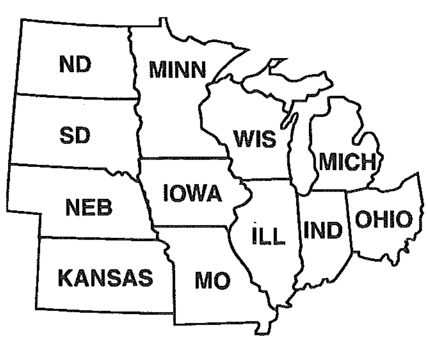
North Central Regional Research Publication No. 341

Effectiveness of Using Low Rates of Plant Nutrients

D. Franzen and **J. Gerwing**

North Dakota State University
and
South Dakota State University

February 1997



Agricultural Experiment Stations of Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota and Wisconsin, and the U.S. Department of Agriculture cooperating.

Sponsored by the agricultural experiment stations of Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota and Wisconsin.

NCR-103 Committee

Fred A. Cholick
South Dakota State University
Administrative Advisor

Regis D. Voss
Iowa State University

Dave Mengel
Purdue University

Jim Gerwing
South Dakota State University

Maurice Vitosh
Michigan State University

Peter Scharf
University of Missouri

Keith Kelling
University of Wisconsin

David Whitney
Kansas State University

Dave Franzen
North Dakota State University

Robert G. Hoeft
University of Illinois

Jay W. Johnson
Ohio State University

George Rehm
University of Minnesota

Robert H. Dowdy
USDA/ARS

Mitch Woodward
USDA/CSREES

Gary Hergert
University of Nebraska

Low rates of nutrients are sometimes applied to crops through the use of fertilizers with a low nutrient analysis, or by applying low rates of higher analysis fertilizers. Low rates of nutrients describe levels of nutrients added at less than levels removed by crops.

There are 13 essential mineral nutrients needed for growth of most crops. The nutrient content of several crops at selected yield levels is shown in Table 1. Nutrients taken up and used by crops are supplied by the soil or by supplemental additions of fertilizer and manure. The amounts of nitrogen (N), calcium (Ca), and potassium (K) taken up by plants add up to hundreds of pounds per acre. Phosphorus (P), sulfur(S), chloride (Cl) and magnesium (Mg) are used in amounts from 10 to 100 lbs/A. Micronutrients, or trace elements (iron (Fe) , boron (B), manganese (Mn), zinc (Zn), copper (Cu) and molybdenum (Mo)) are used in amounts usually less than 1 lb/A. The majority of N and P taken up by plants is removed in the grain. The majority of other nutrients is contained in the vegetation portion of the plants.

Some farm producers may choose to use low rates of fertilizer to reduce input costs. When soil test levels of nutrients are high and very high, nutrient additions are generally not recommended, or are recommended at lower than crop removal rates. However, if soil test levels are very low, low or medium, higher rates of nutrients should normally be added. Foliar fertilizer or fertilizer applied with the seed are also generally applied at low rates. Although there are times when low rates of nutrients are appropriate to apply, careful consideration should be made before using fertilizer at rates lower than crop removal, especially with phosphorus and nitrogen.

Table 1. Nutrient content of several crops at selected yield levels. Field measurements will vary depending on environmental conditions and soil nutrient levels.

Crop and Portion Analyzed	Weight Removed (lb/A)	Yield per Acre	Nutrients accumulated in crops at harvest, lb/A											
			N	P_2O_5	K_2O	Ca	Mg	S	Cl	B	Cu	Fe	Mn	Zn
Alfalfa hay	12000	6 T	270	60	270	168	32	29	41	0.09	0.09	1.20	0.66	0.63
Barley, grain	3840	80 bu	70	30	20	2	4	6	6	0.08	0.06	0.30	0.06	0.12
Barley straw	4000	2 T	30	10	60	16	4	8	1	0.01	0.02	0.01	0.64	0.10
Canola seed	2000	40 bu	124	22	15	9	7	24	0.6	0.03	0.01	0.10	0.08	0.10
Corn, grain	8400	150 bu	135	64	42	15	22	14	2	0.12	0.06	0.15	0.09	0.15
Corn stover	9000	4.5 T	101	36	144	27	18	11	1	0.05	0.03	1.00	1.50	0.30
Oat, grain	3200	100 bu	63	25	19	3	4	6	1		0.04	0.80	0.15	0.36
Oat, straw	5000	2.5 T	31	19	100	10	10	11	1		0.04	0.15	0.15	0.36
Pea, vines and pods	5000	2.5 T	120	31	121	175	15	12	8	0.04	0.06	0.60	0.40	0.02
Potato, tubers	40000	40 cwt	133	50	250	6	10	10	26	0.09	0.07	0.89	0.15	0.09
Sorghum, grain	5000	100 bu	81	44	25	5	6	6			0.01		0.05	0.05
Sorghum, stover	7500	3.75 T	106	31	156	36	23							
Sugarbeet, root	40000	20 T	16	20	32	240	40	40	8				0.20	0.08
Soybean, seed	3000	50 bu	188	44	66	9	9	5	1	0.06	0.05	0.50	0.06	0.05
Soybean, straw	5000	2.5 T	127	30	76	56	25	15	20	0.03	0.01	1.00	0.50	0.30
Sunflower, seed	2000	1 T	52	8	12	2	5	4		0.03	0.03	0.06	0.03	0.10
Sunflower, stover	3000	1.5 T	35	3	51	37	19	7		0.10	0.01	0.46	0.08	0.10
Wheat, grain	3600	60 bu	75	38	23	2	9	5	1	0.06	0.05	0.45	0.14	0.21
Wheat, straw	4500	2.5 T	30	8	53	9	5	8	20	0.02	0.02	1.95	0.24	0.08

Data from Table 1 accumulated from various sources. NFSA Liquid Fertilizer Manual, 1967; Frank, 1995, Blamey, et al., 1987; Grant and Bailey, 1993, Mengel and Kirby, 1987.

What is a low nutrient rate?

Low nutrient rates can come from use of a low analysis fertilizer or from using very low rates of a high analysis fertilizer. All fertilizers are required by state law to have a guaranteed analysis. The guaranteed analysis is shown and described by the following example for the analysis of an 18-46-0 fertilizer:

18	–	46	–	0
% Nitrogen		%Phosphate		%Potash
N		P_2O_5		K_2O

Low analysis fertilizers may be manufactured by dilution of higher analysis fertilizer with water. Others are produced from mined material, or earth or earth-like products. Still others are organic products from plant or animal tissues or byproducts of food or industry processing, such as seaweed extract, composted manure, fish extract or whey. Caution should be used when fertilizer company advertisers claim exceptional or unusual qualities, including such terms as soil conditioning, increased earthworm activity, increased soil biological activity, improved root growth, and natural release of nutrients from soil minerals. Some claims are made that reduced amounts of a certain fertilizer will substitute completely for a conventional fertilizer program.

Low nutrient rates can also be supplied by using low rates of high analysis fertilizers, such as 2 quarts/A of 3-10-10 which supplies less than 3 lbs of nutrients or 5 gallon/A of 10-10-10 as a total program, containing less than 20 lbs of nutrients per acre.

Plant availability of nutrients in the soil

Nitrogen is naturally supplied from the soil through the microbial breakdown of organic matter and crop residues. For example, in North Dakota, a stand of harvested alfalfa with more than 5 plants/square ft. may contribute about 75 lb. N/A to a subsequent crop if seeded to wheat the following year. Manure from an old feedlot can affect nitrogen availability for many years after the feedlot is put into crop production.

Phosphate is largely tied up as iron and aluminum phosphate minerals in acid soils, and as calcium phosphates in high pH soils. Organic phosphorus is also an important form of phosphate in most soils. The availability of phosphate at any time is very small compared to the entire pool of phosphorus in the soil. Soil testing is used to predict the probability of crop response to an application of fertilizer. Soil test methods for phosphorus are specific for various parts of the country and describe the contribution of both organic and mineral phosphate in affecting crop response to fertilizer phosphate addition.

Available potassium in the soil is also much smaller than the total pool. In many soils, such as those composed partially of illite clays, large amounts of potassium are "fixed" between the clay interlayer spaces and are relatively unavailable to plants. Generally, available potassium comes from the potassium that is attached to the surfaces of clay and organic matter.

Calcium and magnesium are available in large amounts in soils that range from slightly acid to more basic pH. Liming to increase pH also increases calcium, magnesium or both nutrients in the soil depending on the limestone source. Usually thousands of pounds of calcium and hundreds to thousands of pounds of magnesium may be present in well-limed soils.

Sulfur is made available through decomposition of organic matter, the presence of sulfides, gypsum (calcium sulfate), and other sulfate minerals as well as natural and industrial sulfur emissions deposited with rainfall. Sulfur is mobile in the soil, and its presence or absence may be temporary depending on the year and the soil minerals.

Chloride is an anion that is mobile in the soil. Some soils have naturally high levels of chloride, while others are relatively low. In areas where potash fertilization is common, chloride levels are usually high due to muriate of potash (KCl) being the dominant potassium source.

Micronutrients become available through a combination of organic matter breakdown, weathering of native soil minerals and pH. Iron, manganese, zinc and copper availability is decreased with increasing pH. Availability of molybdenum is increased by high pH. Boron availability is linked to organic matter, clay content and soil pH.

Low rates of zinc, iron and manganese-containing fertilizers applied as foliar fertilizers may be effective in correcting deficiencies. Low analysis formulations of these nutrients may supply all the micronutrient needed for a season.

Fertilizer fate in the soil

Fertilizers may be sold as liquid or dry formulations. Some liquid fertilizers may claim to be more available than dry granular fertilizers. However, most commonly used dry fertilizers are nearly 100 percent soluble in water. Regardless of original form, fertilizers react with soil minerals and soil microorganisms and are rapidly transformed from their original makeup. Because of these reactions, a 100 percent available fertilizer declines in plant uptake efficiency rapidly after application. The recovery efficiency of nutrient application is only 10-30 percent of P, 35-60 percent of K and 50-75 percent of N in the year of application. Fertilizer nutrients not used the first year contribute to plant uptake in following years as part of the soil reserve.

Phosphate fertilizers are produced by two main methods. The first is called a wet process method, reacting rock phosphate with sulfuric acid. The resulting phosphoric acid is called black or green acid and contains some impurities. The impurities are compounds normally found in soils and are not harmful to crops, nor do they affect availability of nutrients. Furnace acid or white acid is produced by heating rock phosphate in an electric furnace at high temperatures. The resulting phosphoric acid is very pure but very expensive because of high energy costs during its manufacture. In the soil, both black acid and white acid behave identically. Fertilizers produced by either black or white acids form orthophosphates and the final form in the soil is dictated by the soil pH, not the original acid form. Black acids are used to make standard grade fertilizers such as 10-34-0, 7-21-7, 18-46-0 and 11-52-0. White acids are used to make certain fertilizers like 9-18-9.

Polyphosphate fertilizers are produced by driving off water from phosphoric acid and forming chains of orthophosphates called polyphosphates. When introduced into soil, polyphosphates react with water relatively quickly, producing orthophosphates again. Most dry fertilizers are orthophosphates, whereas most liquids contain polyphosphates. However, whether the phosphate fertilizer was ortho or polyphosphate, the majority of plant uptake of P is as the orthophosphate ion. A comparison of crop response to both polyphosphate and orthophosphate is shown in Table 2.

Table 2. Comparison of polyphosphate and orthophosphate on corn yield.

P_2O_5 Applied	P Source: Polyphosphate	Orthophosphate
lb/A	bu/A	
15	124	124
30	134	134
45	142	142

Source: Nebraska Soil test P:Low

Depletion of soil nutrient levels due to the use of low nutrient addition

Information in Table 1 shows that a 150 bu/A corn crop contains 60 lb/A P_2O_5 in the grain. When this amount of phosphorus is removed, release of P from the soil is likely to replace a small portion of the removal. However, the reserve portion of soil P is partially depleted by this event (Table 3). Over a number of years, soil depletion may result in lower crop yields, unless the nutrients are replaced.

If soil test levels for certain nutrients are high, depletion is not a concern as long as soil test levels are monitored and remain high. Long-term crop productivity is affected only by allowing soil fertility to drop below optimal levels.

Table 3. Comparison of effect of low rate and higher rate phosphorus fertilizers on Bray P_1 levels. Mean of four sites. Johnson, Ohio State University.

Treatment	Initial Bray P_1 Level, July 1986	Fall 1987	Fall 1988	Fall 1989
	Bray P_1 levels, ppm			
Low P rate	28	19	13	12
High P rate	28	23	14	16

Low P rate from 6 gal/A 9-18-9, 1987 and 8 gal/A 9-18-9, 1988 and 1989. High P rate from 50 gal/A 4-10-10/A annually.

Use of banded fertilizer applications at planting vs. broadcast fertilizer

Methods of fertilizer application at planting include placement in the seed furrow (pop-up) or side-banded with the band having seed and fertilizer separation, such as 2 inches to the side and 2 inches below the seed (2X2 band). These bands are commonly referred to as starter applications. Side-banded starter fertilizers have been shown effective at increasing plant growth and sometimes crop yields in certain years, especially when soils are cold at early growth stages (Table 4).

Use of a side-banded or pop-up starter, especially containing P, may reduce the amount of nutrient required to achieve an optimum yield in some years. However, in some years, they may effectively increase yields (Table 5). Pop-up starters are used at relatively low rates to avoid salt damage or ammonia volatilization damage to germination when placed with the seed. The rate of row starter should be adjusted so that depletion of soil nutrients does not occur. Often, supplemental broadcast rates of fertilizer are used to help maintain soil nutrient levels.

Maintaining a high level of crop production may require a combination of row starter and a relatively high soil test P level (Figure 1). Row starter sometimes results in yield increases regardless of soil test level, especially in cooler climates and early seeded crops. However, to achieve relatively high yields, higher soil test levels may be required. In the South Dakota study in Figure 1, additional row starter beyond 20 lb P_2O_5/A did not increase corn yield. In order to achieve maximum yield, initial soil test levels needed to be at or above the medium range. Producers should be aware of both short term and long term P management. Short term management means that starter fertilizers should be used when appropriate for more rapid early plant development in cooler soils and increased tillering in small grains. Long term P management means that soil test P levels need to be built to at least medium levels over time to achieve the greatest crop production.

Table 4. Effect of a 2X2 starter fertilizer on corn yield in Illinois during two cool planting seasons. Mean of four locations. Ritchie, et al., 1996. 160 lb/A of N were applied to all plots prior to treatments.

Starter				
N	P_2O_5	K_2O	1994	1995
lb/A			bu/A	
0	0	0	144	100
25	0	0	152	105
25	30	0	155	110
25	30	20	156	114

Bray P1 test levels ranged from 16-46 ppm. K levels ranged from 74-193 ppm.

Table 5. Comparison of pop-up, side-banded (2X2),and broadcast fertilizer application to corn. Ritchie, et al., 1996. 160 lb/A of N were applied to all plots prior to treatments. Average of four locations.

Application Method	Treatment N	P_2O_5	K_2O	Source	1994	1995
	lb/A				Yield, bu/A	
Check	0	0	0		155	94
Pop-up	10	10	0	AN, CSP[1]	156	106
2X2 band	5	17	0	10-34-0	154	98
Broadcast	25	64	0	18-46-0	155	103

[1]AN = ammonium nitrate CSP = concentrated super phosphate

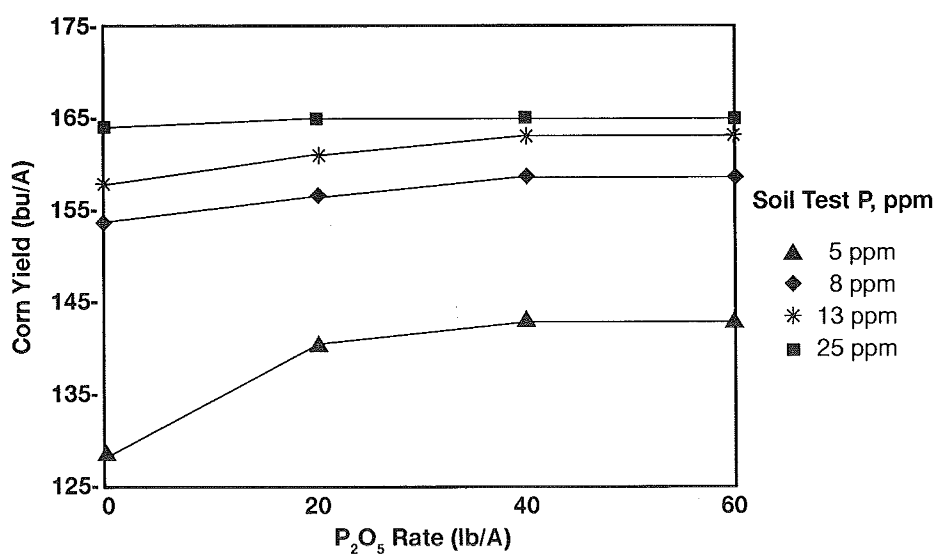


Figure 1. Influence of soil test and banded P fertilizer on corn yield, Beresford, SD, 1994.

Comparison of low rate of fertilizer vs. none and a normal fertilizer program

Crop response to fertilizer programs providing very small amounts of primary nutrients is usually insignificant as published in the Compendium of Research Reports on Use of Non-Traditional Materials for Crop Production. Within the compendium, 22 different research reports were included from 8 states, representing 66 different site years. Occasionally, there is a report of a significant yield increase due to low rates of banded phosphate, as in Table 6. Although application of about 2 gallon/A of 9-18-9 increased wheat yields by 16.1 bu/A over the check, addition of 16 gallon/A increased yields 26.7 bu/A over the check.

Compared to a normal fertilizer program, low rate fertilizer programs often produced lower yields. In a three year Wisconsin program, 300 lb/A of an earth-like substance produced a mean of 58 bu/A compared to 104 bu/A with a standard fertilizer program. In a Kansas study, a low rate of liquid fertilizer produced 66 bu/A of sorghum. However, in this study, the 0 fertilizer treatment produced 68 bu/A and the 80 lb nitrogen treatment produced a significantly higher 74 bu/A.

Table 6. Effect of low and high rates of 9-18-9 on wheat yield. Whitney and Lamond, 1986. Kansas.

Treatment	Yield, bu/A
Check	11.4
2 gal./A 9-18-9	27.5
16 gal./A 9-18-9	38.1

In North Dakota, 3 gallon/A of 9-18-9 produced 13 bu/A wheat while a standard fertilizer program produced 26 bu/A. In Minnesota, a fortified fish and seaweed 8-4-4 liquid fertilizer foliar treatment produced 104 bu/A corn. However, the 0 fertilizer treatment yielded 101 bu/A and the standard fertilizer treatment produced a significantly higher 119 bu/A.

In South Dakota, 200 lb/A/yr of an organic blend 6-2-1 produced a a four year mean yield of 47 bu/A oats and 78 bu/A corn. However, a standard fertilizer program produced 62 bu/A oats and 92 bu/A corn.

These studies and others show that serious losses may be realized when standard fertilizer practices are ignored and a low rate fertilizer program adopted that supplies insufficient nutrients, especially nitrogen.

Foliar fertilization is used to apply small amounts of zinc or other micronutrients to sensitive crops with deficiencies. However, foliar fertilization of small amounts of N, P or K has been unsuccessful in consistantly increasing yields. When these nutrients are deficient, larger amounts are needed by plants than supplied through low rate foliar applications.

Salt index comparison

A frequent claim is that clear liquid fertilizers such as most 9-18-9 materials contain less salt and therefore cause less seed injury when placed with the seed. However, these fertilizers have also been shown to reduce germination when placed with the seed (Table 7). There may be less salt since the source of potassium is potassium hydroxide rather than potassium chloride. However, the urea used as the N source can result in ammonia injury, which is more detrimental than the salt injury.

Regardless of the origin of fertilizer salts, all salts may have a detrimental effect on germination when applied with the seed. There is no absolutely safe amount of salt that can be applied to seed of sensitive crops such as dry bean, soybean and other legumes.

Table 7. Influence of seed placed liquid fertilizer on soybean stands, 2 site average, Brookings, SD. Gelderman, et al., 1995.

Rate of P_2O_5 applied to 30 inch rows	Liquid Fertilizer Grade		
	10-34-0	7-21-7	9-18-9
lb/A	----------- % stand -----------		
0	100	100	100
12.5	92	94	34
25	80	59	9
50	47	26	2

Know how to determine the best fertilizer buy

Fertilizers are a source of plant nutrients. The decision to buy a particular fertilizer should be based on practical handling considerations, personal preference and the cost per unit of plant nutrient. By comparing the cost per unit of nutrient of a "special" low analysis fertilizer with the cost per unit of plant food of a standard high analysis fertilizer source, the economics of low analysis fertilizer use can be better judged.

Comparison example:

Basic fertilizers	$/ton	cents/lb nutrient
Urea (46-0-0)	250	27.2
Triple-super-phosphate (0-46-0)	230	25.0
Potash (0-0-60)	150	12.5

10 gallon of 9-18-9/A at $545/ton ($3/gallon), density of 11 lb/gallon
(10 gal. X 11 lb/gal. X $545/ton)/2000lb/ton = **$30.00/A**

These same amounts of plant nutrients if purchased as standard materials would cost:

N	9.9 lb	X	$0.272/lb N	=	$2.69/A
P_2O_5	19.8 lb	X	$0.25/lb P_2O_5	=	4.95
K_2O	9.9 lb	X	$0.125/lb K_2O	=	1.24

Total comparison with a blend = **$8.88/A**

Comparisons such as these costs of nutrient sources are a natural part of the producers' decision making process when deciding which fertilizer to use. They show that "special" fertilizers are much more costly than conventional materials for equal rate of nutrients.

Summary

There may be a need to supply significant amounts of plant nutrients if soil levels are not adequate. If soil test levels are high, there is no need for any fertilizer. If soil levels are low, low rates of nutrients will not be sufficient to supply the gap between crop need and supply. Continued use of low rates of fertilizer nutrients can deplete the soil nutrient reserves. Depletion of soil reserves may contribute to long-term yield reduction. Decisions to use one fertilizer over another should be based on solid agronomic and economic decisions.

References

Blamey, F.P.C., D.G. Edwards and C.J. Asher. 1987. Nutritional disorders of sunflower. Dep. of Ag., Univ. of Queensland. St. Lucia, Queensland, Australia. pg. 5.

Frank, C.L. ed. 1995. Illinois Agronomy Handbook. Univ. of IL, College of Agric., Coop. Ext. Serv. Circ. 1333, pg 94.

Gelderman, R. and J. Gerwing. 1994. Long-term residual phosphorus study. PR 94-27. IN: Tech. Bull. 99. Soil/Water Research, 1994 Annual Report. Plant Sci. Dept. South Dakota State Univ., Brookings, SD.

Gelderman, R. and J. Gerwing. 1995. The influence of seed-placed fertilizer on corn and soybean emergence and yield. PR 95-18. IN: Tech. Bull. 99. Soil/Water Research, 1995 Annual Report. Plant Sci. Dept. South Dakota State University, Brookings, SD.

Grant, C.A. and L.D. Bailey. 1993. Fertility management in canola production. Can. J. Soil Sci. 73:651-670.

Mengel, K. and E.A. Kirby. 1987. Principles of Plant Nutrition. International Potash Institute. Worblaufen-Bern, Switzerland. pp. 306.

NCR-103 Committee. 1986. Compendium of Research Reports on Use of Non-Traditional Materials for Crop Production. Iowa St. Univ., Ames, IA.

Ritchie, K.B., R.G. Hoeft, E.D. Nafziger, W.L. Banwart, L.C. Gonzini, and J.J. Warren. 1996. Nitrogen Management and starter fertilizers for no-till corn. pp. 55-66. IN: 1996 Illinois Fertilizer Conference Proceedings. R.G. Hoeft, ed. Jan. 29-31, 1996. Peoria, IL. Dep. Crop Sci., Coop. Ext. Serv. Univ. of IL and Illinois Fert. and Chem. Assoc.

Whitney, D.A. and R.E. Lamond. 1986. Effect of phosphorus rate, source and method of application for wheat. pp. 9-10. IN: Kansas Fertilizer Research. Ag. Exp. Sta. Report of Progress 509. Kansas State University. Manhattan, KS.