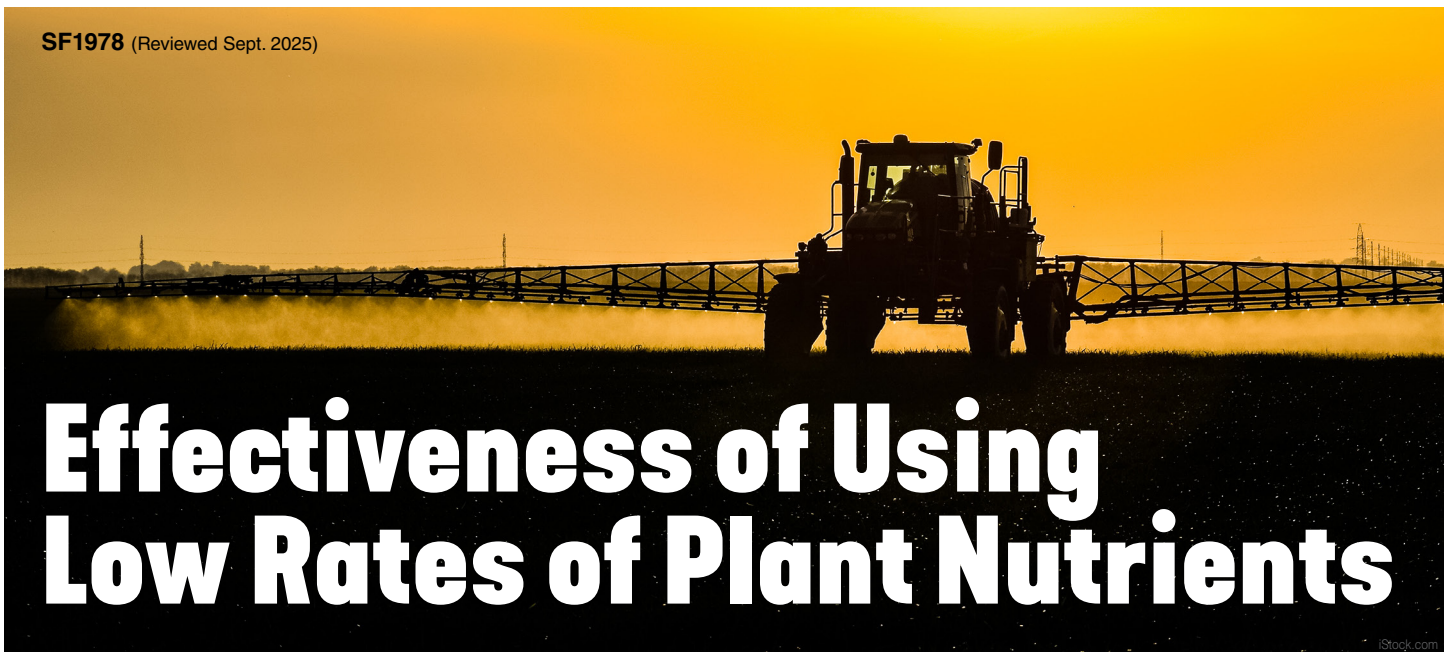


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# Effectiveness of Using Low Rates of Plant Nutrients

U.S. Department of Agriculture-North Central Extension  
and Research Activity-103 Committee on Nonconventional  
Amendments and Additives

## NCERA-103 Committee, 2025

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**“Low rates”** refer to supplemental crop nutrients added at rates much less than crop removal or much less than rates recommended by land-grant university soil fertility specialists. Low rates of crop nutrients are sometimes applied through the use of fertilizers with a low nutrient analysis (1-1-1), by application of low rates of higher analysis fertilizers (9-18-9) or placement and timing of low rates of fertilizers.

Also, nontraditional products may promote low total plant mineral nutrient rates through the application of low-analysis products or low rates of higher-analysis products, with or without alternative additives to replace or enhance fertilizer nutrients. In each case, producers should consider the potential for optimal crop response (yield or other desired outcome) based on university research conducted in similar soils or geographic regions.

Some farmers may choose to use low rates of fertilizer to reduce input costs. When soil nutrients are above critical levels, nutrient additions are generally not recommended or are recommended at lower than crop removal rates. However, if soil test levels are below critical levels, rates more than crop removal often are recommended, particularly for broadcast fertilizer application.

Decisions on rate reductions need to be considered in relation to potential yield response and application methods, which may enhance response, compared with traditional broadcasting. Foliar fertilizer or fertilizer applied with the seed is generally also applied at low rates due to constraints related to plant tissue “burn,” seed germination and seedling safety. Although low rates of nutrients may be appropriate to apply at certain times, careful consideration should be made of all factors influencing short-term and long-term crop yield, maintenance of soil tests and potential environmental impacts.

Fourteen essential mineral nutrients are required for growth and forage/grain yield of most crops. The approximate mineral contents, with the exception of nickel (Ni), of crop components commonly grown in the North Central Region are listed in Table 1. Clearly, crop harvest can remove considerable nutrients from fields. However, not all nutrients should or need to be replaced.

# NDSU

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The reason for fertilization is for the farmer to be profitable in the current season and to position the soil for continued profitability and productivity into the future. This is important because many nutrients are supplied at adequate levels naturally from the soil and are removed at such low rates that fertilization isn't needed.

Several examples are micronutrients, particularly calcium (Ca) and (Mg), which are replaced with liming low-pH soils. In other cases, nutrient removal is so large that fertilization is required in the long term to maintain the soil nutrient resource. Prime examples are phosphorus (P) and potassium (K). For some nutrients, the soil supply of the crop-available form is so low that deficiency always occurs and needs fertilization for optimal supply, typically a specific crop-nutrient interaction with certain micronutrients.

**Table 1. Approximate concentrations of mineral elements in crops grown in the North Central Region at harvest. Considerable variation occurs in a crop in elemental concentration.**

Crop, crop part, % moisture	Concentration of nutrients in crops and crop components at harvest												
	N <sup>†</sup> %	P <sub>2</sub> O <sub>5</sub> %	K <sub>2</sub> O %	S %	Ca %	Mg %	Cl %	B ppm	Cu ppm	Fe ppm	Mn ppm	Zn ppm	Mo ppm
Alfalfa hay	2.25	0.5	2.25	0.2	1.4	0.27	0.3	75	75	100	55	54	0.11
Barley, grain	1.8	0.8	0.5	0.15	0.05	0.10	0.15	21	16	80	16	32	0.25
straw	0.75	0.25	1.50	0.20	0.40	0.10	0.25	25	50	25	16	25	0.12
Canola seed	3.1	0.5	1.0	0.45	0.23	0.16	0.03	75	25	50	20	25	0.75
straw	1.8	0.3	2.0	0.9	0.6	0.10	0.03	25	30	50	20	10	0.1
Chickpeas	3.4	0.35	2.0	0.25	0.10	0.11	0.02	30	35	70	35	35	0.50
Corn grain, 15%	1.5	0.57	0.39	0.11	0.04	0.01	0.03	70	25	36	24	18	0.09
stover 15%	1.0	0.24	1.2	0.10	0.45	0.30	0.08	22	75	14	75	20	0.30
Corn silage, 65%	1.8	0.18	1.0	0.2	0.23	0.22	0.04	30	50	25	25	25	0.25
Dry beans	4.0	0.07	2.1	0.8	0.12	0.20		50	20	20	14	16	0.75
Field pea grain	3.8	0.30	1.0	0.40	0.25	0.10	0.05	70	15	50	10	30	0.80
straw	1.2	0.08	1.3	0.15	0.15	0.10		37	23	30	8	15	0.30
Flax grain	3.2	0.6	1.0	0.35	0.25	0.45		16	12	50	30	40	
straw	1.2	0.30	0.60	0.15	0.3	0.2		30	36		42	12	
Lentil grain	4.0	0.40	1.0	0.30	0.10	0.10		10	10	85	15	45	0.1
straw	1.4	0.1	0.55	0.30	0.10	0.04		5	15	95	20	45	0.05
Oat grain	1.8	0.40	0.60	0.15	0.10	0.10	0.03	20	46	70	50	45	0.40
straw	0.65	0.23	2.1	0.23	0.30	0.15		25	50				0.10
Potato tubers	0.43	0.13	0.56	0.03	0.015	0.03		12	20	28		15	
vines	2.2	0.60	2.2	0.22	0.18	0.10		28	8	55	43	28	
Rye, cereal	2.4	0.70	0.30	0.15	0.05	1.5	0.05	15	4	40	30	40	0.05
Sorghum grain	1.6	0.80	0.50	0.30	0.02	0.06			6	32		28	
stover	1.4	0.3	1.5	0.17						33		66	
Soybean 13%	5.6	1.1	2.0	0.30	0.27	0.19	0.02	28	8	80	22	50	0.16
straw 10%	1.3	0.17	2.6	0.10	0.10	0.05	0.10	33	10	80	20	10	0.3
Sugarbeet roots	0.26	0.03	0.01	0.06	0.04	0.04	0.008	3	1.1	80	13	13	0.13
Beet tops	1.7	0.10	1.6	0.06	0.16	0.09	0.02	25	0.60	80	20	12	0.5
Sunflowers	5.0	1.0	2.0	0.15	0.20	0.30		10	20	30	30	35	
Sunflower stover	0.5	0.22	2.0	0.25	0.30	0.13		50	5.0	10	5	28	
Wheat grain 12%	2.2	0.80	0.44	0.12	0.06	0.13	0.03	5.5	2.8	80	50	33	0.8
straw 10%	0.44	0.20	1.2	0.06	0.04	0.14	0.14	11	3	80	14	20	0.11

<sup>†</sup>N—nitrogen; P<sub>2</sub>O<sub>5</sub>—phosphate; K<sub>2</sub>O—potash; S—sulfur; Ca—calcium; Mg—magnesium; Cl—chloride; B—Boron; Cu—copper; Fe—iron; Mn—manganese; Zn—zinc; Mo—molybdenum. Blanks indicate no data available.

# Use of Low Rates of Plant Nutrients as In-furrow or Near-furrow Starter Fertilizers at Planting

## Corn

Generally, the positive response of phosphorus (P)-based starter fertilizer in North Central Region research is least in the south and increases the further north that the trials were conducted. For example, the average corn yield increase in southern Illinois was from 5 to 10 bushels/acre (bu/a) in about 25% of studies. In central Illinois, the yield increase tended to range from 10 to 15 bu/a about 50% of the time, and in northern Illinois, the yield increase tended to be about 20 bu/a about 75% of the time (Ritchie et al., 1993).

Wisconsin starter P research on 11 sites showed an average of 4 bu/a corn yield increase with starter P, with similar results in seed-placed treatments, compared with 2 inches to the side and 2 inches below the side treatments (2X2). The research showed a tendency for central Wisconsin sites to be more responsive, compared with southern Wisconsin sites (Lauer, 2019).

In Indiana (Camberato et al., 2016), a 2X2 starter P study with six sites having optimum P soil test values (27 to 34 parts per million [ppm] Bray P1) from northern Indiana to southern Indiana showed yield increases at one northern site due to pop-up starter P. Additional yield increase was experienced at this site and one southern site with application of ammonium polyphosphate and 50 pounds of nitrogen (N)/acre in a 2X2 inch band at planting. Both responsive sites were under no-till production.

In a series of P and sulfur (S) starter experiments from four southern Minnesota sites, one in four sites had a yield increase from P starter (Kim et al., 2013). In Minnesota experiments on no-till corn, seed-placed starter P was effective in increasing yields, with the greatest benefit on continuous corn and in a planting system without row cleaners and planting directly into residue (Vetsch and Randall, 2000).

In Iowa, a summary of 31 field trials of broadcast P (100 to 150 pounds/acre  $P_2O_5$ ), compared with 5 to 25 pounds of  $P_2O_5$  per acre as a seed-placed or 2X2 placed starter P alone and starter P plus broadcast P found corn yield increases of about 7% with starter alone, yield increases of about 14% from broadcast P alone and about 15% from broadcast plus starter P on sites where the soil test P was less than 16 ppm Bray P1 (low soil test category) (Mallarino, 2009). At the optimal soil test range (16 to 20 ppm Bray P1), the corn yield increase from starter alone was 7%, while the yield increase from broadcast or broadcast plus starter P was about 8%.

At sites in the high soil test range (21 to 30 ppm Bray P1), the corn yield increases from starter alone and broadcast plus starter P was about 5%, while the corn yield increase from broadcast alone was about 6%. For sites greater than 30 ppm Bray P1, the corn yield increase was about 1% from starter alone, 2% for broadcast alone and 4% for broadcast plus starter P. An additional Iowa study on eight no-till sites showed that yield increase when soil test P was adequate was more likely

due to the additional N applied near the seed at planting than from the P component of the starter fertilizer.

Although the economics of broadcast rates of P compared with starter rates of P may play a financial role in a grower decision to reduce or eliminate broadcast P in hard economic times when the soil test P is in the high soil test range, P removal by the crop eventually will result in a reduction of soil test P values and a decrease in future yield potential. However, Illinois research on two fields subjected to a long period of buildup P fertilizer application followed by no P application showed that the decrease in soil test P was less than what would be predicted by the buildup P rate vs. soil test P change relationship (Franzen, 1993).

Therefore, a starter P application used occasionally instead of a greater rate of broadcast P would not be expected to reduce soil test P a great deal, and expected yield in the year of starter-only application would probably be similar to that which would have been achieved using a broadcast P rate four to six times as great if the soil test P was optimum or greater.

A Kansas study evaluated starter P fertilizer applied as 2x2 band and 2x0 surface band on corn, either alone or in combination with higher rates of broadcast or deep-band with the strip-till. Results during a period of 10 years showed increased yields with starter fertilizers, with greater yield increase in high-yield environments with greater P crop removal through time. Starter fertilizers applied in combination with broadcast or deep-band were superior to broadcast or deep-band P alone (Preston et al.).

In North Dakota, at the northernmost starter P trial for corn recorded in the North Central Region near Carrington, the greatest response to starter P in the region was recorded. Yield increases over the check due to 6 to 8 gallons/acre of 10-34-0 in-furrow were about 50 bu/a (Hendrickson, 2007) in soil with low soil test P.

Overall, starter P application for corn is more likely to increase yield in northern geographies and in soils with lower soil test P. In states where a low likelihood of crop failure is present (the central U.S. Corn Belt or under irrigation), and research supports a maintenance fertilization strategy, starter P use is recommended less, and greater broadcast P rates usually result in greater yield.

The use of starter P rates alone results in reduced soil test P values, which limit yield potential. In northern states, particularly North Dakota, starter P application is always advised for corn, and economic returns would be realized in all but the warmest of spring planting seasons.

Starter potassium (K) application has also been explored in the region, particularly in Iowa. In general, starter K application can increase yield in low-testing soils, but greater rates of broadcast K are usually recommended so that the soil tests will build to optimal values. In no-till studies, deep-banded K has been superior to starter K in increasing yield (Mallarino).

## Soybean

Soybean usually is not responsive to low rates of plant nutrients at seeding. Studies in North Dakota show that seed-placed fertilizer can reduce yield substantially. Low-salt fertilizers have similar safety restrictions as 10-34-0-based fertilizers due to the N in low-salt formulations consisting of either UAN (urea, ammonium nitrate solutions) or urea additions for their N component.

**Table 2. Soybean yield with starter fertilizer application, Carrington, N.D., 2008. Means of treatments using 10-34-0-based and low-salt starter fertilizers.** [Endres and Hendrickson, 2008]

Application Method	Stand, 1,000 plants/acre	Yield bu/acre
Check	188	32.8 a
2X2, 4 gal/acre	189	33.5 a
In-furrow, 4 gal/acre	133	24.5 b
In-furrow, 8 gal/acre	121	18.9 c
LSD 5%	17	4.3

## Wheat

### Spring Wheat

Many trials using a low rate of starter P in spring wheat have been conducted during the past several decades. Rates of P applied as a seed-placed starter fertilizer usually range from 20 to 40 pounds of  $P_2O_5$ /acre. In one of the more recent trials (Goos and Johnson, 2001), the application of 26 pounds of  $P_2O_5$ /acre with the seed at planting resulted in an average 15% yield increase over the untreated check at eight sites, ranging in soil test P values from low to high categories.

A study in northwestern Minnesota across three years investigated starter P compared with broadcast P at the same rate. The results showed that wheat yields were similar whether the P was broadcast or banded. This is in contrast to previous work in Manitoba.

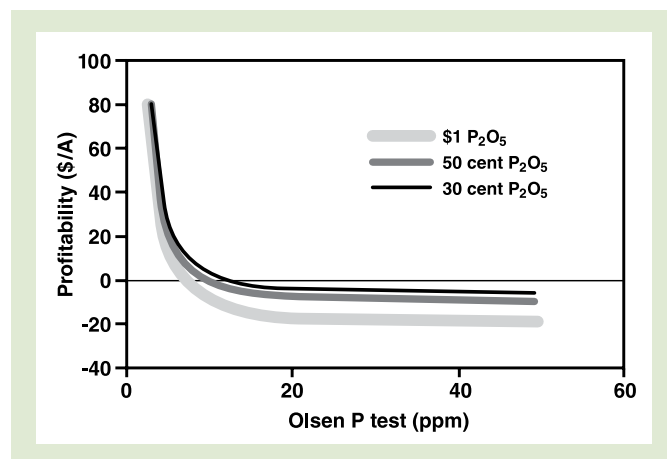
**Table 3. Comparison of spring wheat yield with P broadcast and applied with the seed.** [from Rehm et al., 2003]

Method of Application	Year of study		
	1*	2	3
Check (0 P)	42.0 a	58.9 a	46.5 a
Broadcast	44.8 b	67.8 b	51.2 b
With seed	46.1 b	67.9 b	53.1 b

\*Rate of  $P_2O_5$  year 1 was 52 lb/acre. Years 2 and 3, the rate was 26 lb/acre.

The use of P on spring wheat is an economic decision in the northern Plains of the North Central Region. The cost of P fertilizer and price of wheat may enter into decisions on what rate of P to apply.

Halvorson developed a relationship between spring wheat yield and P rate and used it to produce an economic analysis to help growers determine the profitability of the use of greater than minimal rates of P as a starter. The greater the P cost, the lower the soil test value needed to support higher yields to offset the costs (Figure 1).



**Figure 1. Profitability of application of more than minimal P as a starter with cost of P and a spring wheat price of \$6/bushel.** [From Halvorson, 1986]

### Winter Wheat

In contrast to spring wheat, yield increase from P fertilizer tends to be similar in winter wheat, whether the application was broadcast at seeding or banded when the P soil test is at least in the medium range (Halvorson et al., 1992; Karamanos et al., 2003). When the P soil test is low, banded P with ammonium-N, similar to that applied when the P source is MAP (11-52-0) or DAP (18-46-0), or a liquid starter such as 10-34-0, was superior to a broadcast P application, the same rate in Kansas (IPNI, 1999).

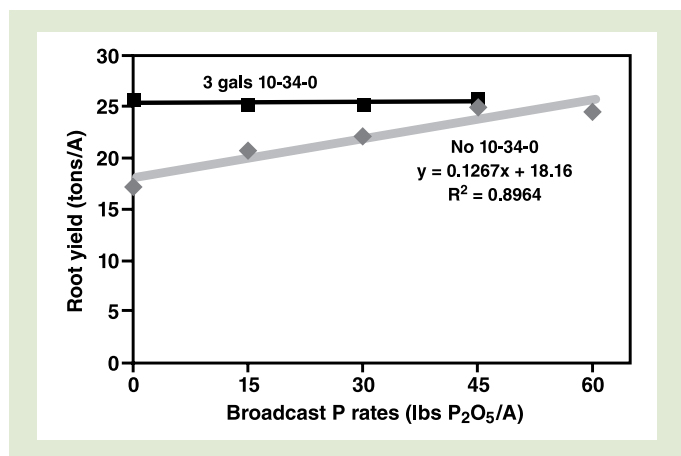
Whether the P fertilizer was banded or broadcast, in most studies, the rate of similar P responses was the same regardless of placement, so low rates of seed-banded or near-seed-banded P were not more effective at increasing yield than the recommended rates of band or broadcast P. However, in late-planted wheat, banded P consistently shows a good yield response even when the soil test P is optimum due to limited fall tillering with a late planting date.



# Use of Low Rates of Starter Fertilizer at Seeding in Other Crops in the North Central Region

## Sugarbeets

Historically, P was applied to sugarbeets at relatively high rates, compared with other crops in the North Dakota/Minnesota region. Broadcast P rates of more than 100 pounds of  $P_2O_5$  per acre were common, given that most soil tests for P in the region were in the low to medium categories. However, studies in northwestern Minnesota found that a 3 gallons/acre rate of 10-34-0 with the seed at planting resulted in similar root and sugar yield, compared with a much larger rate of broadcast P (Figure 2) (Sims and Smith, 2003).



**Figure 2. Sugarbeet root yield with 3 gallons/acre 10-34-0, compared with broadcast P rates.** (Sims and Smith, 2003)

## Canola

Canola is very responsive to near-seed-placed P fertilizer and seed-placed P fertilizer, provided that seed-placed rates do not exceed rates that reduce stand. In a Manitoba study (Bailey and Grant, 1990), a starter P rate of 28 pounds/acre of  $P_2O_5$  produced as great of a canola yield increase as broadcasting 69 pounds/acre of  $P_2O_5$ .

## Value of Foliar Fertilizer Application on Crops in the North Central Region

In spring wheat, when protein premiums from buyers are expected to be high, some growers apply an early post-anthesis application of UAN or liquid urea fertilizer broadcast at a rate of 30 pounds of N/acre. Some slow-release N products have entered this market with claims of much greater N efficiency compared with UAN or urea.

Experiments in North Dakota found that these products were no more efficient at increasing protein than UAN or urea (Franzen, 2019). If used at the same rate of N as UAN or urea, their effect was equivalent, but reduced rates resulted in reduced effects.

In soybean, several experiments have researched foliar fertilizer application mid to late season. In Iowa, application of foliar fertilizer to soybean at 27 sites having optimum or greater levels of soil test P and K at V5 resulted in two small yield increases and four small yield decreases not related to leaf burning (Haq and Mallarino, 2000).

Further study on 18 sites, with treatments including S, Fe, B and Zn, resulted in a similarly low positive response rate (Mallarino et al., 2001). A review of foliar fertilization (Fageria et al., 2009) states that foliar fertilization usually affects plants temporarily, while soil-applied fertilization supplies the plant the entire season. They also observe that foliar fertilization might be best used to supply micronutrients when a soil application may not be effective.

An analysis was made of 207 environments that evaluated N application to soybean in the U.S. (Mourtzinis, 2018). Environment had a much larger effect on soybean yield than N rate or timing.

Overall, a single N application yielded about 0.9 bu/a more than the 0 N check, while a split N application yielded about 1.8 bu/a more than the check. Yield increases due to N application for soybean were generally small and have been difficult to justify economically.

## Conclusions

Fertilizer rates recommended and published by Cooperative Extension Services in the North Central Region are the product of many, sometimes hundreds, of fertilizer rate studies in each state. In specific crops and in specific circumstances, short-term profitability improvement might be possible by applying fertilizer rates less than those recommended.

Crops that respond very profitably to low rates of P fertilizers in a seed-placed or near-seed-placed band at planting are sugarbeets, canola, spring wheat and barley. Corn is very responsive in some years to low rates of P fertilizer with or near the seed at planting, particularly in North Dakota and more northern states in the North Central Region. In other states, the response of corn to lower P fertilizer rates is less frequent and of smaller magnitude.

Although low rates of banded fertilizers may improve crop profitability in the short term in some circumstances, continued use of lower rates of fertilizer compared with crop removal will decrease the amount of available nutrients to crops and may result in chronic yield decreases that affect future production and long-term profitability.

Using low rates of fertilizer to try to achieve greater nutrient use efficiency has not been effective in consistently increasing yields, crop quality and profitability in the region. Foliar fertilization of macronutrients in the North Central Region is not an effective or efficient application method to supply these nutrients to our crops.

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