Phosphorus Fertilizer for Corn; How Should it be Applied?

Armand Bauer and J. C. Zubriski

Soil phosphorus deficiency is known to limit yield of small grain crops (4), alfalfa (10), potatoes (8), and corn (1, 3, 9) in North Dakota as evidenced from yield responses that have been obtained from application of phosphorus fertilizers on many soils throughout the state.

Selecting the most suitable method of applying fertilizer to correct soil phosphorus deficiency varies with, but is not limited to, crop characteristics such as total need, rooting habit, and growth stage when maximum uptake occurs, and with economic factors such as purchasing power and consideration of return on the investment. Investigations with small grains by Norum and Young (7), for example, showed that phosphorus fertilizer applied in the row with the seed at low rates produced as high yields as double or more those rates broadcast. Placing enough phosphorus fertilizer close to the small grain seed is important because these plants take up most needed phosphorus in early stages of growth.

Methods of applying phosphate fertilizers to corn in North Dakota have been investigated for several years. These studies show that a combination of band plus broadcast application of phosphorus produced larger yield increases than the broadcast treatment at four sites. At four other sites yield increases from the combination band plus broadcast were similar to those obtained from the broadcast treatment alone. At the sites where the combination of band plus broadcast application was superior, the yield increase from band plus broadcast over broadcast alone ranged from six to 11 bushels an acre.

Dr. Bauer is associate professor and Dr. Zubriski is professor, Department of Soils.

METHODS

The cooperator, county, year, soil type and phosphorus soil test rating of the experimental sites are presented in Table 1.

The broadcast fertilizer was applied in the spring and plowed down or worked into the soil with a disk or field cultivator. The fertilizer at planting was applied with a split-boot type of attachment in 1955, 1956 and 1957 trials, while in 1966 it was placed two inches to the side and two inches below the seed.

Plant population among trials varied from 13,500 to 18,000 plants per acre. Chemical weed control was used only in the 1966 trials.

RESULTS

The phosphorus application rates by the methods tested and resulting yields are shown in Table 2.

Corn grain yield was increased by fertilizer in seven of 13 trials conducted in 1955, 1956 and 1957. The increases ranged from 9.9 to 23.6 bushels an acre. The three 1966 trials did not include a treatment without fertilizer (0+0+0) because of the nature of the objective of the experiment (2); but in view of the high yields obtained, it appears likely that fertilizers contributed to the outcome.

Corn grain yield was increased by banded phosphorus superimposed over phosphorus broadcast at rates of 26 or more pounds of P (60 pounds

Table 1. Cooperator, county, year, soil type and phosphorus soil test rating of experimental sites.

Cooperator	County	Year	Soil Type	Phosphorus soil test rating[1]
H. Goerger	Richland	1955	Overly silt loam	Very low
Woodbeck	Ransom	1955	Lovell sandy loam	Very low
Holen	LaMoure	1955	Barnes-Aastad loam	Very low
Jordheim	Richland	1955	Ulen fine sandy loam	Very low
Morehead	Dickey	1955	Barnes loam	Very low-low
Heuer	Cass	1956	Gardena fine sandy loam	Very low
Anderson	Richland	1956	Hecla-Letcher loamy fine sand	Very low
Melland	Ransom	1956	Fairdale sandy loam	Very low
Young	LaMoure	1956	Barnes loam	Very low
Hokana	Dickey	1956	Barnes clay loam	Very low
Casselton	Cass	1957	Bearden silty clay loam	Very low
Baumgarten	Cass	1957	Fargo clay	Low-medium
R. Kummer	Richland	1966	Hecla loamy sand	medium
Ista	Richland	1966	Hamar loamy fine sand	Low-medium
Haverland	Richland	1966	Hamar fine sandy loam	Very low

[1] Sample from 0 to 6-inch depth. Based on standards used at NDSU Soil Testing Laboratory.

Table 2. Effect of fertilizer treatment on yield of corn grain.

Cooperator	Fertilizer Treatment: Band	Fertilizer Treatment: Broadcast	Yield, bu/acre	LSD[2]
H. Goerger	0+0+0[1]	0+0+0	74.7	7.8
	0+0+0	40+17.6+33	82.2	
	10+17.6+0	40+17.6+33	89.0	
Woodbeck	0+0+0	0+0+0	63.4	9.3
	0+0+0	40+17.6+33	75.5	
	10+17.6+0	40+17.6+33	68.4	
Holen	0+0+0	0+0+0	61.5	8.6
	0+0+0	40+17.6+33	71.4	
	10+17.6+0	40+17.6+33	65.6	
Jordheim	0+0+0	0+0+0	28.7	4.1
	0+0+0	40+17.6+33	44.0	
	10+17.6+0	40+17.6+33	52.3	
Morehead	0+0+0	0+0+0	39.7	N.S.[3]
	0+0+0	40+17.6+0	40.2	
	10+17.6+0	40+17.6+0	38.4	
Heuer	0+0+0	0+0+0	44.1	4.3
	0+0+0	60+26+50	58.5	
	10+17.6+0	60+26+50	64.5	
Anderson	0+0+0	0+0+0	54.8	N.S.
	0+0+0	60+26+50	59.8	
	10+17.6+0	60+26+50	64.2	
Melland	0+0+0	0+0+0	56.1	3.7
	0+0+0	60+26+50	70.6	
	10+17.6+0	60+26+50	77.6	
Young	0+0+0	0+0+0	47.9	N.S.
	0+0+0	60+26+50	44.7	
	10+17.6+0	60+26+50	49.0	
Hokana	0+0+0	0+0+0	47.5	N.S.
	0+0+0	60+26+50	37.6	
	10+17.6+0	60+26+50	41.1	
Weiser Bros.	0+0+0	0+0+0	43.4	N.S.
	0+0+0	60+26+0	45.5	
	0+17.6+0	60+26+0	41.2	
Casselton Seed Farm	0+0+0	0+0+0	78.0	N.S.
	0+0+0	60+26+0	84.8	
	0+17.6+0	60+26+0	80.6	
Baumgarten	0+0+0	0+0+0	64.1	8.1
	0+0+0	60+26+0	73.5	
	0+17.6+0	60+26+0	78.6	
R. Kummer	10+0+17.6	160+70+66	131.0	Less than 7.0
	10+4.4+17.6	160+70+66	131.6	
	10+8.8+17.6	160+70+66	142.3	
Ista	10+0+17.6	70+31+29	131.5	N.S.
	10+4.4+17.6	70+31+29	128.6	
	10+8.8+17.6	70+31+29	129.8	
Haverland	10+0+17.6	80+35+33	136.9	N.S.
	10+4.4+17.6	80+35+33	137.8	
	10+8.8+17.6	80+35+33	135.5	

[1] Refers to pounds per acre of total nitrogen (N) + available phosphorus (P) + soluble potassium (K). To convert from P to P_2O_5 multiply by 2.3; to convert from K to K_2O multiply by 1.2.

[2] Least significant difference. Yield difference must be as large or larger than number indicated to be significant at the 5% confidence level.

[3] Yield differences are not significant.

P_2O_5) per acre in three trials (Heuer, Melland and Kummer), and by banded phosphorus plus 10 pounds nitrogen superimposed over phosphorus broadcast at a rate of 17.6 pounds P (40 pounds P_2O_5) per acre in one trial (Jordheim). Of these, three were on soils testing "very low" in phosphorus and the other "medium". In all four cases the soil was coarse to moderately-coarse textured (loamy sand or sandy loam). Yield increases from the combination band plus broadcast treatment were no larger (based on statistical analysis) than from the broadcast treatment in four trials (Goerger, Woodbeck, Holen, Baumgarten). Of these, three tested "very low" in phosphorus and the other "low-medium". Soil textures included one moderately coarse, two medium (loam, silt loam), and one fine (clay).

Yields were not increased by fertilizer in six trials conducted in 1955, 1956, 1957 (based on statistical analysis).

DISCUSSION

Compared to wheat, corn takes up most of its phosphorus later in the season. Whereas wheat takes up about 60 per cent of its phosphorus within 40 days after emergence (5), corn takes up only about 10 to 15 per cent during the same time interval (6). Corn requires about 80 days after emergence to take up 70 to 75 per cent of its phosphorus (6) (based on a 120-day uptake period after emergence). Further, uptake of phosphorus by corn continues through the entire growing season, while with wheat, uptake may cease or phosphorus may even move from plant to soil after heading (5).

Because of the relatively later growth stage at which most phosphorus is taken up by corn as compared to wheat and because of the greater length of time over which uptake occurs in corn, fertilizer phosphorus for corn may best be applied as a combination of band plus broadcast; the largest portion broadcast and plowed down and the remainder banded at planting. Banded phosphorus placed near the emerging corn seedling usually will stimulate early growth (1, 9) as well as provide for yield responses. However, restricting phosphorus application to corn to a band placement at planting may not be satisfactory because the phosphorus may become "positionally" unavailable at critical demand periods, especially if the soil at the depth at which the banded fertilizer was placed becomes dry enough to inhibit root activity. Broadcast and plowed-down phosphorus is placed deeper into the soil and is less likely to become "positionally" unavailable. Thus the deeper placed phosphorus can provide for plant needs during the high demand period. Restricting phosphorus fertilizer application to a broadcast plowdown treatment may not stimulate early growth or rapidly advance the vegetative growth stage.

Rapid early growth, in a growing season already relatively short in North Dakota, can be expected to make a difference in moisture content of corn grain at harvest, especially in years of earlier than average killing frost. Further benefits from rapid early growth may accrue from earlier ground coverage that helps reduce water loss by evaporation and shades out weeds, possible earlier cultivation to control weeds, and better competition for light, nutrients and water.

Because it slows down planting operations, some farmers prefer to eliminate a band application and restrict phosphorus application to broadcasting. Whether such a practice will provide for maximum response may well depend upon fertilizer phosphorus application rate in relation to the degree of soil phosphorus deficiency and to the distribution of the fertilizer phosphorus in the seedbed. It is suggested that greater amounts of fertilizer phosphorus may need to be applied to achieve maximum response if application is restricted to broadcasting than if the combination band plus broadcast method is used. However, advantages gained from speed-up of the planting operation may offset cost of the additional phosphorus fertilizer and/or lower yield responses.

How much fertilizer phosphorus to apply will depend upon the soil phosphorus test level. The more phosphorus deficient the soil, the more supplemental phosphorus it needs.

When the combination of band plus broadcast is used, the minimum amount of phosphorus to band should perhaps be no less than 8.8 pounds P per acre (20 pounds P_2O_5). This is suggested by the outcome of the 1966 Kummer trial.

SUMMARY

Banded phosphorus fertilizer superimposed over broadcast phosphorus increased corn grain yield over a broadcast treatment alone in 50 per cent of the responding trials. Yield increases were 6 to 11 bushels per acre.

Yield increases from the banded phosphorus superimposed over the broadcast phosphorus ocurred on "medium" as well as "very low" testing soils of coarse to moderately-coarse texture.

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Barley Aging, Disease and Protein

Evan H. Pepper

High-protein barley can cause serious processing problems for the maltster and the brewer, and it may be discounted heavily on the grain market. High protein levels are caused by certain cultural practices, high fertility levels, temperature and moisture effects, time of seeding, and other factors. Barley diseases have been implicated in protein alternations but without substantial experimental evidence. Similarly, natural aging of the barley plant is known to affect the protein level of the harvested kernels. This article reports results of a study on the relationship of several common foliar diseases, natural senescence, and the nitrogen content of the barley plant in the NDSU Plant Pathology Department.

EXPERIMENTAL

Eight barley varieties and advanced breeding lines were grown in replicated field plots at Fargo. The plots were (1) inoculated with three barley foliar disease organisms, (2) treated with a fungicide, or (3) untreated (therefore exposed to natural infection). The plants were harvested at maturity and analyzed for nitrogen content. Similar analyses were made with both greenhouse grown plants and plants grown under "germ-free" conditions. Slides prepared of leaf sections from healthy, diseased, and aging barley plants show changes in leaf tissue either as a result of disease or aging.

RESULTS AND DISCUSSION

Barleys sprayed with disease organisms or exposed to natural infection had a higher nitrogen level than the plants protected with a fungicide. Other tests proved that the lower nitrogen level was caused by the absence of the disease fungi and not by the fungicide itself.

Other tests showed that the nitrogen content of infected barley leaves varied with the location of the disease organism. The yellowed portions of diseased leaves had the least amount of nitrogen. Brown leaf portions (containing the body of the pathogen) had a higher nitrogen content. The green tissue at a distance from the diseased area had an even higher nitrogen content, while the green tissue immediately adjacent to the disease site possessed the highest nitrogen level. Since the yellow leaf color indicates the destruction and loss of nitrogen-containing chlorophyll, this reduction in nitrogen is to be expected. The higher nitrogen level in the dead leaf area is probably due to the combination of barley and fungal nitrogen. The higher nitrogen level in the green tissue adjacent to the disease site suggests that the fungus causes nitrogen to move from other portions of the leaf to the area of infection.

The reduction of nitrogen in aging tissues is well known. As the plant matures, nitrogen is transported from the stems and leaves to the developing grain head. This decrease in foliar nitrogen is accompanied by an increase in yellowing — a phenomenon associated with both natural senescence and disease. Additional similarities between aging and the disease process exist at both the macroscopic and the microscopic level:

Macroscopic	Microscopic
Yellowing	Chloroplast breakdown
Death of tissue	Brown pigment produced
Flowering and fruiting	Disorganized structures
Moisture loss	Vacuoles formed
	Vascular dysfunction
	Nuclei disintegrate

Young barley leaves, infected by certain fungus pathogens, resemble aging leaves. They display all of the properties of senescent leaves, despite the difference in "age." Under the microscope it is difficult to distinguish infected young or mature leaves from uninfected senescent leaves.

Based on the results of these experiments, a new hypothesis was developed to account for the interrelations of disease, senescence, and protein levels in barley. This hypothesis states that barley foliar diseases, such as Spot Blotch, Net Blotch, and Septoria Leaf Blotch, cause infected plants to age prematurely. The presence of the pathogen causes the plant to take up more than normal amounts of nitrogen from the soil. This nitrogen accumulates at the site of fungus infection on the leaves (the "spots" of the disease). The infected plant matures at an accelerated rate, and the nitrogen is carried to the developing grain heads. The nitrogen in the developing barley kernels is transformed into protein at a higher level than found in uninfected plants.

This research helps explain the elevated protein levels found in barleys grown in some areas of North Dakota. It also explains why Dickson, a variety with resistance to certain foliar diseases, consistently shows a lower kernel protein than other disease-susceptible varieties. It further suggests that fungicidal applications may someday be recommended to enhance both yield and quality of malting barley. Present recommendations for the control of barley foliar diseases, combined with sound agronomic recommendations, will maintain barley protein at a desirable level. Finally, this study sheds new light on the disease process, and indicates some promising new areas of investigation.

Dr. Pepper formerly was assistant professor, Department of Plant Pathology.