY

Baker et al (1993) used a combination of annual crop yield data and climatic data to illustrate the so-called "benign climate" period when reduced year to year climatic variability contributed to the agricultural expansion and inflation of the the 1970s. Figure 1 from that study shows the linear trend lines which relate to the changes in Minnesota state average corn yields over the period from

1866 to 1991. It is assumed that these trend lines represent changes in yield due to technology, and that the variations about these trend lines are due to weather effects. Figure 2 represents the annual deviations in state averaged corn yields from the trend lines. These are expressed as a percentage. The period from 1937 to 1973 is noted as it represents a time when the percentage departure in yield on an annual basis did not exceed 15 percent. Figure 3, also from this study, shows a moving 13 year standard deviation in annual temperature which indicates minimal values in close correspondence to the same period of reduced yield departures. In addition to Baker et al (1993), Thompson (1975), Changnon (1984) and Ausubel (1991) have discussed implications of the benign climate period, one of which was that perhaps technology had effectively overcome most climatic influences on production practices. This view is no longer held by many climatologists, as recent years have shown a return to variability on the order of that seen earlier this century - some would say a return to a more hostile climate. Among the conclusions in the study by Baker et al (1993) were:

that ..."such a condition (low climatic variability) permits the full expression of applied technology.....While a benign climate can be of great profit to a good farmer, it also protects the poor and careless farmer."

and that ..."usual climate (that of greater variability), such as that experienced previous..., requires greater conservatism and attention to detail than one in which the climatic conditions are both near optimum and exhibit low variability."

VARIABILITY IN MINNESOTA CLIMATE RECORDS

In order to examine climatic variability in more detail, the Bird Island-Olivia (Renville County in south-central Minnesota) daily temperature and precipitation observations covering the period from 1901 to 1993 were studied. Daily maximum and minimum temperatures were used to calculate Growing Degree Days (GDD) for field corn using the standard 50/86 degree F bases.

Figure 4 shows the 93 year average monthly precipitation values during the growing season months of April through October. This pattern is typical of many southern Minnesota locations, with a peak value in June of over 4 inches and a secondary peak in August. Figure 5 shows the standard deviations for the same months. They are highest during the May through September period when convective precipitation is a primary feature of our climate, producing a high degree of both spatial and temporal variability. Figure 6 shows the standard deviations expressed as coefficients of variability (percentage of the mean). Note that they represent 50 percent or more of the monthly mean values, especially so for September and October. This substantiates the claim by many producers that we never have a so-called "normal fall." It is either dry and very favorable for harvesting and other field activity, or it is wet and very difficult to schedule any field work.

Figures 7, 8, and 9 show the precipitation statisitics for the heart of the growing season, the months of May through September. The 93 year mean for the Bird Island-Olivia record is 17.14 inches and the associated standard deviation is 4.06 inches. Figure 7 shows the grand mean and standard deviation boundaries along with the year to year total precipitation for the period.
Some of the seasonal departures in precipitation approach 1.5 to better than 2 standard deviations from the grand mean. The drought years of 1910, 1922, 1931, 1936, 1955, 1969, 1976, and 1988 clearly show, with 1922, 1931 and 1976 showing extremely low amounts ranging from only 7 to 8 inches. Conversely, years with extreme moisture surplus such as 1903, 1906, 1945, 1991 and 1993 can be seen as well. In fact 1991 and 1993 rank as the two wettest growing seasons this century. Figure 8 shows the running 30 year standard deviations of the precipitation for May through September. With the exception of the mid 1960s, the period from 1945 to 1975 shows relatively low variability against the balance of the record. Further, the period since 1975 shows extraordinarily high variability, with a most recent standard deviation approaching 4.5 inches. Figure 9 is a similar graph showing running 10 year standard deviations over the record period. Again the most recent years stand out with a higher degree of variability than any other portion of the 93 year record.

Figure 10 shows the mean monthly corn Growing Degree Days (base 50/86) for the Bird Island-Olivia record. Note the steep temporal ascent in the spring and the sharp drop in the fall from September to October. The total mean GDD in the months of July and August exceeds that of the April through June period, and further the May and September means are roughly equal. Unless corn is planted exceptionally early, the 147 GDD which normally accumulate in April do not contribute substantially to crop development. Conversely, the 199 GDD which normally accumulate in October are <u>always valuable</u> with respect to the corn crop. In years when crop development is retarded, the GDD in October can contribute significantly to the maturation process as long as the first killing frost does not occur. But, even in years when corn matures normally, around mid September, the October GDD help to substantially dry the crop in the field prior to harvest.

Figure 11 shows the standard deviations of monthly GDD values. They range roughly from 60 to 80 GDD. In Figure 12 these are expressed as coefficients of variation, showing greatest stability in the months of July and August, and the most variation in April and October.

The 93 year mean total for the months of May through September is 2559 GDD with a standard deviation of 217. Figure 13 shows the year to year variation in GDD for the months of May through September at Bird Island-Olivia, along with the mean and standard deviation boundaries. Some years where the departure in GDD exceeds 1.5 to 2 standard deviations really stand out. Years with significant positive departures include 1931, 1933, 1936, 1955, 1959, and 1988. Those with significant negative departures include

1903, 1904, 1907, 1915, 1924, 1942, 1945, 1992, and 1993. Some of the greatest extremes have occurred over the past 6 years. Some of these departures suggest that there are particular climatic scenarios which cannot be overcome by spreading risk. For example, with respect to field corn production, many producers plant hybrids of differing relative maturity (RM) spread over a series of planting dates. Typically in southern Minnesota 105 RM hybrids use about 2250 GDD from planting to maturity. But, as Table 1 shows for the Bird Island-Olivia data, there have been 8 growing seasons this century when GDD accumulations during the May through September period did not even reach 2200 GDD.

Figure 14 shows the running 30 year standard deviations for May through September GDD at Bird Island-Olivia. The mean of the 30 year standard deviations is 193 GDD and is shown by the solid straight line. Relatively low standard deviations can be noted for the period from the early 1950s to the early 1970s, with a sharp recent increase. Figure 15 shows the running 10 year standard deviations for the same data. It too shows a pattern of relatively low standard deviations over the period from the mid 1950s to late 1970s, with a sharp increase in recent years.

DISCUSSION OF STATISTICS, PROBABILITIES AND OUTLOOKS

The variability characteristics of both GDD and precipitation in the 93 year record from Bird Island-Olivia, expressed in terms of standard deviations, are in broad agreement with the contention of other climatological studies which show that the growing season climate is now more variable than it was a number of years ago when agriculture was going through rapid expansion and inflation. This infers that the statistics of central tendencies such as mean, mode and median are less descriptive of climate and of declining value in terms of anticipating climatic conditions. Frequency distributions and probabilities are more important than ever to the agricultural producer in assessing management options and risks.

With respect to climate impacts, the spatial and temporal dimensions of probability are important. In recent years, both the magnitude and the spatial scale of climatic abnormalities have been relatively larger than that of recent decades. For example the drought of 1988 brought greatly reduced crop yields to most of the upper midwest and the flooding of 1993 produced disastrous results for nearly all the major river basins in the area. The low temperatures experienced during the 1992 growing season which greatly retarded crop development and maturation were at least in part due to the atmospheric debris circulating in the northern hemisphere as a result of the eruption of Mt. Pinatubo in the Philippines. The reduction in solar radiation reaching the ground was measured and reported by scientists from the National Oceanic and Atmospheric Administration. This climatic anomaly too was rather broad in scale, though its impact was felt more profoundly in states like Minnesota which lie near the marginal fringes for crop adaptability in terms of growing season length.

To examine the temporal dimension, the example of field corn planting dates and relative maturity can be used. Figure 16 shows the mean (44 years) GDD at Waseca associated with a series of 8 planting dates, ranging from April 10th to May 29th. As stated before, a value of 2250 GDD is typically associated with the maturation of 105 RM field corn in southern Minnesota. Surplus or more than adequate GDD totals are evident across the first four planting dates, even considering that the standard deviation of the long term mean GDD is about 200. But, by May 8th the difference between the mean GDD total and the amount needed for 105 RM field corn is less than 1 standard deviation, such that the probability of maturing that kind of crop on that particular planting date begins to approach 50 percent. Certainly, for the later planting dates of May 22 and May 29, the probability of having an insufficient number of GDD for the growing season is well over 50 percent.

Lastly a word about conditional probability. Many times the climatic pattern of a week, month or growing season is predicated on certain conditions or patterns which precede. That is to say, not only does the weather of today somewhat determine what the weather will be tomorrow, but the climatic condition today to some degree determines the range of possibilities for the climatic conditions of next week, next month, or even next spring. The spring outlook for 1994 can serve as an example.
Figure 17 is a map which shows estimates for the percent available soil moisture in the top 5 feet of the soil profile in each of the climatic divisions in Minnesota. These estimates were determined from a soil moisture model used by the Midwest Climate Center and run near the end of September. They have since been substantiated by measurements taken by the USDA/SCS and the University of Minnesota Agricultural Experiment Station. The high levels of water storage in the soil have remained so throughout most of the autumn with little change in total, but some internal redistribution of moisture due to gravity. Note that the deviations from average are rather large. In addition, hydrologists measuring the flows this fall in the major river basins of Minnesota have noted very high levels, ranging from the 80th to 90th percentile for this time of year.

Hydrologists and forecasters have correlated spring flood potential to five climatic factors: a high level of stored soil moisture and river flows in the fall; a rather long and deep winter ground frost with a slow thaw period; a high water content of winter snow cover before the onset of spring melting; above normal amounts of rainfall during the snow melt period in early spring; and a more rapid than normal rate of snow melt in the spring. In general, three of these five factors must be present to have spring flooding in the state. Winter has just begun, but it is already evident that one of these factors is present and will still be important in the spring - the high soil moisture levels and river flows of this late fall will likely remain the same during the winter months, even if mild and dry conditions prevail. Thus, the potential for spring flooding is conditional and already somewhat higher than normal. Additionally, prospects for early field preparation for the 1994 crop season seem dim, even if somewhat normal weather conditions prevail until that time. This is an example of conditional probability that exists every few years in Minnesota, as the spring field working season must be compressed into a few short weeks in order to prevent crops from being severely delayed and more subject to other stresses.

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Table 1. Ranking of the lowest GDD seasons (May-Sept) this century at Bird Island-Olivia.

Year	GDD Total
1915	2053
1924	2099
1992	2102
1945	2130
1993	2142
1907	2167
1903	2180
1904	2195

* Note approximately 2250 GDD are associated with the maturation of 105 RM field corn.

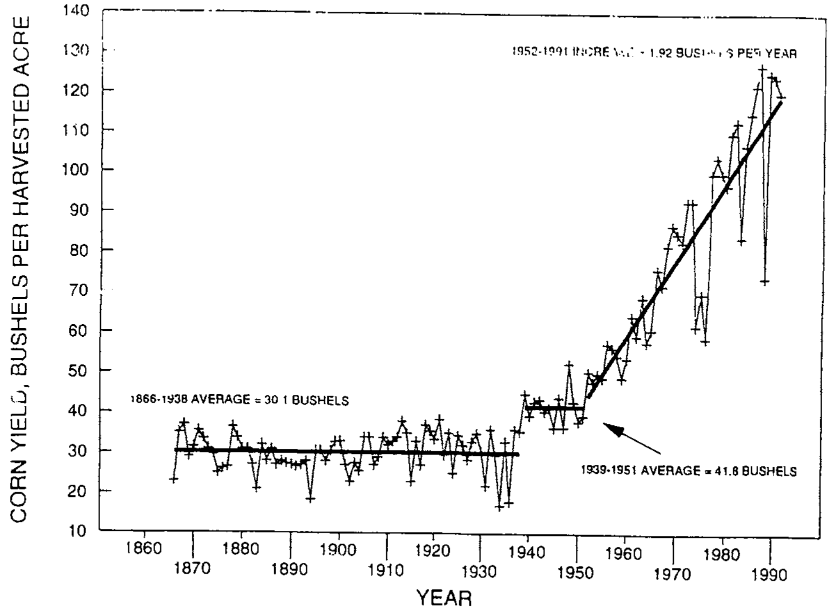

Figure 1. Historical State Corn Yields in Minnesota Showing Trend Lines and Year to Year Values.

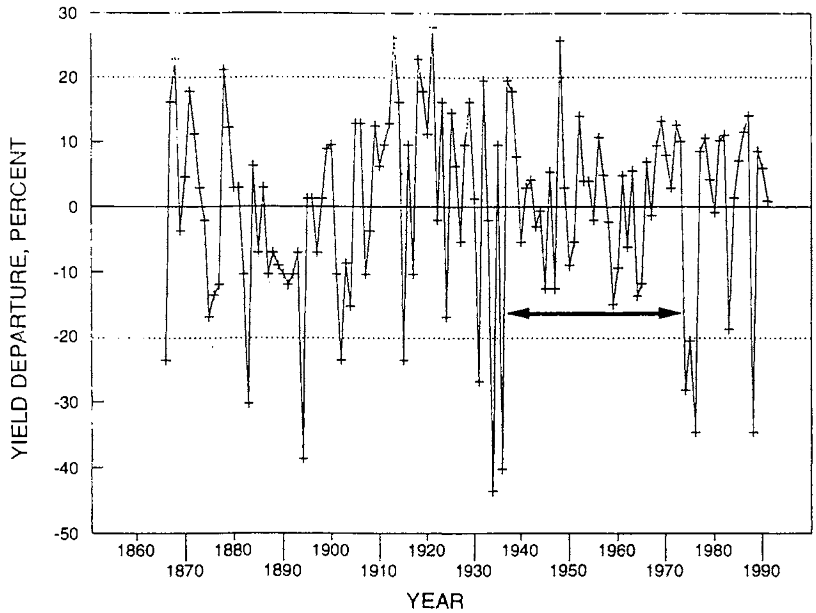

Figure 2. Historical State Corn Yield Departures from Trend Lines, Assumed to be Related to Weather.

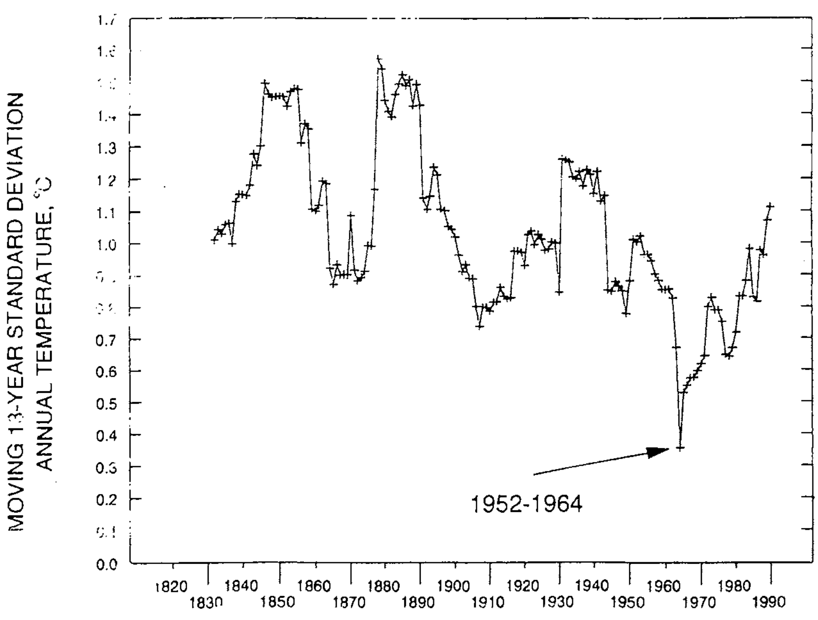

Figure 3. Moving 13 Year Standard Deviations in Annual Temperature from the Eastern Minnesota Climate Record.

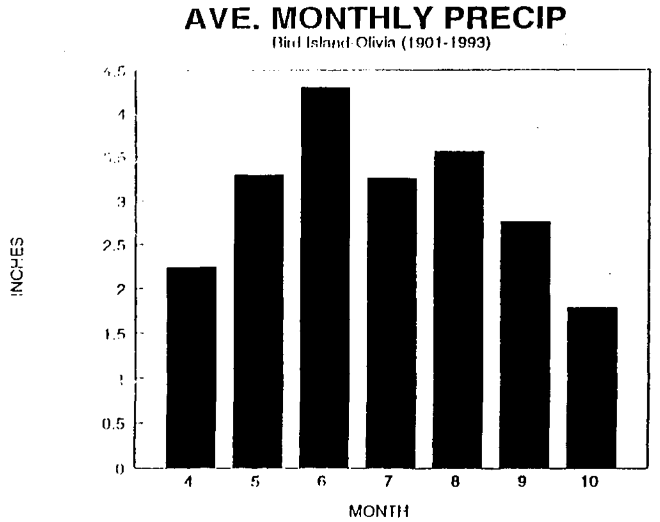

Figure 4. Average Monthly Precipitation Values from the Bird Island-Olivia Climate Record (1901-1993).

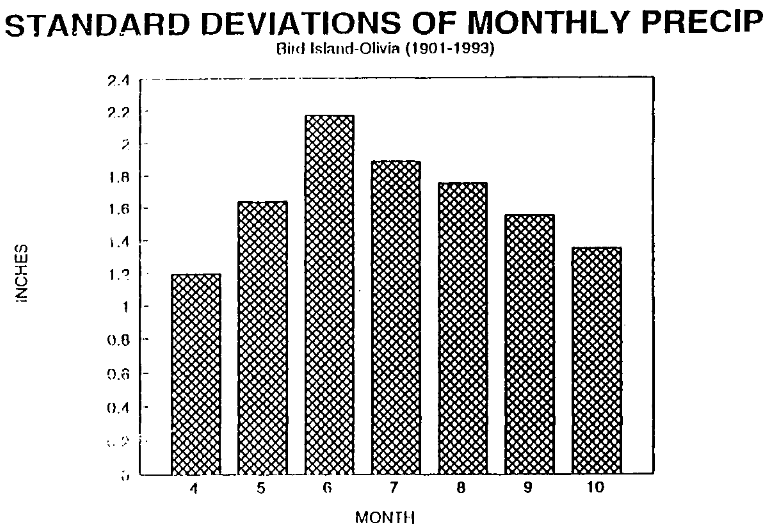

Figure 5. Standard Deviations in Monthly Precipitation Values from the Bird Island-Olivia Record (1901-1993).

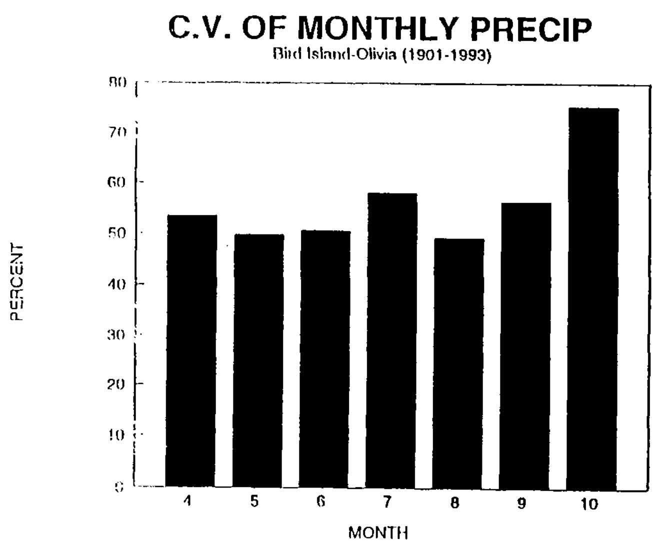

Figure 6. Coefficients of Variability for the Monthly Precipitation Values from Bird Island-Olivia Records (1901-1993).

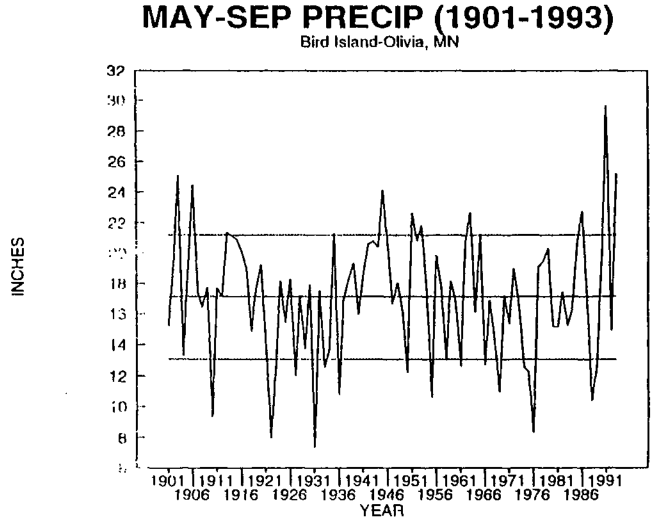

Figure 7. May through September Precipitation Totals from the Bird Island-Olivia Record Compared to the Grand Mean and Standard Deviation Boundaries (1901-1993).

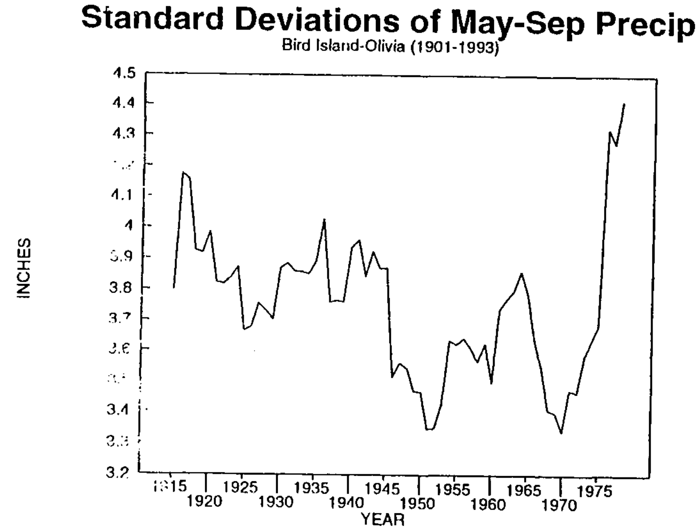

Figure 8. Running 30 Year Standard Deviations of the May through September Precipitation Totals in the Bird Island-Olivia Records (1901-1993).

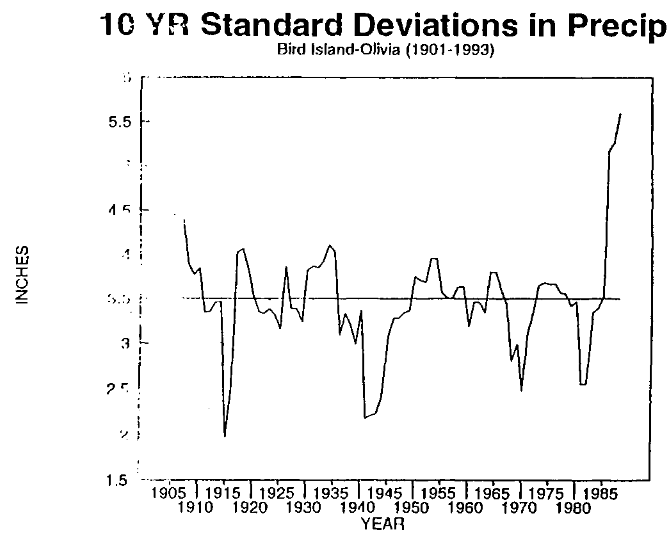

Figure 9. Running 10 Year Standard Deviations of the May through September Precipitation Totals in the Bird Island-Olivia Records (1901-1993).

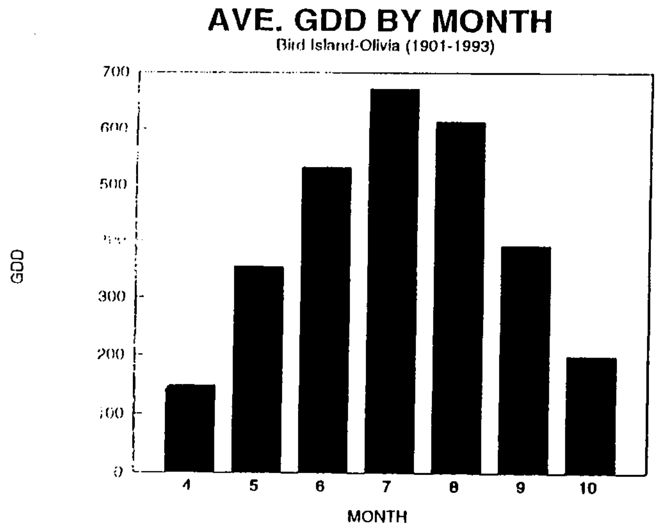

Figure 10. Average Monthly Growing Degree Days (base 50/86) for Field Corn from the Bird Island-Olivia Climate Records (1901-1993).

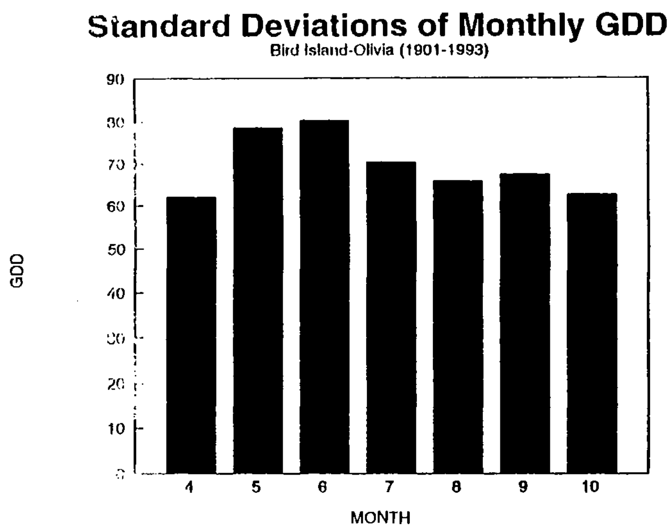

Figure 11. Standard Deviations of Monthly Growing Degree Days (base 50/86) for Field Corn from the Bird Island-Olivia Records (1901-1993).

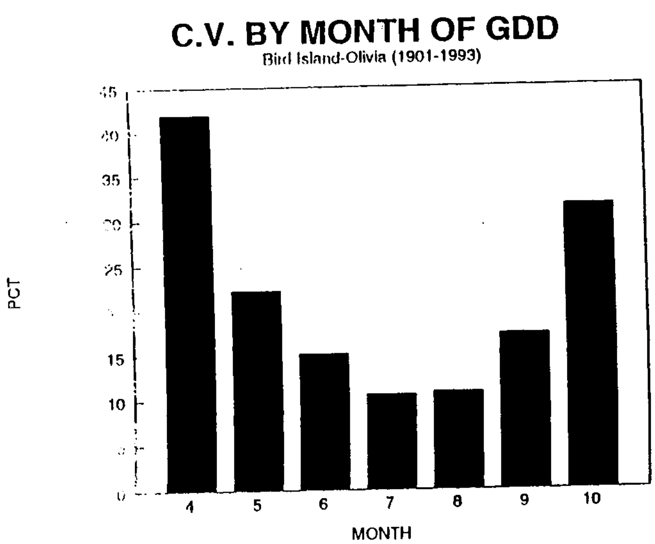

Figure 12. Coefficients of Variability in Monthly Growing Degree Days (base 50/86) for Field Corn from the Bird Island-Olivia Records (1901-1993).

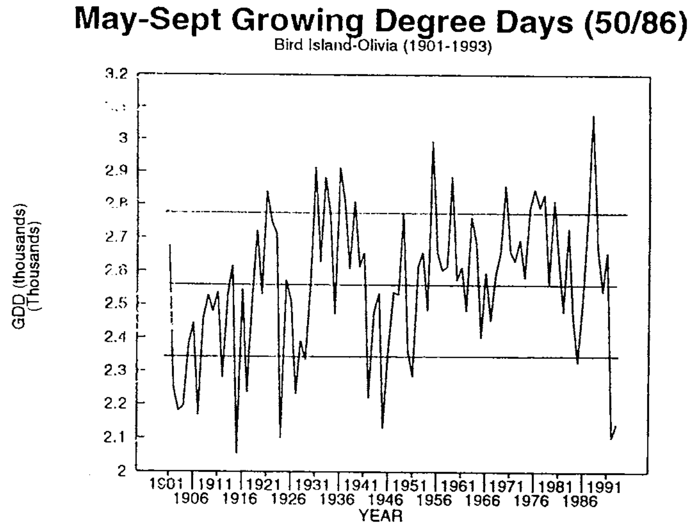

Figure 13. Total Growing Degree Days for the May through September Period at Bird Island-Olivia Compared to the Grand Mean and Standard Deviation (1901-1993).

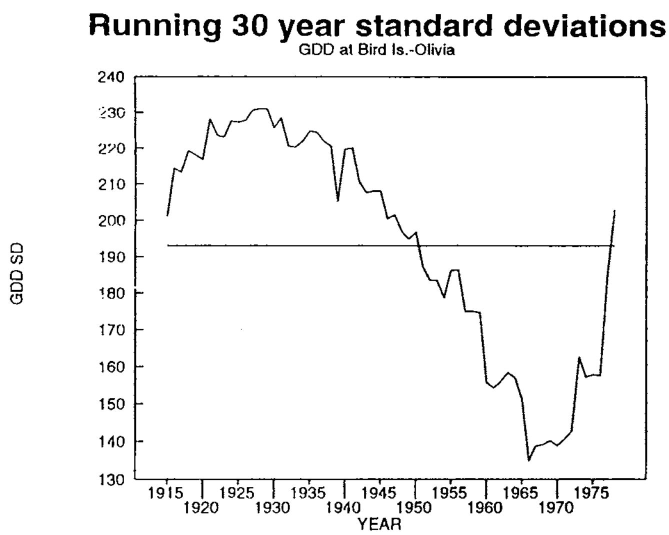

Figure 14. Running 30 Year Standard Deviations for May through September Growing Degree Days at Bird Island-Olivia (1901-1993).

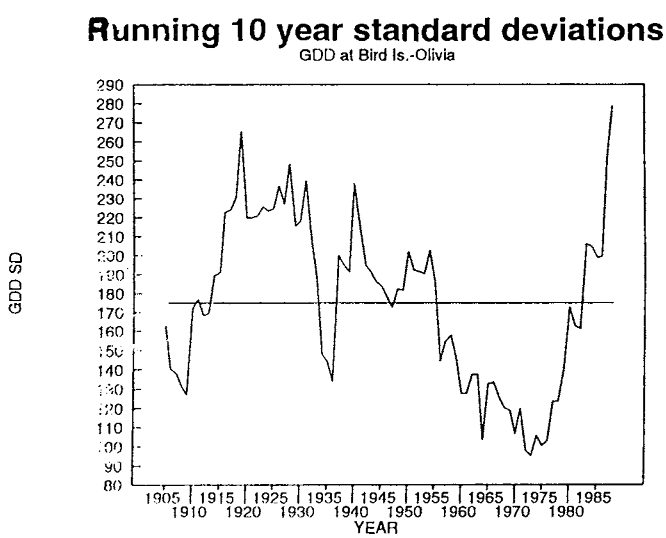

Figure 15. Running 10 Year Standard Deviations for May through September Growing Degree Days at Bird Island-Olivia (1901-1993).

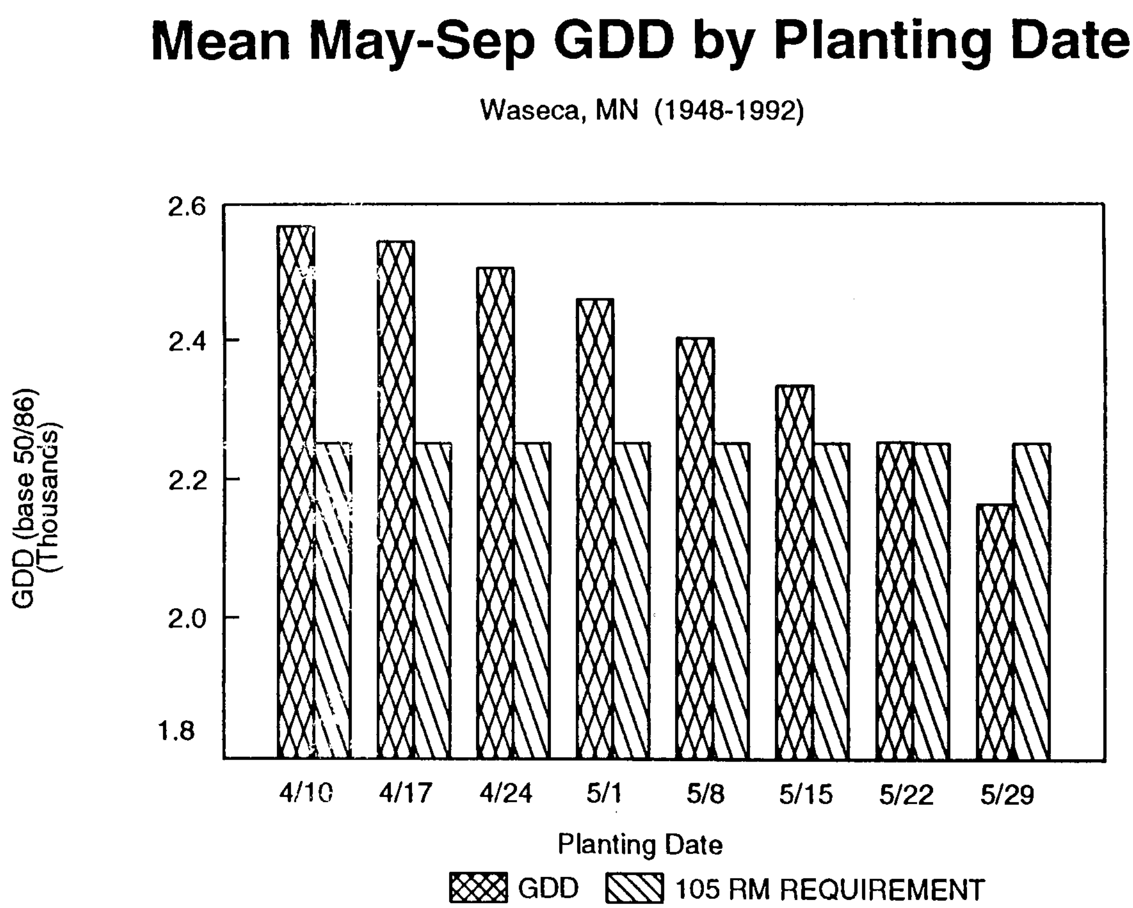

Figure 16. Mean May through September Growing Degree Days for Field Corn over a Sequence of Planting Dates at Waseca (1948-1992) Compared to a Requirement of 2250.

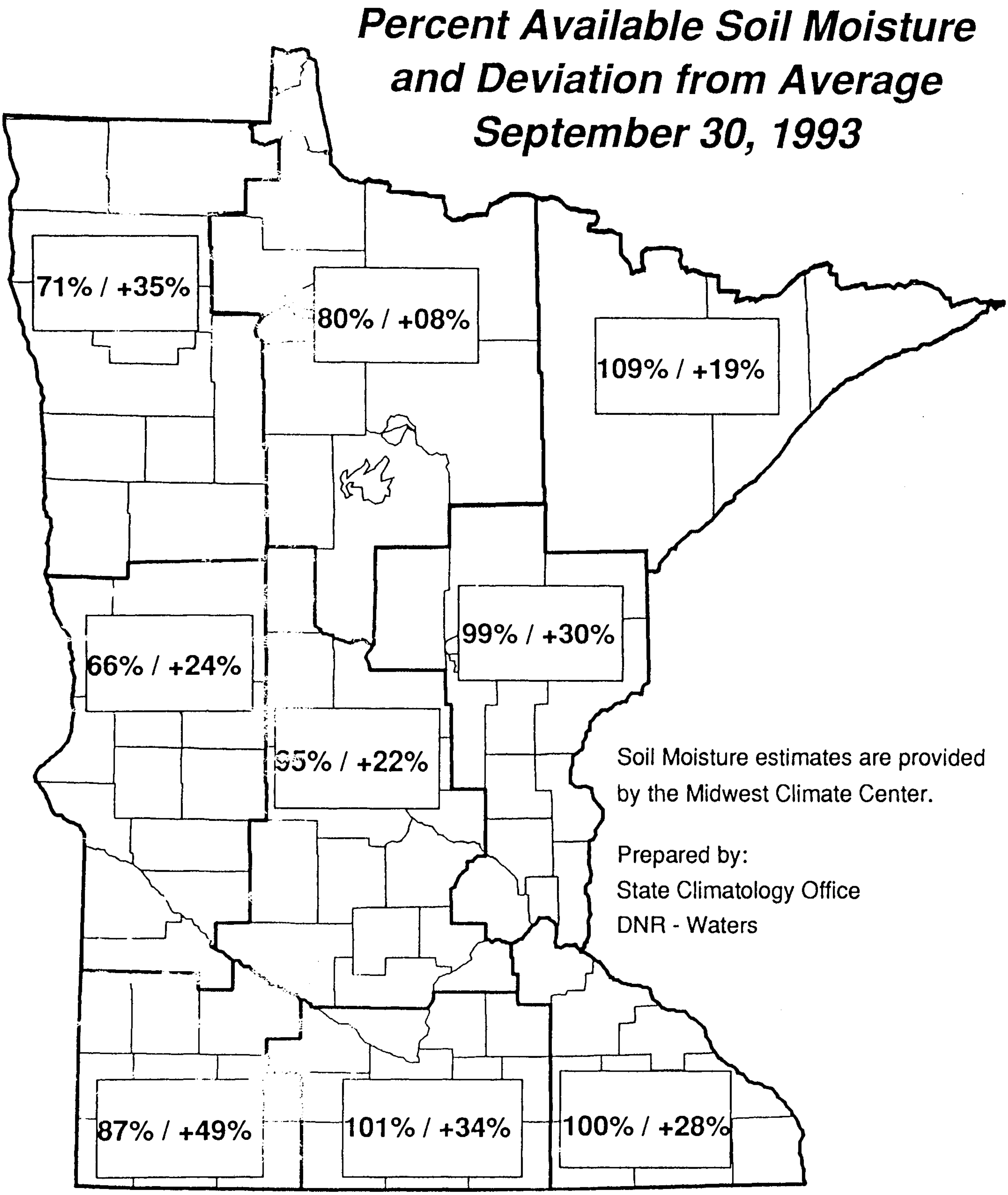

Figure 17. Estimates of Percent Available Soil Moisture and Deviation from Normal in the Fall of 1993 by Climatic Division.

SOYBEAN ROOT HEALTH

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Soybean root health, or the lack of healthy roots has been a serious problem the last two years. The past cold, wet season clearly had problems with root development and function. The importance of early season root health must be understood and changes are needed to insure that the soybean plants get off to a good start. The establishment of a successful crop depends on seedling health first and then a series of additional events that result in a yield. The importance of soybean germination and emergence was a concern or potential problem in clean tillage, but is a much larger concern when soybeans are planted early into cold wet soils. This wide spread, poor start of the soybean crop was observed all over southern and west central Minnesota soybean growing areas in 1993. Replanting was reported more often in 1993 than ever before and even the replanting results often were poor. In previous years I heard few reports of replanting a third time.

The results of poor root development continued into late June and at the July 8, Morris Summer Field Day, I displayed soybeans with root rots and limited root development. Reduced plant growth and consistent isolation of typical root pathogens-Pythium, Rhizoctonia and Phytophthora were found, as well as species of Fusarium. The season ended with plants that did not develop or yield as well as expected. Plant rows did not canopy over and plants were short. Certainly the growing season had its problems and root health was not the only concern, but the need exists to review the seed and seedling health factors.

Seed Decay, Pre- and Postemergence damping-off and root rot of soybean is reported from several species of Pythium. These fungi are present where soybeans are grown and survive in soil as saprophytes, colonizing soybean or other types of organic matter. An increase in plant organic material near the surface or newly incorporated favors the activity of these fungi. Soil temperature in the range of 50 to 60 degrees F is most favorable for several Pythium species, while at temperatures from 60 to 70 F damping-off declines rapidly. Seedling loss is greatest when soil temperatures are in the 40's. Small plants, up to 10 days old are reported to be most susceptible to infection and slow development of soybeans prolongs the period of susceptibility. Infection is favored by high soil moisture because lack of oxygen during seed germination increases the amount of nutrients-sugars lost from the seed. This sugar stimulates the germination and growth of Pythium. Management based on resistance is limited as few varieties are reported to be resistant to Pythium. Planting good quality seed, free of cracks and having high germination scores into a warm, well drained fertile soil is recommended. The use of seed treatments is suggested if soil conditions are not favorable.

Pre- and Post-emergence damping-off, root and stem decay - Rhizoctonia diseases have been increasing in frequency the last several years. More and more reports of stem cankers have been reported. The fungus can attack the seedling plant at germination, as the plumule emerges which usually results in seedling death and decay. Red brown lesions on the seedling stem and roots near the soil surface are most common. The lesion can be surface only and later develop into a cortical decay that will reduce nutrient movement through the stem (girdle action). The weakened stem may not die, but break over in midseason. Often root development and nodulation is reduced. This fungus is a soil inhabitant, upper 4 inches, with excellent saprophytic ability, colonizing all types of plant debris. Management is based on adequate soil drainage, rapid early soybean growth as resistance is limited and use of seed protectant fungicides.

Phytophthora Rot of root and stem tissue is a common problem for soybean growers and since it's discovery in 1948, resistance has been the main management method. Seed rot, preemergence damping-off(often called water damage a misidentification) and wilting with plant death are all common symptoms. The stunting found on "tolerant" lines can kill, but often only reduces growth and yields. The roots of plants not killed by PRR are damaged at the branch root level. These plants are slightly chlorotic, like a mild nitrogen deficiency. These mild symptoms are not recognized and are referred to as "Hidden Damage". This symptom is only evident when fungicides or near-isogenic lines are grown side by side.

The classic mid season wilting and death of plants or the brown water soaked basal stem lesion are often not seen in the newer soybean varieties. The evidence that PRR has remained a problem for growers is the development of new races of the fungus that over come the sources of resistance. The standard method of race identification is the hypocotyl inoculation test. Newer isolates of this fungus don't always behave like they are expected to when challenged with the hypocotyl inoculation method. The current thinking, not proven is that not all Phytophthora fungal isolates(races) will be identified by this method, especially those that are mainly root pathogens and do not grow into a stem lesion. The management of PRR is based on race-specific resistant cultivars and optimum cultural conditions-good drainage and soil preparation for rapid seed germination and seedling establishment. Seed treatment is needed to control damping-off in some fields with select varieties.

The roots of many soybean plants were very poor and definitive results from isolation were not possible, however the species Fusarium was commonly isolated from brown to black vascular systems in roots. The most common species was F. oxysporum and we also isolated a "blue F. solani isolate". This sample from west central Minnesota was similar to isolates that have been found in the Red River Valley (Dr. Carol Windels). The "blue strain of F. solani" is reported to cause Sudden Death Syndrome. The isolate we have has not been tested for pathogenicity. Isolates from the valley have damaged roots in pot testing, however typical field symptoms have not been produced at this time. Fusarium is reported to invade soybean plants through wounds. Nematode damage is also reported to predispose infection by Fusarium. The significance of this isolation work finding a "blue strain of F. solani" has not yet been made clear, however one must be ready to accept the fact that Fusarium isolates typical of those that are associated with SDS (Sudden Death Syndrome) are now found in Minnesota.

The soil in 1993 was cold and wet. The soil compaction levels were as high or higher than ever reported. Roots in low tillage soils had great difficulty. Is root disease the only factor? No. Cool soil temperature, excess water, lack of oxygen and reduced sun light are factors also. The weather we can't control, but one can insure or protect the seed and seedling from some of the negative aspects of crop production in seasons like this past one.

The percent no-till of total soybean acres in Ohio and Indiana for '93 was 38%, with Illinois at 28% and Iowa 20%. The figures for Minnesota are not available but clearly the trend to low till or no till is present here also. Those who have tested low till/no till have found that it can work due to improved herbicides, planting equipment, varieties and research information. Agronomic adjustments needed include: selection of soils that have good soil drainage, planting later than conventional tilled soybeans, killing weeds at planting with an effective herbicide, planted at reduced planting speed, used press wheels on drills, added a harrow behind the drill to scatter residue (helps cover seed and improves weed control) and added skip rows to allow for late season problems/weed wiping or an early cultivation when in narrow rows.

Another factor to consider in no till or low till and early soybean planting in Minnesota is seed treatment. The reason for treating soybean seed was seedborne diseases in the past, however the reason now is the management of soil borne diseases. In cool wet soils, seed treatments are needed to establish a good early stand. The standard "Warm Germination Test" is important, but does not reflect the real world and even a "One Week Cold Test" is not long enough to reflect what happens in nature.

The cool wet soil conditions expected when one plants early or into residue increases the exposure of soybean seeds and young seedlings to root rots and reduces the vigor and growth rate, which is the main mechanism of disease escape. This situation can be mediated by using fungicide seed treatments. All soybean seed planted early into cool wet soils/no till sites should be treated, commercially treated with a fungicide. Seed being planted into Phytophthora infected fields should be treated with

Apron fungicide, even those varieties with resistance when planted no-till should be Apron treated since resistance does not develop until after emergence. Depth of planting should also be carefully controlled. Shallow planting (3/4 to 1 inch deep) will put the seed into warmer soil where growth and emergence is faster. Remember shallow planting increases risk of herbicide exposure and requires better planting skills and tools to insure precise depth control. Speed of planting needs to be slow or adjusted to soil conditions, as speed increases the depth of planting decreases and uniformity of seed coverage decreases. A general rule is that speed of planting in no-till fields is slower than conventionally tilled soils.

The need for seed treatment on soybeans has been a concern for me for several years as growers plant soybean earlier into low tillage/high residue sites. While the need for treated soybean seed exists most farmers can not get commercially treated seed. The on farm hopper box method is believed to be less effective than commercial treatments and the time required results in a delay at planting time. This option for the producer is a large negative for on site seed treatment.

There are three conditions in Minnesota that call for seed treatment:

one, Soybean varieties with low or no resistance to Phytophthora Rot when planted into sites where you expect the disease.

two, Soybean seed with low levels of seed infection-Phomopsis.

three, Early planting of soybeans into low or no-till, high residue sites.

The need for seed treatment in this 3rd area exists because the seed and seedling is exposed to additional stress factors. The stress factors are not always present, but when present seed treatment can make a difference in stand establishment, which can result in a yield advantage. Other advantages from early vigorous seedling growth are faster canopy development and more effective weed control. The need for seed treatment does not exist on all soybean acres. Seed suppliers or seed conditioners should consider providing a seed treatment service or have a portion of the seed available in a treated form. Growers need treated soybean seed, commercially treated seed on a portion of the land.

CORN AND WHEAT THE 1993 TOXIN STORY

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The continuous wet weather during the 1993 growing season had a profound effect on the wheat and corn crop this year. One of the major problems with grain quality was caused by infections of Fusarium graminearum. Infection by this organism caused scab in wheat and kernel rots in corn.

Scab can overwinter on infested cornstalks and produces its spores on these stalks in the spring. If these spores are in the air in sufficient quantity and the weather is warm and wet during flowering scab infections will occur. The spores germinate and indiscriminately invade flower parts, glumes or other portions of the spike. Infections are most common and most serious during flowering. Blight symptoms develop after infection when temperatures range between 77° and 86° F.

Scab can be recognized on the wheat head by the pink or orange colored mycelium growing on the spiklet. If the rachis is infected all tissue above that point will not fill properly. Grain from infected heads will be light and shriveled. Some of the seeds will have a pink cast. These seeds are not good for seed as they will be killed during germination and seed vigor of surviving seeds will be affected. Infected seeds may also have various amount of deoxynivalenol (DON) which can effect the performance of livestock especially hogs.

All seed which is to be used for planting should be cleaned before applying seed treatments. Seed treatments have been shown to significantly increase stand of seed containing Fusarium infection. Seed treatments which are recommended are Vitavax 200 + 1/4 oz of thiabendazole, RTU Vitavax Thiram, and Vitavax extra. A 1987 study at NDSU also show Maneb+Imazalil combinations to also be effective.

Feeding of infected seed should be done according to the guidelines provided by the FDA (Table 1). Table 2 lists additional information on the feeding of infected seed. An extensive survey of infected grain revealed concentrations of 0 to 17 ppm in barley and 0 to 10 ppm in barley.

The cool wet weather also caused a significant problem in the corn crop. Plants subjected to adequate inoculum during silking can cause significant ear and kernel rot. Moisture at 22-25 % allow the fungus to grow. Fluctuating moderately low and somewhat higher temperatures seem to stimulate fungal growth and mycotoxin production.

Fusarium toxins found in corn this year include Zearalenone and Deoxynivalenol (DON or Vomitoxin=Deoxynivalenol). Infected corn is reported to contain more Zearalenone that the infected small grains. Concentrations as high as 2.7 ppm have been found in this years corn crop. This would be significant when mixed in a corn ration. DON has been found in corn in concentrations ranging from 0 -21 ppm. The average found so far is 3.44 ppm. Feeding of infected corn in rations will have an effect on hogs and should be fed with caution. The only control is to avoid grain contaminated with the mycotoxins. Suspected grain should be tested to determine if the amount of mycotoxins present are significant in rations. Use the information in Table 2 as a guideline for feeding.

When collecting a sample for testing be sure to get as representative a sample as possible. This can be done by extracting small amounts of grain from a grain stream or systematic probing of a bin. The 5 pound sample should be dry and shipped in a paper bag inside a cardboard box. Research has shown that 5 pound is the best sample size for significant results. A dry sample is important so that the fungus does not grow in transit and increase the mycotoxin content.

Throughout the year we have been asked many questions about the significance of infected corn and wheat. The following is a summary of the most common questions along with our response.

Commonly Asked Questions about Mycotoxins in Corn

1) What are the mycotoxins produced by *Fusarium graminearum* in corn and wheat?

    a) Deoxynivalenol, a trichothecene mycotoxin also known as vomitoxin is produced in both corn & wheat.

    b) Zearalenone, an estrogenic compound is found mainly on corn and rarely in small grains.

2) Will the mycotoxin continue to be formed in storage?

    a) No. *F. graminearum* grows at moisture contents above 22% and will not grow at normal storage moisture contents of 13-15%.

3) Are certain can hybrids more susceptible than others?

    a) We have no data to tell for sure. Some reports from certain areas of the state have suggested this based on local observations. A thorough analysis of this situation is needed before any judgement can be made.

4) Are there other storage complications which can be expected with Fusarium infected grain?

    a) Fusarium itself will not continue to grow however, the grain this year tends to be of poor quality and low test weight. This corn may have a higher breakage potential and does not store as well as normal high quality corn. Wheat will be light and should be stored at low (12.5%) moisture.

5) What precautions should be taken in storing the 1993 corn crop?

    a) We are attempting to get better storage data for corn of the 1993 quality. The tendency for breakage may leave more fines in the grain leaving it harder to aerate because of the plugged interseed spaces. Screening weight fines is very important. Other precautions to take are:

- Suggest 13-14.0% moisture for corn, 12.5-13.5% for wheat.
- Normal aeration, cool to 25-35°F for winter storage.
- Check bins more frequently than usual.
- Don't plan on keeping this grain for long term storage.
- Watch for moisture migration and insects.

6) If we have a cool wet summer and fall next year do we have the potential for a repeat problem?

a) Yes. The potential for infection is present as the inoculum is present. The cool wet weather means more fungi in grain but it does not have to be Fusarium. In the 1992 corn crop we had a lot of moldy corn but we found very little Fusarium infection. Most of the molds found were common black molds which have a low toxicity risk. It seems we are at the mercy of the weather as to which fungi will be present under the 1992, 1993 conditions. If wet weather persists during wheat flowering the condition could also repeat.

7) Does high temperature drying decrease vomitoxin levels?

a) Normal grain drying temperature won't significantly decrease vomitoxin levels. Grain temperatures of 230°C are needed to completely detoxify the vomitoxin compound. This temperature causes roasting of the grain and may effect nutrients.

8) Is there any way to detoxify the vomitoxin?

a) Chemical reagents such as sodium bisulfite, chlorine and ammonia have had limited success however, no procedure is approved for such a practice on a large scale.

9) Do the mycotoxins pose a risk to grain handlers at harvest or in storage?

a) There is no evidence in the literature to suggest this however, this years grain could contain a higher number of mold spores which could, when inhaled, create an allergic reaction. Double layered face masks with 2 rubber straps need to be used to protect from inhaling grain dust. These masks should always be used when working in grain dust even during "normal years".

10) What precautions should be taken when feeding Fusarium infected grain?

a) Testing is recommended for suspected fields. Hogs are much more susceptible than poultry or ruminants. One ppm of DON or higher will cause feed refusal in hogs and one ppm Zearalenone will cause reproductive problems in sows and gilts. Always watch for any abnormal signs in animals when fed feed containing molds. Sometimes unexplained problems can arise which cannot attribute to amounts of known mycotoxins. FDA Guidelines for DON in wheat could be used as a guide for feeding infested corn. They are: 1) 10 ppm for cattle & poultry with no more than 50% of the infested corn in the total ration, and 2) 5 ppm for hog rations with no more than 20% of infested corn in the final ration. Infested grain is not recommended for breeding stock and no guidelines are available for horses.

11) What about using corn stalks or straw from infected crops for bedding?

a: No data is available to show any adverse affects in any species. Precautions should be taken however in sow bedding, especially just before farrowing.

12) What levels of mycotoxins have been found in Minnesota corn and wheat?

a) DON, 0-21 ppm ave. 3.44 ppm, 20 samples tested. Only one test of a very moldy ear was tested so far with and it yielded 2.7 ppm. DON in wheat this year ranged from 0-21 ppm.

13) Where can I get samples tested?

a) The Vet. Diagnostic Clinic at the University of Minnesota
Dept. of Vet. Med at North Dakota State University
State Department of Agriculture
Various Private Labs

14) How should I submit a sample?

a) In a corn field walk a Z pattern and collect ears at random. Enough to yield 5 lbs. of shelled grain. Probe a bin of wheat or corn to get as representative a sample as possible. Submit 5 lbs. Shelled corn should be dried at room temperature in a single layer over night. Put in a paper bag and ship bagged grain in a cardboard box.

Table 1. FDA Advisory Levels for DON in Wheat.

1. 1 ppm DON on finished wheat products, e.g. flour, bran and germ, that may potentially be consumed by humans. FDA is not stating an advisory level for wheat intended for milling because normal manufacturing practices and additional technology available to millers can substantially reduce DON levels in the finished wheat product from those found in the original raw wheat. Because there is significant variability in manufacturing processes, an advisory level for raw wheat is not practical.

2. 10 ppm DON on grains and grain by-products destined for ruminating beef and feedlot cattle older than 4 months and for chickens with the added recommendation that these ingredients not exceed 50% of the diet of cattle or chickens.

3. 5 ppm DON on grains and grain by-products destined for swine with the added recommendation that these ingredients not exceed 20% of their diet.

4. 5 ppm DON on grains and grain by-products destined for all other animals with the added recommendation that these ingredients not exceed 40% of their diet.

Table 2. Animal Response to Various Doses of Zearalenone and Deoxynivalenol.

		Zearalenone
Cattle:	Cows:	Oral doses of 500 mg purified zearalenone per cow per day through two estrus cycles did not affect serum progesterone, red blood cells, white blood cells, packed cell volume, estrus cycle length, or sexual behavior, although there was a subjective trend towards smaller corpora lutea.
	Heifers:	Virgin heifers given 250 mg/day in a similar experiment had a slightly lower conception rate (62%: 3 of 16) versus control heifers (87%: 2 of 15) on first service.
Both studies approximate continuous 50 ppm dietary exposure.		
Sheep:		Similar to cattle.
Swine:	Gilts:	1 to 5 ppm: vulvovaginitis, vaginal and rectal prolapses.
	Barrows:	1 to 5 ppm: rectal prolapses, precocious mammary development.

Sows: 5 ppm: reduced litter size if fed throughout gestation.
3 to 10: ppm anestrus or pseudopregnancy.

Does not cause abortion.

Poultry: Chicks: At 300, 800, and 1600 ppm: increased weight gain, comb weight, and bursal weight.

Layers: At 250 to 637 ppm: no affect on body weight, egg production or feed consumption.

Clinical signs: Swelling of vent and cloacal prolapses.

Horses: No information available.

Vomitoxin or DON (deoxynivalenol

Cattle: Chronic feeding studies with DON at naturally occurring concentrations (approximately 10 ppm) failed to cause any discernable affects in cattle. feeding or 10.5 ppm for 18 weeks, no feed refusal seen. Feeding 6.4 ppm to dry cows produced no affect.

Essentially no excretion of DON in milk of two cows given single oral doses of approximately 2 mg/kg body weight. Trace amounts of DON were detected in the urine and feces of cattle fed a ration contaminated with 66 ppm DON twice daily for 5 days (0.1 to 0.7 mg/kg body weight) but none was detected in the milk.

Sheep: Similar to cattle. Feeding at 16 ppm produced no clinical illness.

Swine: At 1 ppm get a mild (~5%) feed refusal, at 5 to 10 ppm significant (~50%) feed refusal, and at 20 to 40 ppm essentially complete refusal of feed. At 10 to 20 ppm, may see actual vomiting of swine.

Poultry: Chicks: Oral lesions at 49 ppm in the feed. Contaminated wheat at 16 ppm produced reduced growth rate, impaired feed conversion, increased liver size, and anemia.

Layers: At 18 ppm for Day 1 through 168 of egg production, no affect was seen on hen day production, egg weights, feed efficiency, eggshell thickness, fertility, hatchability, or chick weights at hatching. Similarly, no affects were seen at 38 ppm when fed for 4 weeks or 83 ppm when fed for 27 days.

Horses: No information available

TILLAGE DECISIONS FOLLOWING WET YEARS

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Wet conditions the last three years coupled with cool growing season temperatures have had a significant impact on corn and soybean production in Minnesota. Corn fields have exhibited much variability, yields and test weight have been low, and harvest moisture has been high. Soybean growth was limited and yields highly variable, especially in 1993. Tillage and internal soil drainage were factors that many growers felt influenced yield. Consequently, many fields were tilled this fall.

The purpose of this paper is two-fold:

1) To determine if rainfall the previous year has an effect on crop response to tillage and
2) To present a rationale approach to making tillage decisions -- similar to how a farmer makes hybrid decisions.

EXPERIMENTAL PROCEDURES

Long-term experiments have been conducted at the agricultural experiment stations at Lamberton, Morris, and Waseca and on farmer's fields in southeastern Minnesota. These experiments along with good rainfall records allow us to see if any trends or interactions occur between tillage systems and moisture conditions (rainfall) in the previous year. They also allow us to see the impacts of dry vs wet conditions on the present year crop yields and whether yields were influenced more by tillage system in dry or in wet years.

RESULTS, OBSERVATIONS AND DISCUSSION

A 6-year continuous corn study conducted on a moderately well-drained soil (Tara silt loam) at Morris showed significant affects of rainfall on the present crop as well as some effect on the subsequent crop (Table 1). Ridge tillage (RT) yields were consistently good and averaged higher than the other three tillage systems. Following the three wettest years (1984, 1985 and 1986) yields among the four tillage treatments showed a range of 17, 47 and 22 bu/A, respectively. Lowest yields were obtained with no-till (NT) in 2 of these 3 years with fall moldboard plow (MP) giving the lowest yield in 1986. Surprisingly, no-till gave the lowest yield in 1987 -- a year in which only 11.8" of growing season rainfall.

A 7-year study compared four tillage systems in a corn-soybean rotation on a somewhat poorly drained soil at Lamberton (Tables 2 and 3). Tillage rotations consisted of moldboard plow (MP) following corn and chisel plow (CP) following soybean in one system and CP following corn and no-till (NT) following soybean in another system. Average corn yields were highest with the MP/CP system and lowest with the two systems where NT was practiced (Table 2). Yield differences among tillage systems after wet years were not clear cut. The two wettest years (1986 and 1985) only resulted in 11 and 7 bu/A differences among the yields in the subsequent years. However, later in the study yield differences among the tillage systems were 17 to 23 bu/A higher for the CP/MP systems compared to the NT system. Previous season rainfall did not appear to impact these yield differences. Yields were not different among tillage systems in 1991 - a very ideal year following a dry year.

Table 1. Continuous corn yields as influenced by tillage and rainfall for 1983 - 1989 at the West Central Experiment Station, Morris. (Data courtesy of Dr. Sam Evans).

	Tillage System [1/]				Rainfall		
Year	Fall MP	Fall CP	RT	NT	Apr-Jun	Aug-Oct	Apr-Oct
	------ Grain Yield (bu/A) -----				------- inches -------		
1983	---- Plot area was NT Corn ----				6.7	9.1	20.0
1984	135	128	140	115	7.2	17.4	25.9
1985	91	98	88	81	11.9	9.4	23.8
1986	102	139	149	129	14.2	9.0	29.7
1987	161[2/]	150[2/]	167	145	5.2	4.8	11.8
1988	59	49	49	67	2.8	9.6	14.2
1989	155	160	167	168	8.9	7.8	21.0
Avg.	117	121	127	118	8.2	9.6	20.9

[1/] Pioneer 3906 @ 160 lb N/A.
[2/] Spring MP and CP due to wet conditions in fall, 1986.

Table 2. Corn yields in a corn-soybean rotation as influenced by tillage and rainfall for 1985 - 1992 at the Southwest Experiment Station, Lamberton. (Data courtesy of Dr. David Huggins and Dennis Fuchs).

	Tillage System for Corn				Rainfall		
Year	CP/MP	NT/CP	RT	NT	Apr-Jun	Aug-Oct	Apr-Oct
	------ Grain Yield (bu/A) -----				------- inches -------		
1985	----------------------				12.7	14.2	29.2
1986	141	138	145	142	13.3	14.2	34.7
1987	136	125	125	132	5.2	4.6	15.8
1988	77	70	82	74	4.9	7.5	13.2
1989	139	128	133	122	4.9	5.7	14.7
1990	137	120	118	114	9.7	8.2	20.7
1991	132	134	129	133	15.1	9.0	25.4
1992	154	131	145	134	8.5	10.6	23.9
Avg.	131	121	126	122	9.3	9.2	22.2

Average soybean yields in this 7-year study were highest for the MP/CP system and lowest for the continuous NT system (Table 3). Yield differences among tillage systems were not apparent in the first two years or the seventh year of the study. However, yields were 6 to 8 bu/A lower with NT compared to MP/CP in 1988-91. Rainfall in each of the previous years was below normal. Based on these data, one could assume that tillage has a greater impact on soybean yields in drier than normal years or when the previous year has been dry.

Table 3. Soybean yields in a corn-soybean rotation as influenced by tillage and rainfall for 1985 - 1992 at the Southwest Experiment Station, Lamberton. (Data courtesy of Dr. David Huggins and Dennis Fuchs).

	Tillage System for Soybeans				Rainfall		
Year	MP/CP	CP/NT	RT	NT	Apr-Jun	Aug-Oct	Apr-Oct
	------- Yield (bu/A) ------				------- inches -------		
1985	- - -	- - -	- - -	- - -	12.7	14.2	29.2
1986	48	47	47	47	13.3	14.2	34.7
1987	39	40	39	39	5.2	4.6	15.8
1988	33	26	27	27	4.9	7.5	13.2
1989	49	46	49	41	4.9	5.7	14.7
1990	52	52	49	45	9.7	8.2	20.7
1991	48	46	41	40	15.1	9.0	25.4
1992	37	38	35	36	8.5	10.6	23.9
Avg.	44	42	41	39	9.3	9.2	22.2

Three tillage systems were compared in a weed control study in a corn-soybean rotation on a somewhat poorly drained soil at Lamberton (Table 4). Corn and soybean yields from <u>weed-free plots</u> averaged about 10 bu/A higher for the continuous MP and CP systems compared to the NT system. Compared to MP and CP, corn yields in the NT systems were reduced the most in 1987 and 1992, which were preceeded by the two wettest years for this study. Soybean yields from NT were 11 to 21 bu/A lower than from MP in the last four years of the study. Rainfall, either in the previous year or in the present year, did not appear to have an impact on soybean yield x tillage interactions.

A 10-year continuous corn tillage study on a somewhat poorly drained Nicollet clay loam at Waseca showed average MP and CP yields to be 13 to 16 bu/A higher than with NT (Table 5). Yield differences among tillage systems in the first year of the study were not large, but increased dramatically in the last two years. These differences occurred under both wet and average rainfall conditions.

A 11-year continuous corn study compared two tillage systems on a poorly drained Webster clay loam soil at Waseca (Table 6). Yield averages were 21 bu/A higher for MP compared to NT. However, yield differences between the two tillage systems became more extreme in the 8th through the 11th years of the study; averaging 42 bu/A lower for NT. These extreme differences occurred under both wet and dry conditions. These data indicate that the maturity of a continuous tillage system for continuous corn is more important than rainfall or soil moisture conditions. This also appeared to be true in the aforementioned studies at Waseca (Table 5) and Lamberton (Tables 2 and 4).

Table 4. Corn and soybean yields in a corn-soybean rotation as influenced by tillage and rainfall for 1986 - 1992 at the Southwest Experiment Station, Lamberton. (Data courtesy of Dr. David Huggins and Dennis Fuchs). [1/]

Year	Tillage System				Rainfall		
	Crop	MP	CP	NT	Apr-Jun	Aug-Oct	Apr-Oct
		(bu/A)			inches		
1986	- - -	- - -	- - -	- - -	13.3	14.2	34.7
1987	Corn	126	146	107	5.2	4.6	15.8
	Sb	46	43	41			
1988	Corn	54	57	65	4.9	7.5	13.2
	Sb	16	15	14			
1989	Corn	177	177	164	4.9	5.7	14.7
	Sb	43	38	32			
1990	Corn	167	158	160	9.7	8.2	20.7
	Sb	49	43	37			
1991	Corn	120	128	115	15.1	9.0	25.4
	Sb	48	44	33			
1992	Corn	162	154	143	8.5	10.6	23.9
	Sb	43	38	22			
Avg.	Corn	135	137	126	9.3	9.2	22.2
	Sb	41	37	30			

[1/] Yields are from weed-free plots in a milkweed study.

Table 5. Continuous corn yields as affected by tillage and rainfall for 1970 - 1979 on a somewhat poorly drained soil at the Southern Experiment Station, Waseca.[1/]

Year	Tillage System			Rainfall		
	MP	CP	NT	Apr-Jun	Aug-Oct	Apr-Oct
	bu/A			inches		
1970	164	157	156	11.0	12.3	29.6
1971	103	110	96	9.8	6.7	19.2
1972	136	133	130	8.5	9.1	25.4
1973	144	146	133	14.3	11.5	30.5
1974	100	92	86	10.9	8.7	21.4
1975	53	49	50	13.4	4.5	18.3
1976	68	67	83	6.6	4.4	13.6
1977	131	128	122	13.7	14.1	32.0
1978	157	155	130	12.6	7.4	24.0
1979	177	169	132	10.7	11.7	32.0
10-Yr Avg.	139	136	123	11.2	9.0	24.6

[1/] Nicollet clay loam

Table 6. Continuous corn yields as affected by tillage and rainfall for 1981 - 1992 on a poorly drained soil at the Southern Experiment Station.[1/]

Year	Tillage		Rainfall		
	MP	NT	Apr-Jun	Aug-Oct	Apr-Oct
	bu/A		inches		
1981	-	-	12.0	12.1	30.2
1982	146	144	11.0	12.6	25.1
1983	106	102	13.7	12.0	31.0
1984	118	106	13.1	8.5	25.0
1985	160	145	7.7	13.3	23.5
1986	143	136	15.8	10.8	30.5
1987	158	153	6.0	9.2	22.4
1988	101	83	5.8	10.0	16.4
1989	153	128	7.0	5.0	15.9
1990	147	105	14.8	9.3	30.2
1991	163	121	15.8	12.3	36.8
1992	121	64	10.0	13.5	37.8
Avg.	138	117	11.0	10.7	26.2

[1/] Webster clay loam.

Average corn yields following soybeans in a 3-year study at Waseca were slightly lower (5 bu/A) for NT compared to the other three systems (Table 7). The greatest difference (13 bu/A) was found in 1987 which was a normal rainfall year preceeded by a wet season.

Table 7. Corn yields following soybeans as affected by tillage and rainfall for 1985 - 1988 on a poorly drained soil at the Southern Experiment Station, Waseca.

Year	Tillage System[1/]				Rainfall		
	CP/MP	NT/CP	RT	NT	Apr-Jun	Aug-Oct	Apr-Oct
	bu/A				inches		
1985	-	-	-	-	7.7	13.3	23.5
1986	134	141	137	135	15.8	10.8	30.5
1987	161	151	158	148	6.0	9.2	22.4
1988	92	99	98	92	5.8	10.0	16.4
Avg.	129	130	131	125	8.8	10.8	23.2

[1/] Average from 5 hybrids grown each year on a Webster clay loam.

A 6-year study on a well drained soil in Goodhue County showed little difference between the yields from CP compared to NT in the first two years of continuous corn. Yields in the third and fourth year were 9 to 18 bu/A lower with NT, partially due to greater weed growth with NT. Soybean yields were not different between the CP and NT tillage systems. However, corn yields in the plots following soybeans, which had not received any tillage for 6 years, were 36 bu/A lower compared to CP tillage in this very cool year. Weeds were very well controlled in 1992 and were not a factor. Again, the yield differences between tillage systems appears to be accentuated as the duration of continuous no tillage increases.

Table 8. Corn and soybean yields as affected by tillage and rainfall for 1987 - 1992 on a well drained Port Byron silt loam in Goodhue Co.

Year	Tillage System			April - October Rainfall
	Crop	CP	NT	
	bu/A			inches
1987	C	187	190	20.39
1988	C	116	114	16.11
1989	C	141	132	17.73
1990	C	140	122	30.87
1991	Sb	58	58	28.20
1992	C	149	113	?

SUMMARY OF RESEARCH

In summary, high rainfall and soil moisture conditions in the previous year did not appear to be consistently related to yield differences among tillage systems for corn and soybeans. In fact, at one location drier years appeared to impact soybean yield differences among tillage systems greater than wetter years. The most consistent trend was the widening difference in corn yield among tillage systems with increasing age of the tillage system. Yields with NT often failed miserably after continuous NT had been practiced for 6 or more years. Surface soil consolidation (compaction) resulting in poorer early season root growth is speculated as a major factor contributing to these findings.

CONSIDERATIONS WHEN MAKING TILLAGE DECISIONS

Selecting the best tillage system should involve a set of specific considerations and factors much like a farmer uses when selecting a hybrid. Yield, maturity and lodging are factors carefully considered by most farmers as they make their hybrid and variety decisions. Often, certain hybrids are chosen to meet specific soil conditions. A similar approach should be taken for tillage. Considerations to be weighed in the tillage selection process are:

- Soil Characteristics
    - Erosion potential -- Are the slopes long and/or steep or is the field rather flat? Is the field considered highly erodible (HEL) and thus requires 30% surface residue after planting for conservation compliance? If the erosion potential is high, conservation tillage systems are highly recommended and necessary.
    - Internal drainage -- Are the soils poorly drained or is the internal drainage quite good? Poorly drained soils warm up more slowly and often require more tillage than the better drained soils. System tiling helps on soils with poor internal drainage but may not be enough to ensure consistent success with little or no tillage.
    - Soil fertility level -- Having a high level of fertility is necessary if reduced tillage systems are to perform well. Low fertility conditions offer too many obstacles and generally limit yields more severely in reduced tillage systems.
    - Surface soil compaction -- Field activities conducted under wet conditions often result in surface compaction. Short, yellow and spindly corn is evidence of this compaction and is highly visible in field headlands, spots within fields, and wheel tracks. Primary tillage is needed to alleviate this surface soil compaction. Without primary tillage, good seed:soil contact and quicker root development in the spring will be more difficult.
- Cropping System
    - Continuous corn generates more residues and, therefore, requires more tillage for residue incorporation. This is especially important on poorly drained soils. On the

other hand a corn:soybean rotation generates less residue and allows greater tillage flexibility. Little residue exists following soybeans and very reduced tillage, i.e., no tillage often works well. Soybeans following corn are not as sensitive to tillage and can be grown very successfully with tillage systems ranging from moldboard plow to no till provided proper planting equipment is used.

- Herbicide Program

  It is extremely important that farmers adjust their herbicide program to fit their tillage system. Tillage provides some weed control, offers greater herbicide flexibility, and perhaps some economic savings for weed control. Perennial weeds are often economically controlled very satisfactorily with tillage. Herbicide incorporation with tillage minimizes herbicide runoff and volatilization losses. Farmers must not design their tillage system around a herbicide program, but must fit their herbicides to the dominant weeds and their tillage program.

- Equipment:Type and Age

  Reduced tillage systems require state-of-the-art planters that are capable of providing good seed:soil contact and good stands. Row cleaning devices that remove residues from a 6 to 10" band over the row may assist early plant growth, maturity and yield in very reduced tillage systems. Using an old, light planter designed for moldboard tillage conditions can be a very expensive and frustrating practice when used with no-till or conservation tillage systems. Thus, it is important to match planting equipment with the desired tillage system.

- Management Ability

  Some growers have the ability to put together a very successful minimum, tillage-based cropping system. Others are much less comfortable with this type of system and struggle each year with components of the system to make it successful. Asking questions and getting a stronger educational background is helpful for improving management.

- Risk

  Economical risk is increased as less and less tillage is used, especially over the long-term. Crop development can be delayed and yields reduced in wet and cool years. The degree of risk is highly dependent on some of the preceding factors. But with today's tight farm economy, risk is a factor which needs to be strongly considered by crop producers if they are to stay in business.

In summary, various sets of soil, crop, and economic conditions facing farmers in the future will require tillage flexibility. To remain fixed on one tillage system, unless in a ridge-plant system, could cause critical challenges and even obstacles that will be difficult to overcome. In the future, farmers should match tillage systems with their soil and cropping conditions by practicing tillage rotation.

FACTORS AFFECTING PROFITABLE CORN POPULATIONS

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Management factors which may affect the optimum corn populations include the hybrid, maturity of the hybrid, seed cost, planting date, soil fertility, and available soil moisture which is conditioned by soil type and rainfall amount and distribution. We have recently conducted extensive plant population trials which address some of these management factors.

Hybrid

Corn growers should ask their seed dealer or company agronomist for a population recommendation for the hybrids they intend to grow. Seed companies have tested their hybrids under many different environments and can give precise recommendations for each hybrid.

We tested seven high-yielding hybrids and found the optimum population to be between 28,000 and 33,000 plants per acre (ppa) without major differences among hybrids (Figure 1). While growers should consider the population recommendations of their seed company, they should challenge their hybrid choice if the recommended population is appreciably below 28,000 to 30,000 ppa.

Hybrid Maturity

The target harvest population of 28,000 to 30,000 ppa is for full season hybrids. Hybrids that are less than full season for a growing zone will generally require higher populations to reach their yield potential. Harvest populations should be increased 1,000 ppa for every five (5) relative maturity units earlier. For example, if a grower considers 100 RM to be "full season" for his/her farm and wants to plant a 95 RM hybrid, the harvest population should be 29,000 to 31,000.

Management Practices

When management practices other than plant population are limiting yield, population can be reduced below the 28 to 30,000 level without reducing yield. One cannot expect a yield response to higher plant populations if fertility (any element) is limiting, or one has poor weed control, or the crop is planted too late (after May 10). Under these conditions, maximum yield has been predetermined and a yield response to higher populations, particularly an economic one, is less likely to occur.

Environments

Locations and years represent different environments. Yield results from two locations and three years presented in Figures 2 and 3 show that populations between 28,000 and 33,000 are optimum populations for each year and location.

Summary

Corn harvest populations between 28,000 and 32,000 ppa are optimum for corn production in Minnesota. Combined with good management programs of early planting, weed control, good fertility, and hybrid selection, these harvest populations should lead to maximum profitable corn yields.

Figure 1. Grain yield of seven corn hybrids for plant populations ranging from 23,000 to 43,000 plants per acre, averaged over locations (Lamberton and Waseca) and years (1990-1992). Individual lines correspond to individual hybrids.

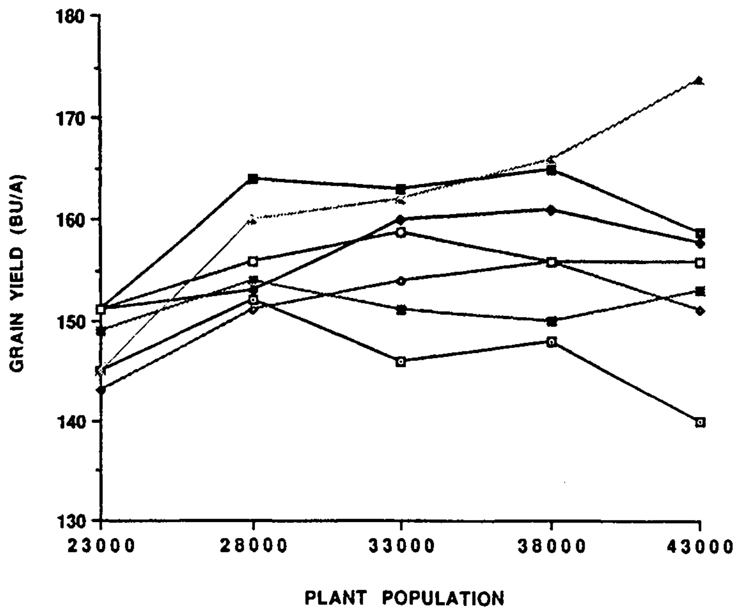


Figure 2. Grain yields for corn populations ranging from 23,000 to 43,000 plants per acre at Waseca and Lamberton, averaged over 7 hybrids and 3 years (1990-1992).

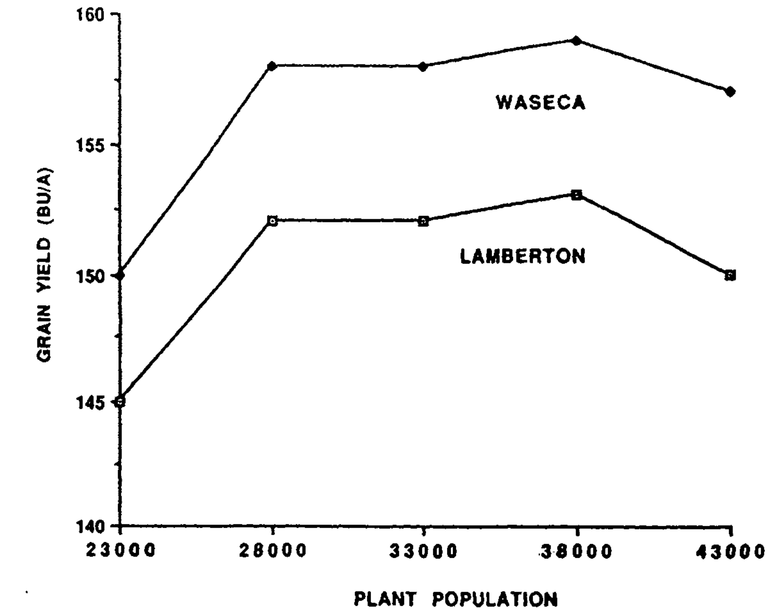
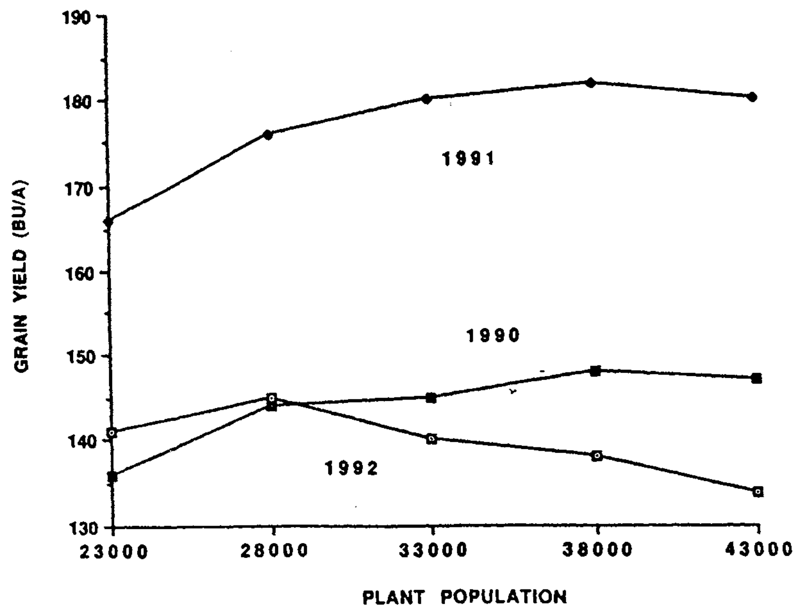


Figure 3. Grain yields for corn populations ranging from 23,000 to 43,000 plants per acre for 3 years, averaged over 2 locations and 7 hybrids.



WHAT HAPPENS TO ANHYDROUS AMMONIA IN SOIL

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Anhydrous ammonia (AA) is the predominant fertilizer N source in Minnesota in terms of the amount of actual N applied each year. There are several reasons why AA is used as so widely. First, because AA is the initial step in the manufacture of almost all commercial N, it is the least costly source of fertilizer N. Anhydrous ammonia also contains 82% N, which is the highest nutrient concentration of any fertilizer.

Anhydrous ammonia also has some drawbacks that limit its total domination of the fertilizer market. Because AA is a gas that is stored as a pressurized liquid, special application equipment is always required. This application is sometimes relatively slow compared to other products. As AA is released from tanks, it is a gas that can be a risk to human health if proper safety precautions are not followed.

As AA is discussed in respect to other fertilizer N products, often times information is stated that may or may not have a solid foundation. This article is a compilation of scientific data that have evaluated from several perspectives AA after it is applied to soil.

RETENTION IN SOIL AFTER APPLICATION

Anhydrous ammonia applications result in bands of inorganic N beneath the soil surface. The bands are generally oval or tear-dropped shaped with the elongation being vertical. Generally more AA diffuses upward rather than downward and the width of the band increases as AA rate increases--all other things being equal. The zone of AA spreads to a diameter of approximately 2 to 5 inches depending on soil texture, AA rate, cation exchange capacity, and soil moisture content (Tisdale et al., 1985). In Minnesota, soil moisture content plays the most significant role in AA retention zones.

Anhydrous ammonia would stay in the gas form and be lost to the atmosphere if it did not react quickly with moisture in the soil. When AA is released in the soil, it is retained in the soil by various chemical and physical mechanisms. The most common are reactions with free hydrogen ions in the soil (function of pH) and with water. The result of these reactions is ammonium being formed, held to exchange sites, and not subject to loss in the soil.

Loss of AA as ammonia gas at the time of application is dependent on the depth of injection and the soil moisture status. Too little moisture will allow ammonia to escape up to the atmosphere. Too much moisture will prevent the sealing of the injection knife opening to the soil surface. The depth of injection relates to the distance the ammonia would have to move to be lost to the atmosphere.

Figures 1 graphically show the effects of application depth and soil moisture status on ammonia loss. While soil moisture level around 16% results in minimal ammonia loss at any application depth, either wetter or drier soil conditions favor deeper applications. In Figure 2, dry soil (2%) results in immediate (<2 hr) gas loss whereas wet soil (23%) had gradual soil N losses for the first day and a half. Note that maximum ammonia loss in either case was around 12% for this dataset in which the AA was applied at a depth of only 3 inches. In Minnesota, the fine-textured soils rarely get so dry that these immediate losses occur, although losses have occurred. On the other hand, soils have been very wet the past couple years in instances and the losses with poor sealing have occurred.

For very wet soils, application management strategies that minimize N loss include applying the AA at least 6 inches deep and using some type of covering knife apparatus that closes the slot made by the knife. With very dry conditions, deeper applications are generally better, keeping in mind that rarely do soils get to 2% moisture at commonly used application depths.

EFFECT ON SOIL MICROBIAL POPULATIONS

The chemical properties of AA cause it to be toxic to microorganisms in the zone of application. The extent of the microbe eradication is highly dependent on the microenvironment in the application zone. Soil sampled on the day of application showed a drastic reduction in soil bacteria, but the populations did not go to zero (Table 1). As the length of time increased after application there was an increase in the bacterial population compared to the injection zone that had no AA applied in it. Approximately 5 weeks after application there were no major differences in the number of bacteria between the sets of plots, which had either 0 or 100 lb N/A applied.

The effect AA had on soil fungi was a bit more long lasting than with the bacteria. This effect is characterized with the data in Table 2, with there still being a net negative effect in the row at 31 days after application. In a matter of inches from the center of the application zone, the effect of the AA drastically decreased. C.F. Eno and W.G. Blue summarize their research on soil bacteria and fungi stating: "Although applications of AA had an effect on the microbiological population of the soil, it does not seem that this is likely to cause more than a temporarily unbalanced condition in the zone of retention."

EFFECT ON SOIL PHYSICAL AND CHEMICAL PROPERTIES

Anhydrous ammonia is often perceived as being detrimental to several physical and chemical soil properties. Results from a long-term (10 yr.) study comparing the effects of several N sources and a control provide data that is noteworthy (Table 3). Soil bulk density data, one measurement often used to determine soil compaction, was collected and showed that none of the N sources were significantly different each other or the control (no N). This was true when measured in the plow layer (shallow) or just beneath the plow layer (deep).

Applications of all of the N fertilizer sources did however significantly reduce soil pH as compared to the control treatment. The equal lowering of pH among all the N sources was evident both in the shallow and deep soil samples. Because nitrification of ammonium is an acid forming reaction, the net effect will be a lowered pH; the exception being with ammonium sulfate. Soil organic matter content was not affected by any of the fertilizer N sources at any time.

KNIFE SPACING AND AA CONCENTRATIONS

A management practice that has been receiving widespread attention in the past several years is the switching of AA application knife spacing from 30 inches to 60 inches. This practice would allow less energy to be used in pulling the application equipment through the field and fewer knives to be maintained.

From an agronomic perspective, there may be a real advantage of this type of practice based on the concentration of AA that would be in each application zone. When AA is applied to soil, it creates a high pH and this results in an inhibition of nitrification (conversion of ammonium to nitrate). The higher the N concentration, the longer the inhibitory effect. Thus, as one would switch from 30 to 60 in. knife spacings, the concentration of AA would double in each zone.

Research work from Nebraska by Marake et al. (1993) summarized that on some of their fine-textured soils ammonium persistence greatly increased as application spacing increased. They measured a half-life of 66 days for AA with 60-in. row spacings, thus 25% of the applied AA would be present in the ammonium for 132 days after application.

The logistical configuration concern between the N application zone and crop rows has led to the primary recommendation that these wider row spacings only be used with sidedress AA applications. By using 60-in. spacings at sidedressing time, each plant will have an N application zone 15 inches away. Research work in Illinois comparing 30- and 60-in. rows concluded that knife spacing had no significant effect on yield (Table 4).

Planting Corn After Anhydrous Application

A common question regarding spring AA application is how soon after application can corn be planted. The primary goal is that the seed cannot be planted in the AA retention zone, thus AA rate, application depth, and soil moisture and texture are important.

Figure 3 depicts the effect of application N rate and depth on corn stands. When 100 lb N/A was applied corn stands were slightly reduced with the shallow application whereas the rate of 400 lb N/A severely reduced stand at the 4- and 7-in. application depth. The 200 and 300 lb N/A application rate effects were intermediate. Normal application rates of AA are generally between 100 and 200 lb N/A with the typical application depth being around 7 inches. From this study, these stands would then be at 90% or greater.

In this study, the corn was planted directly over the marked zone of AA application and the corn was planted on the same day as AA application. Assuming typical AA retention zones and an application spacing of 30 inches, the chance of planting directly over an AA zone would be approximately one-sixth. Hence, a 90% stand reported in this study would translate to 98% stand if planter rows were random with respect to AA rows.

Delaying time of planting with respect to AA application would increase stands in Figure 3, especially with the 300 and 400 lb N/A rates. Assuming normal or wet soil moisture conditions, which would speed the conversion of ammonia to ammonium in the zone, a delay of several hours to a day between application and tillage or between application and planting should be adequate for typical Minnesota conditions and practices.

SUMMARY

Anhydrous ammonia is a widely used N fertilizer because of the many positive agronomic and logistical characteristics of the product. The effects AA has on the soil are generally minimal with regard to soil physical and chemical properties when compared to other N fertilizer sources. While AA can have an immediate effect on soil microbe populations, these effects are localized and not long lasting.

Altering the concentration of AA in the retention zone by varying knife spacing can have an effect on ammonium persistence in the band. This effect can lead to less N losses in the soil when conditions for loss are favorable. Yield data has concluded no significant difference in grain yields at different AA band application widths.

LITERATURE CITED

Marake, M, D.H. Sander, and D.T. Walters. 1993. Ammonia band spacing effects on ammonium persistence in the band. In Proceedings of the 23rd North Central Extension-Industry Soil Fertility Conference. 9:27-38. Potash & Phosphate Institute, Manhatten, KS.

Tisdale, S.L., W.L. Nelson, and J.D. Beaton. 1985. Soil Fertility and Fertilizers. Macmillan Publishing Co., New York, NY.

Table 1. Numbers of bacteria in soil in the anhydrous ammonia injector row compared with untreated areas. (Eno and Blue, Soil Sci. Soc. Am. J., 18:178)

Time after Application	AA trt	Check	Net
- days -	--- millions/gram soil ---		
0	0.26	2.25	-1.99
3	6.28	1.29	4.99
10	9.20	3.09	6.11
24	4.18	1.33	2.85
31	3.35	4.25	-1.17
38	0.95	0.93	0.02

Table 2. Soil fungi populations (net effect, treated area less untreated area) as affected by distance from the point of anhydrous ammonia injection and time after application. (Eno and Blue, Soil Sci. Soc. Am. J., 18:178)

Days after	Distance from Injection Point (in.)			
Application	0	1	2	3
- days -	------- millions/gram soil -------			
0	-15.00	+2.00	+0.88	-1.13
3	-9.87	-5.62	-1.87	1.00
10	-5.75	-6.87	-4.12	-1.75
24	-13.00	-7.50	0.00	-2.50
31	-6.67	-4.17	4.50	-2.17

Table 3. Physical and chemical properties of soil taken from two layers in field plots. (Stone et al., 1982, Coop. Ext. Serv., C-625, Kansas St. Univ., Manhatten, KS)

N Source	Depth	Density	pH	OM
		lb/ft^3		%
Control	shallow	81.7	6.4	2.3
Anhydrous		83.6	5.7	2.3
Urea		81.7	5.7	2.4
UAN-28		81.7	5.7	2.4
Control	deep	84.2	6.4	2.0
Anhydrous		83.6	5.9	2.1
Urea		84.2	5.8	2.1
UAN-28		84.7	5.9	2.1

Table 4. Corn grain yields as influenced by sidedress N knife injection spacing and N rate on an Illinois fine-textured soil. (Sawyer et al., Agron. Abstracts, 1991 pg. 300)

	Knife Spacing (in.)	
N Rate	30	60
lb/A	------- bu/A ------	
120	160	159
180	165	160
240	170	170
ave.	165	163

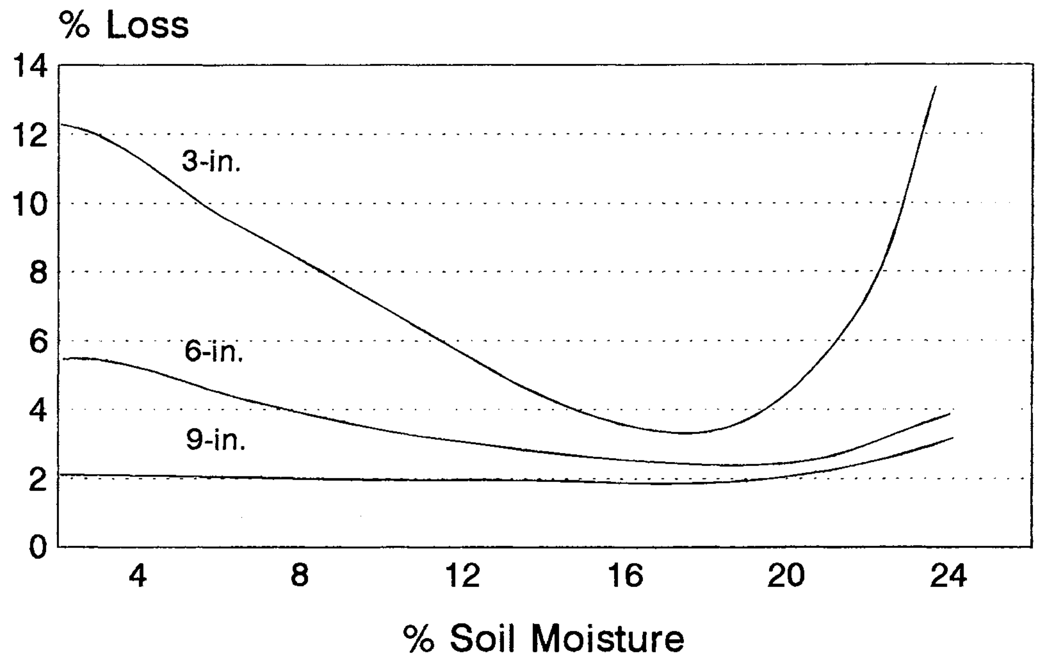

Figure 1. Losses of ammonia from soil as influenced by depth of application and soil moisture. (Stanley and Smith, Soil Sci. Soc. Am. J., 20:557)

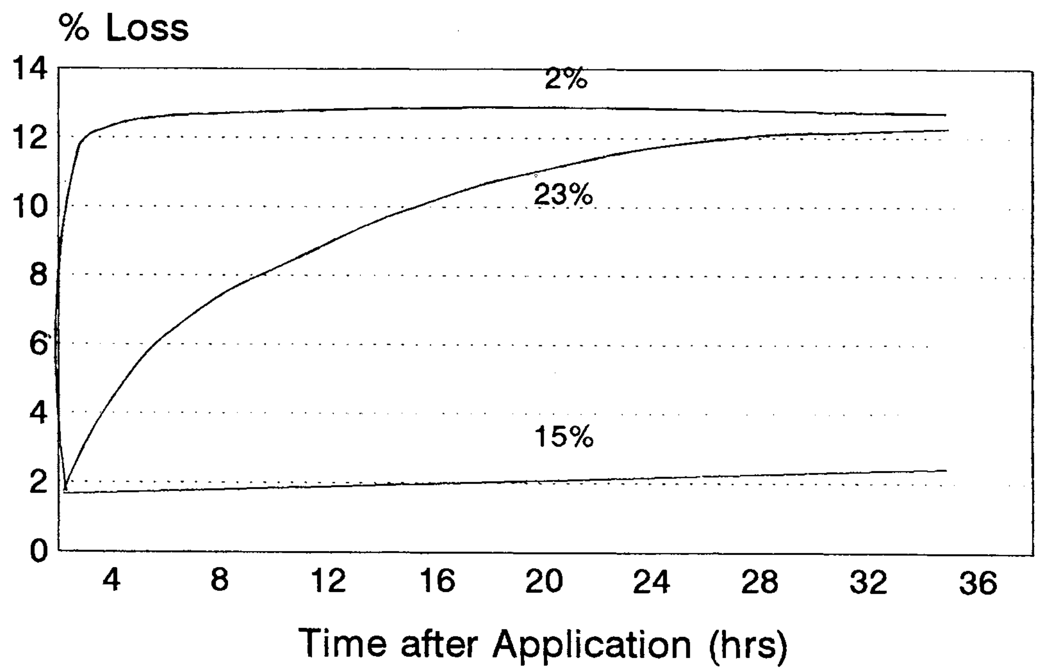

Figure 2. Rates of ammonia loss from soil at different soil moistures. (Stanley and Smith, Soil Sci. Soc. Am. J., 20:557)

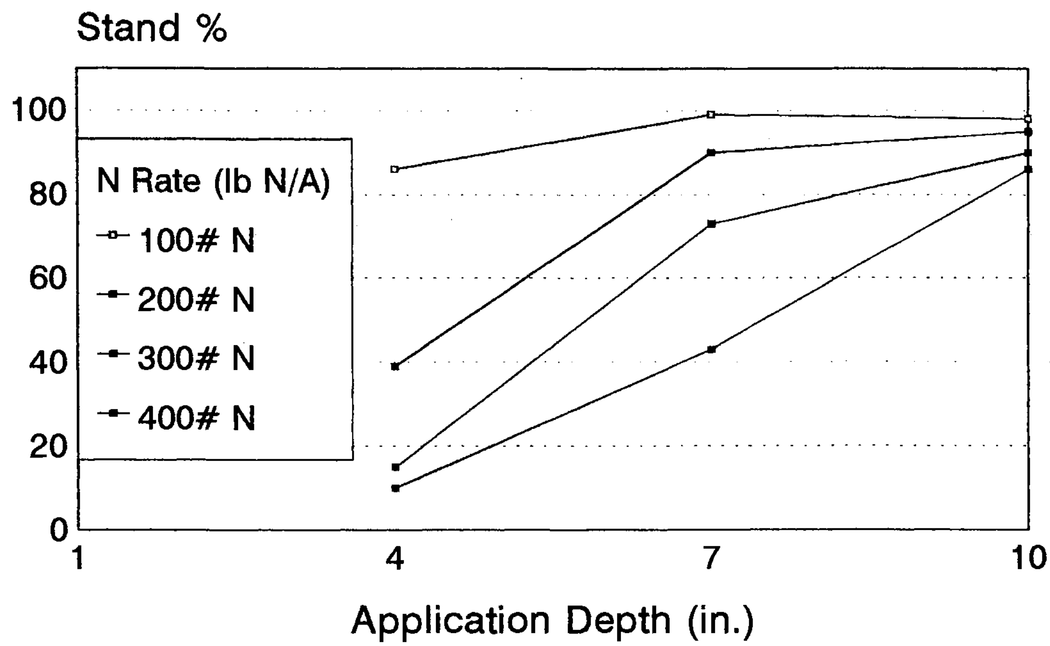

Figure 3. Corn stands 12 days after planting as influenced by rate and depth of anhydrous ammonia applied the same day as planting. (Colliver and Welch, Agron. J. 62:341)