Do Hybrids Differ In Response To Differential Levels Of Nitrogen Fertilizer?[1]

Donald N. Duvick and Anthony J. Cavalieri[2]

INTRODUCTION

In the absence of other limiting factors, maize yield increases with nitrogen fertilizer application to very high levels. In fact, researchers attempting to maximize maize production have reported a yield response at levels of N greater than 300 lbs/acre. Because there are many limiting factors in addition to nitrogen, nitrogen fertilizer must be managed to minimize costs and maximize response. In addition to managing the crop's productivity, recent concerns about high levels of nitrates and other farm chemicals in the groundwater have increased concern about nitrogen management. The challenge is for a farmer to produce the best return on his farm in a way that is consistent with maintaining groundwater quality.

Periodic responses of nitrogen prices to increases in the cost of petroleum have raised concerns about the cost/benefit ratio of nitrogen use; however, in recent years even with low commodity prices, the ratio of corn prices to the cost of nitrogen has made nitrogen application highly favorable if the levels are in the linear response range. With recent prices of corn below $2.00 per bushel and nitrogen at $.15/acre, the economic penalties for underapplication far exceed those for overapplication. While this economic reality is widely recognized, the recent farm crisis has forced farmers to closely examine the costs and returns of all their inputs.

Various groups have taken different perspectives on the use of nitrogen by farmers. Alternative agriculture groups have encouraged farmers to lower input costs and oppose the use of synthetic forms of nitrogen. Other industry groups have promoted maximum economic yield. While the official name of the program is "maximum economic yield", maximum yield has been the major concern and the economics of high yield have followed as a second thought, if at all. In addition, some chemical companies and crop consultants have sought to offer the farmer sophisticated programs for managing both nitrogen fertilizer response and corn hybrid selection based on the latest university data. All of these approaches have been widely reported in the farm press.

---

[1]Presented at the Seventeenth North Central Extension-Industry Soil Fertility Workshop, October 28-29, 1987.

[2]Senior Vice President - Research, Pioneer Hi-Bred International, Inc., 700 Capital Square, 400 Locust Street, Des Moines, IA 50309. Director, Dept. of Research Specialists, Pioneer Hi-Bred International, Inc., 7301 N.W. 62nd Ave., Johnston, IA 50131.

Interest in nitrogen management at both high and low nitrogen levels has raised a number of questions about hybrid response to nitrogen. Do differences in response to nitrogen exist among hybrids? If differences do exist, are they large enough and stable enough to be useful to farmers making crop management decisions? This discussion may allow identification of areas of agreement as well as areas in which more research is needed.

Controlled environment studies

Corn responds to nitrogen by increasing grain yield to a maximum level above which additional nitrogen application no longer results in an increase in yield. The basic response curve has been assumed to be similar across all corn hybrids and is the basis of university nitrogen recommendations. A farmer simply estimates his yield goal, accounts for residual nitrogen, and fertilizes at a rate of 1-1.2 lbs of N/acre for every bushel of yield he expects to attain. The question that arises is: Do all hybrids respond in a similar manner over a range of nitrogen rates?

The relative efficiency with which a corn plant obtains and uses nitrogen to produce grain is related to a number of physiological processes and morphological traits. Moll et al. (11) identified the basic physiological processes involved in nitrogen use efficiency as absorption, translocation, assimilation, and redistribution. A number of greenhouse and growth chamber studies have established that substantial genotypic differences exist for each of these traits within modern elite corn germplasm (see 15 for review of literature). In fact, some of the enzymatic steps in the assimilation of nitrogen are understood in considerable detail and have been studied for use in breeding programs (7). Unfortunately, extrapolation, from a few specially chosen genotypes grown under carefully controlled conditions to numerous commercial hybrids grown in the field, has been notoriously difficult. In addition, the difficulties of predicting yield performance over many environments from a few of the thousands of biochemical steps involved are well known. It is necessary to turn to field experiments in which yield is measured over a number of environments to answer the question of genotypic differences in response to nitrogen.

Field studies of hybrid response to nitrogen

To rigorously evaluate the existence of differential hybrid response to nitrogen a number of experimental criteria should be met. The experiment should include a number of elite, adapted hybrids of similar maturity. Hybrids included need to have a minimum level of agronomic performance to allow adequate expression of nitrogen response. Since later maturing hybrids generally have greater yield potential than earlier ones, it is easy to confound nitrogen response with hybrid maturity if the maturity range of hybrids in a test is not limited. In addition, as with all yield tests, data should be collected over a number of locations and years.

Published reports meeting these criteria are relatively limited; however, a number of good studies exist. Brown (3) studied 2 hybrids in 1979 and 4 hybrids in 1980 - 1983 at three nitrogen rates in Canada. Differences in hybrid response to nitrogen or hybrid x nitrogen rate interaction was significant in 1982 and 1983 but not in other years. Nitrogen response also depended on plant density. Hatlitligil et al. (8) studied 6 hybrids at 2 locations for a single year. The experiment included 2 nitrogen levels. There was no significant hybrid x nitrogen rate interaction. Similar results were obtained by Bundy and Carter (4) in a study of 5 hybrids in Wisconsin. The experiment was run for 2 years and included 4 nitrogen rates. The hybrid x nitrogen rate interaction was not significant. A number of nitrogen response studies have been conducted at Iowa State University. Fakorede and Mock (6) found significant differences among variety hybrids tested in 2 locations and 2 years. In a study of 20 single cross hybrids by Balko and Russell (1) over 6 environments, the hybrids responded differently to nitrogen rates. In a later study with only 3 hybrids, the hybrid x nitrogen interaction was not significant (14). One additional study that requires comment is the work by Tsai and his associates at Purdue (16). This paper has received a large amount of interest and attention from the farm press and to some extent has resulted in much of the current interest in classifying hybrids by their nitrogen response. While the increased interest in this area is surely warranted, the conclusions reached by Tsai and associates are in need of additional experimental support. The study was carried out in a limited number of environments and contained only 3 hybrids. The maturity range of the hybrids was quite large and at least one of the hybrids was not adapted to the area (and the plant density) in which the experiment was grown.

This review of the literature makes it clear that the experience of classifying hybrids has been decidedly mixed. Perhaps the most important conclusion to draw from this work is that the environment in which the tests are grown can have an important effect. In addition, the selection of experimental material can also influence the results.

<u>Pioneer experiments</u>

Pioneer researchers have been interested in the way in which hybrids respond to nitrogen for a number of years. A summary of the experiments conducted by Pioneer researchers largely supports the public experience.

Studies comparing hybrids released since the introduction of hybrid corn in the 1920's give some insight into the changes in nitrogen response that have occurred in successive hybrids, over the years. One researcher (12) examined a number of older and modern hybrids at varying nitrogen rates at 5 locations in 1978. While the slope of the response curve was not different in the different hybrids, the modern hybrids out-yielded the older ones at both the lower and higher nitrogen rates. Planting rate (plant density) did not change the hybrid x N rate response; that is, the newer hybrids out-yielded the older hybrids at both low and high plant densities. Similar results have been obtained by other (non-Pioneer) workers (5). This suggests that although selection is generally done at optimal nitrogen rates, breeders have been successful in improving yield at all nitrogen levels.

Two additional Pioneer experiments (9, 13) were conducted in 1978 to evaluate the hybrid era x nitrogen rate interaction; they comprised an early and a late set of hybrids. Each set contained 10 hybrids from different eras. The 10 early maturity hybrids were grown at 3 nitrogen rates, at 5 locations. No significant hybrid x nitrogen interaction was seen; the newest hybrids outyielded the older hybrids at all levels of nitrogen fertility. The 10 later hybrids were grown at 4 locations and 3 nitrogen rates. While the hybrid x nitrogen rate interaction was significant in this experiment, there was also a significant hybrid x location x nitrogen level interaction and there were no large hybrid differences in yield for the different nitrogen levels. Although these two experiments had a number of locations to provide some experience across locations, they were only grown in a single year. Two or more years' data would have been more desirable.

A fourth group of Pioneer workers (10) conducted a 2 year experiment at 5 nitrogen rates. The experiment contained an early group of genotypes and a later one. The hybrid x nitrogen rate interaction was significant in the early hybrid group but not in the later hybrids.

In a fifth (and the most extensive) study conducted within Pioneer, workers (2) studied a number of hybrids at 4 nitrogen rates, 60, 120, 180 and 240 lbs/acre. A set of four early hybrids was grown over 7 location-years. The nitrogen and hybrid effects were both highly significant but the hybrid x nitrogen rate interaction was not. In contrast, a later maturing set of 9 hybrids grown in 7 location-years did show a significant hybrid x nitrogen rate interaction, however the size of the interaction term was relatively small compared to the other sources of variation.

We are now in the midst of a multiple year study to more rigorously examine the nitrogen use of Pioneer commercial hybrids. This study was begun in 1986. It evaluates 12 hybrids of diverse genotype at 3 nitrogen rates. The experiment was grown at 2 locations in Missouri, and one location each in Iowa, Indiana, and Illinois. Analysis of 1986 data shows significant hybrid x nitrogen interaction for yield; however, the environment x nitrogen treatment interaction was about 9 times larger than the hybrid x nitrogen treatment interaction. The hybrid x environment x nitrogen interaction was also highly significant. In 1987 this experiment is being grown in 15 locations throughout the entire midwest.

Discussion

What can we learn from the research data that has value to farmers for crop management decisions? First, it is clear that the conclusions one draws from experiments of this type are highly dependent on the environment and, to some extent, the hybrids involved in the test. In the studies reviewed here, the hybrids generally showed a response to nitrogen, but the differences in hybrid response were often small and the relative response was often different in different environments. For this reason, our ability to make definitive recommendations of nitrogen management for a given hybrid is quite limited. Other management decisions such as hybrid maturity, stress tolerance, disease reaction, and root and stalk quality should be more pertinent to farmers at this time. In addition, the usefulness of university nitrogen recommendations is apparent regardless of the hybrid involved. Certainly with the increase in concern about groundwater quality, the farmer's decisions on nitrogen management will be under increasing scrutiny.

If we are not yet in a position to make dependable recommendations, what research is needed to provide the farmer with good solid advice? More nitrogen-hybrid experiments are needed. The current need is for data on genetically different modern commercial hybrids that are grouped by relative maturity and area of adaptation. Data on hybrids grown in areas where they are not adapted may be deceiving to farmers who try to use that information to manage the same hybrid in an area where it is adapted. In addition, we need experiments grown across locations and years. It is widely recognized that hybrids perform differently in different environments and this fact needs to be recognized as it relates to hybrid-nitrogen interactions. We need to design and conduct experiments that will allow us to understand how many location-years of data are required to characterize a hybrid and to predict its performance at a given level of confidence.

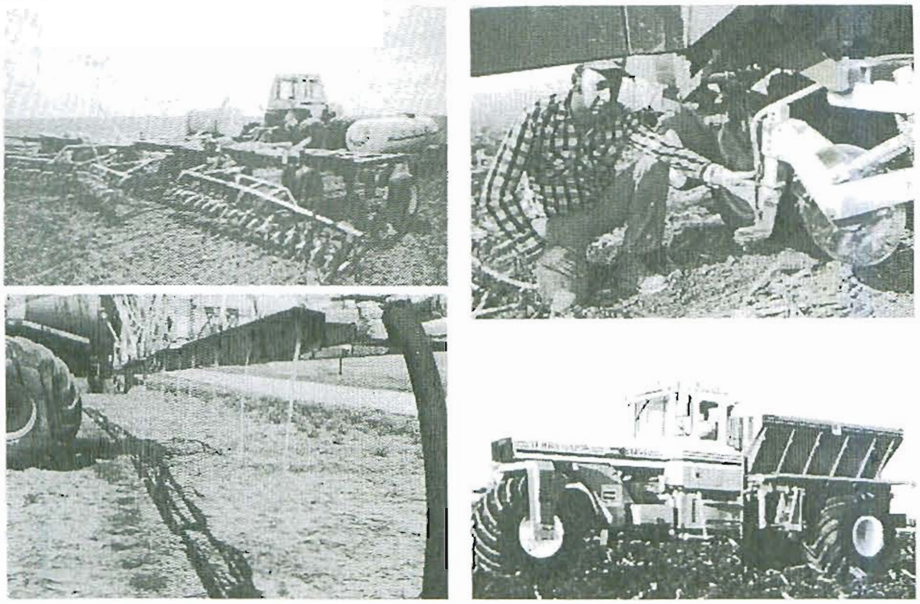
REFERENCES

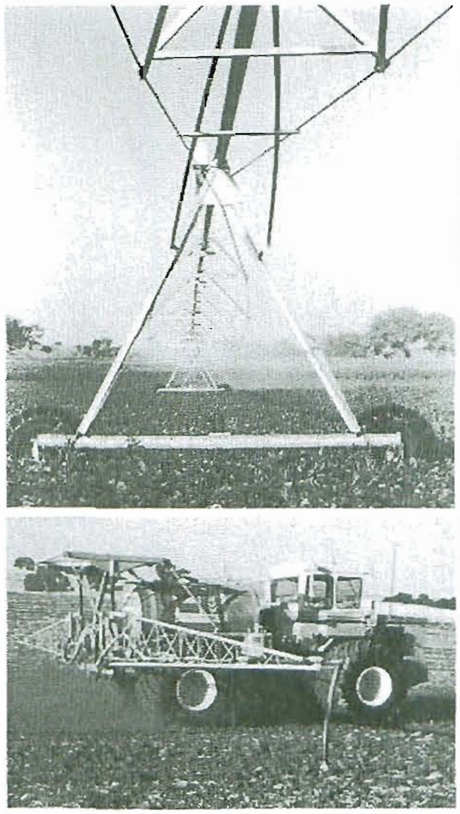
1) Balko, L.G. and W.A. Russell. 1980. Effects of rates of nitrogen fertilizer on maize inbred lines and hybrids progeny. I. Prediction of yield response. Maydica XXV:65-79.
2) Brinkman, G.S., D.L. Mason, R.L. Newell, D.A. Wickham. 1987. Corn hybrid response to nitrogen rates. Pioneer Internal Report.
3) Brown, D.M. 1986. Corn yield response to irrigation, plant population and nitrogen in a cool humid climate. Can. J. Plant. Sci. 66:453-464.
4) Bundy, L.G. and P.R. Carter. 1987. Nitrogen - Hybrid interactions. Paper presented at Fertilizer, Ag lime, and Pest Mngt. Conf. Univ. Wisc. Extension.
5) Carlone, M.R. and W.A. Russell. 1987. Response to plant densities and nitrogen levels for four maize cultivars from different eras of breeding. Crop Sci. 27:465-470.
6) Fakorede, M.A.B. and J.J. Mock. 1982. Correlated responses to recurrent selection for grain yield in maize. ISU Ag & Home Econ. Expt. Stat. Res. Bull. 596. 177-208.
7) Hageman, R.H., E.R. Lang and J.W. Dudley. 1967. A biochemical approach to corn breeding. Advan. Agron. 19:45-86.
8) Hatlitligil, M.B., R.A. Olson, and W.A. Compton. 1984. Yield, water use and nutrient uptake of corn hybrids under varied irrigation and nitrogen regimes. Fertilizer Res. 5:321-333.
9) Kuhn, W.E. 1978. The response of hybrids to different levels of nitrogen. Pioneer Internal Report. 10) Lightner, J.W., S.J. Lupkes, M.D. Culy and G.P. Bonnetta. 1987. Response of corn (Zea mays L.) hybrid and inbred lines to different levels of nitrogen. Pioneer Internal Report.
11) Moll, R.H., E.J. Kamprath, and W.A. Jackson. 1982. Analysis and interpretation of factors which contribute to efficiency of nitrogen utilization. Agron. J. 74:562-564.
12) Noble, S. 1978. Nitrogen utilization by old and modern corn hybrids. Pioneer Internal Report. 13) Oestreich, D.C. 1978. Nitrogen Rate Study-North. Pioneer Internal Report.
14) Russell, W.A. 1984. Further studies on the response of maize inbred lines to N fertilizer. Maydica XXIX:141-150.
15) Sherrad, J.H., R.J. Lambert, M.J. Messmer, F.E. Below and R.H. Hageman. 1984. Plant Breeding for Efficient Plant Use of Nitrogen, in Nitrogen in Crop Production. ASA-CSSA-SSSA. 363-378.
16) Tsai, C.Y., D.M. Huber, D.V. Glover, and H.L. Warren. 1984. Relationship of N deposition to grain yield and N response of three maize hybrids. Crop Sci. 24:277-281.

Vol. 3

PROCEEDINGS

Of the Seventeenth North Central Extension-Industry Soil Fertility Workshop





St. Louis, Missouri
Oct. 28-29, 1987

Published for
The North Central Extension-Industry Soil Fertility Workshop
by
Potash & Phosphate Institute
1220 Potter Drive, Suite 108B
W. Lafayette, Indiana 47906-1334