Effects of Nitrogen Fertilizer on Corn Yield
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Nitrogen (N) is the most limiting and therefore the most important fertilizer element for corn. An inadequate N supply can greatly reduce yield and profit. Recent changes in corn and fertilizer prices require a new look at the economics of fertilization. Inadequate supplies of nitrogen fertilizer also require a closer look at the most profitable N rate and how reduced rates affect total profit per acre. Higher priced fertilizers and supply shortages have also provided the incentive to make the most efficient use of available N supplies.

This publication provides information on (1) corn response to N fertilizer, (2) the most profitable N rate, (3) adjustments in the N rate, (4) efficient use of N fertilizers and (5) allocation of N fertilizers.

Yield Response to Nitrogen

The response of corn to N under varying soil and climatic conditions follows the law of diminishing returns. As the N rate increases, the additional yield produced by each additional increment of N decreases until, ultimately, there is no additional yield. In order to predict yield response to N fertilizer at all levels of production, a computer model was developed using field experimental data. Some typical N response curves using the model are shown in Figures 1-3.

Yield response to N can be obtained by providing some basic information about the soil, climate and existing management. Some soils have the natural ability to produce more corn than others, therefore, each soil has its own yield potential (YP). Climate and existing management are important clues to selecting the proper yield potential. If a soil is not adequately drained or moisture is limiting, or plant population, planting date, hybrid and weed control are not optimum, the yield potential will be lower than where all factors are optimum. Crop rotation and past fertilization also affect the yield potential. Only after taking all factors into account can one select a realistic yield potential for the soil or field being considered.

Figure 1 shows three N response curves for three soils with different yield potentials. Note that the first increments of N give the largest yield increase and that a much smaller yield increase is obtained with the same amount of N as we approach the maximum yield.

Most Profitable N Rate

The most profitable N rate (MPR) can easily be obtained from the yield response curves by calculating the added revenue for each additional pound of N. The added revenue (profit over and above the cost of the last 10 pounds of nitrogen added) is plotted as the dot-dash line in Figure 1 using the right axis. It decreases with each additional 10 pounds of N until the additional yield will no longer pay for the added N. **The amount of N applied at this point is the most profitable N rate.**

In Figure 1, the most profitable rate for the loamy sand soil with a yield potential of 70 bushels per acre (YP = 70) is 80 pounds of N per acre. For the sandy loam (YP = 100), it's 117 pounds, and for the clay loam (YP = 130) it's 145 pounds. Soils with higher yield potentials always require more N fertilizer unless it can be supplied by some other means such as manure or legumes. High yields also remove more N than low yields and therefore require larger applications.

Figure 2 shows how varying prices of N fertilizer affect the most profitable rate of application when corn is $3.00 a bushel and yield potential is 100 bushels per acre. As the price of N increases, the most profitable rate decreases. The largest decrease in the MPR comes when cost of N increases from 10 to 20 cents and the smallest decrease occurs when cost of N increases from 30 to 40 cents.

Figure 3 shows how corn price affects the most profitable rate when yield potential and N price are held constant. Increasing the price of corn increases the most profitable N rate.

Since both N and corn prices affect the most profitable N rate, one can show the combined relationship by calculating the corn to N price ratio. Table 2 contains the corn to N price ratios which cover a range of corn and N prices. Table 1 may be helpful in converting fertilizer prices per ton to price per pound of nutrient which is required in Table 2. It is evident from Figures 2 and 3 that as long as the corn to N price ratio remains the same, so does the most profitable N rate. The most profitable rate for $2.00 corn and 20 cent N (10:1 corn to N ratio) is the same as for $3.00 corn and 30 cent N (10:1 corn to N ratio). The most profitable rate for either situation at the 100 bushel yield potential is 110 pounds of N per acre. This does **not** mean that $2.00 and 20 cent N will be as profitable as $3.00 corn and 30 cent N. The latter will be more profitable (i.e., 50 bushel increase x $3.00 − 110 pounds N x $.30 = $117 profit whereas $2.00 corn and $.20 N equals $78 profit).

The most profitable N rates for eight yield potentials and five corn to N price ratios based on the computer model are shown in Table 3. Thus, if yield potential is 130 and the corn to N ratio is 10:1, the most profitable N rate = 140 pounds/acre.

Table 4 gives the expected yield in bushels per acre for 8 yield potentials for every 20 pounds of applied N. The most profitable N rate can be obtained by calculating the added revenue for the last 20 lbs. of N added. For example, consider a 100 bushel yield potential, $3.00 corn and 20 cent N. The expected yield increase by increasing the N rate from 100 to 120 pounds is 1.9 bushels (98.3 − 96.4). For $3.00 corn we realize a gross profit of $5.70 (1.9 x $3.00). The investment of $4.00 (20 pounds N x $.20) returns $1.70. It is profitable to use 120 pounds of N in this situation. By increasing the N rate to 140 pounds we find a net loss of $1.00 because only a $3.00 gross profit is realized. Table 4 should also give the grower a good idea of the yield reduction he can expect if he is forced to reduce his N application.

Adjustments to MPR of N

Adjustments to the most profitable N rate should be made if other sources of N contribute to the total amount of available N beyond that normally contributed by the soil. These sources include soil organic matter, N in residues from the previous crop, previous N application, residual N due to excessive application the previous year and/or adverse climatic and environmental conditions.

Table 5 contains some suggestions for adjusting the most profitable N rate. If your field deserves a credit (+), subtract the amount suggested from the most profitable rate found in Table 3. If the value is preceded by a minus (—), add the amount suggested to the most profitable rate.

Efficient Use of N

The model used in predicting response to N assumes efficient use of N fertilizer by proper methods of application. If less efficient methods of application are used, you should make adjustments for the losses which are likely to occur.

Fall vs. spring applications

Research in Michigan and other states has shown that spring applications of ammonium N are more efficient than fall (estimated fall losses are 5-10% on fine and medium textured soils and 10-30% on coarse textured soils). There are some situations, however, where the price advantage of fall fertilization or management practices on fine and medium textured soils may compensate for the lower efficiency. Fall applications should not be used on coarse textured soils because nitrate leaching is a potential source of ground water contamination. Fall applications should only be used on fine and medium textured soils and then only in the ammonium form (anhydrous ammonia, urea, diammonium phosphate, aqua ammonia and ammonium sulfate) after the soil temperature is below 50°F. Applications above 50°F will permit ammonium to be converted to nitrate and thereby increase the chance for loss by leaching or denitrification (gaseous loss under anaerobic conditions). Studies have shown that at 60°F about 40% of the ammonium fertilizer applied will be converted to nitrate in 1 week, 90% in 2 weeks and 100% in 3 weeks.

Plow-down vs. sidedress

Sidedress applications of N on sandy soils have also been shown to be more efficient than spring plow-down N. Plow-down N on sandy soils can be leached deep into the soil by heavy rains. One inch of rain on a sandy loam soil at field moisture capacity will leach nitrates approximately one foot assuming all of the water penetrates the soil and no runoff occurs. Under the same conditions nitrates might move only six inches in a loam soil, however, chances for some runoff to occur on this soil are great. The amount of penetrating rainfall, the amount of N in the nitrate form and the amount of soil moisture at the time of rain all determine the magnitude of N losses.

Sidedress N on fine textured soils may also have an advantage especially where a potential anaerobic (waterlogged) condition exists. Plow-down N on these soils can be lost by denitrification if the N is in the nitrate form at the time waterlogging occurs. Adjustments can be made at the time of sidedressing depending on denitrification and leaching losses. The best time for sidedress N is when corn is 6-12 inches tall. Later applications can cause root pruning and may be impossible to apply if wet, rainy conditions occur.

Topdress N—volatilization losses

Efficient utilization of N also means soil incorporation for most N fertilizers. Volatilization losses of N from the surface applications of urea and 28% N solution can be appreciable if rain does not occur within several weeks of the time of application (10-20%). High temperatures, low relative humidity and wind which result in a high rate of evaporation tend to favor volatilization loss of N. High soil pH (above 7.0) and residues which prevent the fertilizer from coming in contact with the soil also favor volatilization losses. Climatic conditions in Michigan are quite often wet and humid in the spring which helps to minimize this loss. Losses from surface sprays of herbicide plus 28% N solution in Michigan are estimated at 0-10%.

N through sprinkler systems

Nitrogen applied through the irrigation system is probably the most efficient method of all in supplying a limited amount of nitrogen. The center pivot and solid set systems are the most common systems which utilize this method of applying N, however, the giant gun has also been used satisfactorily. Nitrogen solutions (28% and less) work best through all sprinkler systems. Aqua ammonia and anhydrous ammonia can cause problems if ammonia precipitates with salts in the irrigation line and there may be some loss of free ammonia.

The amount of N that can be applied through the irrigation system is limited only to the capacity of the injection pump. Even at the highest rates of injection, the concentration of N will be greatly diluted by the irrigation water and will not cause injury to corn. Most operators, however, will normally apply only 20 to 40 pounds of N per acre in one irrigation. On very sandy soils it may be best to use a good starter, a small amount of sidedress or preplant N and apply most of the N through the irrigation system. Nitrogen through the irrigation system can be effectively applied up until the time of silking. Nitrogen applied after silking is not recommended because it may not be efficiently utilized.

Allocation of Inadequate N

The current fertilizer shortage has left some corn producers with inadequate supplies of N fertilizers. Thus, some growers must use less than the most profitable rate. To obtain maximum profits in this situation, the last pound of N should give an equal yield response for each acre of corn. It will be more profitable to fertilize all your corn at a reduced rate rather than to fertilize part at the most profitable rate and put none on

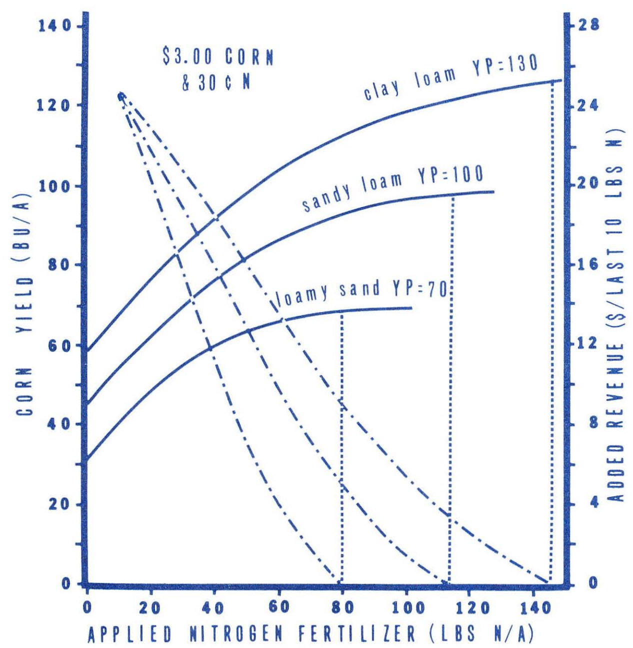

Figure 1. Yield response of corn to nitrogen fertilizer on three soils with different yield potentials (YP). Dot-dash line shows the added revenue for the last 10 pounds of N applied using the right axis while the vertical dotted line shows the most profitable rate (MPR) of fertilization based on $3.00 corn and 30 cents nitrogen. Thus, if YP = 70, MPR = 80 pounds N/acre.

the remaining acreage. Consider the following example. A producer has a 100 bushel yield potential. Because of price relationships the most profitable N rate is 110 pounds per acre, however, his current allotment is 75% of his need or enough for 80 pounds per acre. According to Table 4, if he applies 110 pounds N per acre his ex-

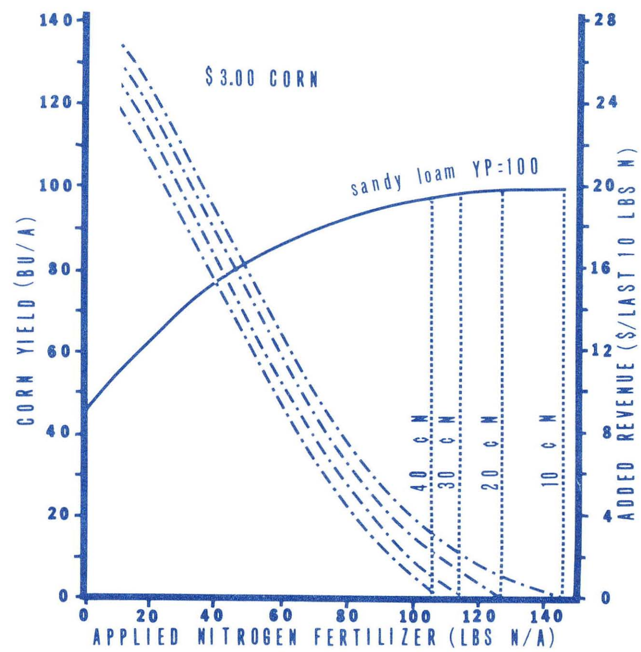

Figure 2. Effect of varying nitrogen prices on the most profitable rate of application for a soil with a 100 bushel yield potential holding corn price constant at $3.00.

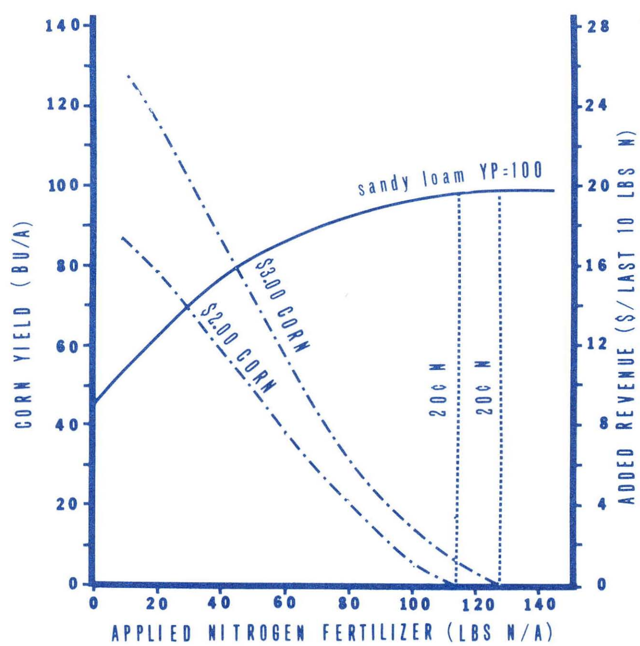

Figure 3. Effect of varying corn prices on the most profitable rate of application for a soil with a 100 bushel yield potential holding nitrogen price constant at 20 cents.

pected yield will be 98 bushels per acre. At 80 pounds N, his yield will be 93 bushels. If he applies 110 pounds N to 75% of his acreage and none on the remaining 25%, his average yield is 85 bushels per acre (98 x .75 + 45 x .25). Average yield under an even allocation program will be 93 bushels per acre or 8 bushels higher.

Farmers with land varying yield potential should cut back N at the same **percentage** on each field.

If N rates must be reduced too drastically, then it may be advisable to look at alternative crops such as soybeans which require little or no N. In making decisions concerning the kind of crops to grow, producers need to consider expected returns above variable costs per acre, the riskiness of returns, the consequences of crop rotation, herbicide residues, equipment and management.

Table 1. Cost per pound of nitrogen in some common fertilizer materials.

Nitrogen Source	% Nitrogen	Fertilizer Cost - $/ton							
		60	80	100	130	180	200	250	300
		---- cost per pound of element - $./lb ----							
Anhydrous Ammonia	82	.04	.05	.06	.08	.11	.12	.15	.18
Urea	46	.07	.09	.11	.14	.20	.22	.27	.33
Ammonium Nitrate	33	.09	.12	.15	.20	.27	.30	.38	.45
Nitrogen Solution	28	.11	.14	.18	.23	.32	.36	.45	.54
Ammonium Sulfate	21	.14	.19	.24	.31	.43	.48	.60	.71
Calcium Nitrate	16	.19	.25	.31	.41	.56	.62	.78	.94

Table 2. Corn:nitrogen price ratios based on various prices of corn and costs of nitrogen.[a]

Nitrogen Cost ($./lb N)	Corn Price ($/Bu)						
	$1.00	1.50	2.00	2.50	3.00	3.50	4.00
	--------------- corn:nitrogen price ratio ---------------						
$.05	20:1	30:1	40:1	50:1	60:1	70:1	80:1
.10	10:1	15:1	20:1	25:1	30:1	35:1	40:1
.15	7:1	10:1	13:1	17:1	20:1	23:1	27:1
.20	5:1	8:1	10:1	12:1	15:1	18:1	20:1
.25	4:1	6:1	8:1	10:1	12:1	14:1	16:1
.30	3:1	5:1	7:1	8:1	10:1	12:1	13:1
.35	3:1	4:1	6:1	7:1	9:1	10:1	11:1
.40	2:1	4:1	5:1	6:1	8:1	8:1	10:1

[a] To obtain the needed corn:nitrogen price ratio, determine the cost of nitrogen and the price of corn which most nearly represents your situation and read the corresponding corn:nitrogen price ratio in the table.

Table 3. **Most profitable nitrogen rate for corn based on a computer model for predicting yield and corn to nitrogen price ratios.**[a]

Corn:Nitrogen Price Ratio	Yield Potential - Bu/acre 85	100	115	130	145	160	175	190
	---- most profitable nitrogen rate - lbs N/acre ----							
5 : 1	80	90	100	110	130	140	150	170
10 : 1	90	110	130	140	160	180	190	210
15 : 1	100	120	140	160	180	200	220	240
20 : 1	110	130	150	170	190	210	230	250
25 : 1	120	140	160	180	200	220	240	260

[a]Select the yield potential and the corn:nitrogen price ratio. The corresponding value in the table is the most profitable nitrogen rate.

Table 4. **Predicted corn yield with added nitrogen fertilizer for eight soils with varying yield potentials in a continuous corn cropping system.**

N Rate lbs/acre	Yield Potential -- Bu/A 85	100	115	130	145	160	175	190
	------expected yield -- bu/A------							
0	38.2	45.0	51.8	58.5	65.2	72.0	78.7	85.5
20	55.8	62.8	69.6	76.5	83.3	90.1	96.9	103.7
40	68.6	76.6	84.3	91.7	99.0	106.1	113.2	120.2
60	76.7	86.4	95.4	103.8	111.8	119.6	127.2	134.6
80	81.3	92.7	103.1	112.8	121.9	130.6	138.9	147.0
100	83.5	96.4	108.2	119.2	129.5	139.2	148.4	157.3
120	84.4	98.3	111.4	123.5	135.0	145.7	155.9	165.6
140	84.7	99.3	113.1	126.3	138.7	150.5	161.6	172.2
160		99.7	114.1	128.0	141.2	153.8	165.8	177.2
180			114.6	128.9	142.8	156.1	168.8	181.0
200				129.5	143.8	157.6	171.0	183.8
220					144.3	158.6	172.4	185.8
240						159.2	173.4	187.2
260							174.0	188.2
280								188.9

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Table 5. Suggested nitrogen credit or deficit for various management practices, soil types, climatic and environmental situations.

Situation		Nitrogen credit or deficit[a]
		lbs/acre
Soil organic matter		
0-2%		(-) 20-40
2-4%		0
4-8%		(+) 20-40
> 8%		(+) 40-80
Previous crop		
Alfalfa		
60-100% stand		(+) 80-100
30-60% stand		(+) 40-60
0-30% stand		(+) 0-40
Red clover and other clovers		(+) 40-60
Soybeans		(+) 0-40
Field beans, small grains, corn grain		0
Corn silage		(-) 30-50
Previous nitrogen application		
0-50 lbs/acre		(-) 10-30
50-150 lbs/acre		0
150-200 lbs/acre		(+) 30-50
Manure application		
1 ton dairy, beef or hog manure	1st year	(+) 4-6
	2nd year	(+) 1-2
1 ton sheep or poultry manure	1st year	(+) 10-12
	2nd year	(+) 3-4
Adverse climatic or environmental conditions		
Yield reduction due to drought, poor stand, insects or disease (medium and fine textured soils only)		From the total N applied, subtract 1 lb N for each bushel of corn harvested and divide by 2 Example: 200 lbs N and 80 bu corn $\frac{200-80}{2}$ = 60 lbs credit

[a](+) sign indicates a credit and should be subtracted from the recommended rate.
(-) sign indicates a N deficit and should be added to the recommended rate.