ND-1

1984 ANNUAL REPORT

TO

PHOSPHATE-POTASH INSTITUTE

Phosphorus and Potassium Management In Western North Dakota

By

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I. Project Orientation

Two experimental designs were used in 1984. The first involved phosphorus (P) rates and placement methods for established alfalfa. The results of these trials has been summarized for the journal Fertilizer Issues, and an advance copy of this article is attached to serve as a report on this aspect of our research. The second experimental design involved potassium rates and sources for malting barley.

II. Malting Barley Experiments

A. Introduction

Potassium fertilization has been shown to increase yields of barley in around 50% of the trials conducted in Montana and North Dakota. The reason for these observed increases is not apparent. Soils in North Dakota are, in general, very high in exchangeable K. These experiments were conducted to determine if a chloride ion - root disease interaction could be the explanation. Such interactions have been observed with winter wheat and take-all root rot in other states.

B. Methods and site descriptions

Experiments were established at five locations in central and western North Dakota. All were successfully carried through to harvest. Experimental design was a six treatment randomized complete block design with six replications (five at Williston). Treatments employed are shown in Table 1. Basal rates of N and P were added to insure adequate nutrition for maximum yields.

Table 1. Treatments employed.

Treatment number	K_2O applied: With seed	K_2O applied: Pre-plant incorporated	K Source
	- - - - lb/A - - - -		
1	0	0	0
2	25	0	KCl
3	25	75	KCl
4	25	0	K_2SO_4
5	25	75	K_2SO_4

Selected site characteristics are documented in Table 2. All sites would have to be classified as of high general fertility. All sites, except Minot, were summerfallowed the previous season.

Table 2. Site characteristics.

Site (nearest town)	Major soil type	NO_3-N 0-2' (0-4')	Basal N rate	Olsen P	NH_4OAc K	pH	Organic matter	MCP SO_4-S 0-2'	Previous Crop	Variety
				0-6" depth						
		- - - - - - - - - - lb/A	- - - - - - - - -				%	avg. ppm		
Carrington	Heimdal	115 (231)	0	53	740	7.6	3.7	17	fallow	Morex
Minot	Max	56 (130)	60	26	960	7.0	3.1	12	barley	Robust
Powers Lake	Williams-Wyard	72 (114)	30	42	1010	8.3	3.2	7	fallow	Morex
Fortuna	Bowbells	70 (110)	30	45	1390	7.5	2.2	35	fallow	Morex
Williston	Max	100 (122)	30	40	880	7.3	2.2	6	fallow	Morex

Plant measurements include: tissue total nitrogen, nitrate and chloride at boot and milk stage; incidence of *Helminthosporium sativum* root rot at boot stage; severity of the same disease at milk stage; tillering; grain yield; grain plumpness; and grain protein content. Only the major disease parameters and grain yield will be discussed here, as the plant analyses are not complete. Statistical analyses are not available yet.

It is important to note that all possible effort was taken to eliminate bias in root disease ratings. Twenty-four random sub-crown internodes per plot were rated. A "single blind" method (rater did not know which plot he/she was rating) was used for the first sampling (except Minot). A "double blind" system (neither the rater nor the recorder knew the identity of the plot when rating the roots) was used with the second root rating (and at Minot with the first rating).

The effect of potash source and rate on root rot incidence is shown in Table 3. Effects were noted at 4 of 5 trials. Seven of the nine reductions (78%) in root disease were observed with the chloride source (KCl). This indicates a superiority of the chloride source, and gives preliminary (but not conclusive) support to a chloride ion effect. This contention is further substantiated by the second disease sampling (Table 4). Severity of root disease was reduced in 3 of 5 trials. Five of the six treatments (83%) giving reductions in root disease were from the chloride source, further indicating a superior performance of KCl over K_2SO_4.

Informal visual notes indicated that KCl reduced severity of spot blotch leaf disease (also incited by *H. sativum*) at Carrington. This effect was also observed by Dr. Vasey in the 1960's. Intensive sampling will be done in the future to confirm this effect. Normally spot blotch is favored by cool, wet conditions and root rot favored by warm, dry conditions.

Grain yields were increased in 2 of the 5 trials (Table 5). The treatments giving yield increases had also given reductions in root disease earlier in the season. Yield increases of 3-7 bu/A were noted. All three of the three treatments (100%) giving yield increases were potassium chloride treatments, which again implicates a chloride (or at least an osmotic) explanation for these results. The 100 lb rate of K_2O as KCl was superior to the 25 lb/A rate at the two sites that indicated a yield increase (Minot and Powers Lake) however the two rates were similar in reducing disease.

Table 3. Effect of potash rate and source on incidence of *H. sativum* root rot in malting barley at boot stage. Central and western ND, 1983.

Rate of K_2O		K	Site					
Drill	bcst	Source	Carrington	Minot	Powers Lake	Fortuna	Williston	Average
lb/A			- - - - - - - - - - - - % plants infected - - - - - - - - - - - -					
0	0	-	13	60	87	39	94	59
25	0	KCl	21	44+	74+	33+	73+	49
25	75	KCl	15	42+	68+	42	79+	49
25	0	K_2SO_4	22	48+	83	40	88	56
25	75	K_2SO_4	13	60	72+	34	93	54

+Readings lower than control in at least 5 of 6 replications.

Table 4. Effect of potash rate and source on severity of *H. sativum* root rot in malting barley, milk to dough stage. Central and western ND, 1983.

Rate of K_2O		K	Site					
Drill	bcst	Source	Carrington	Minot	Powers Lake	Fortuna	Williston	Average
lb/A			- - - - - - - - - - Disease Severity Index* - - - - - - - - - -					
0	0	-	2.5	2.3	3.2	2.3	3.6	2.8
25	0	KCl	2.5	2.0+	3.0+	2.3	3.2+	2.6
25	75	KCl	2.5	2.1+	2.6+	2.4	3.5	2.6
25	0	K_2SO_4	2.7	2.3	3.2	2.5	3.6	2.9
25	75	K_2SO_4	2.7	2.3	2.9+	2.5	3.7	2.8

*1 = none, 2 = slight, 3 = moderate, 4 = severe.

+Readings lower than control in at least 5 of 6 replications.

Table 5. Effect of potash rate and source on malting barley grain yields. Central and western ND, 1983.

Rate of K_2O		K	Site					
Drill	bcst	Source	Carrington	Minot	Powers Lake	Fortuna	Williston	Average
lb/A			bu/A					
0	0	-	65	79	59	70	41	63
25	0	KCl	66	79	64+	74	42	65
25	75	KCl	67	82+	66+	69	39	65
25	0	K_2SO_4	66	74	61	73	43	63
25	75	K_2SO_4	64	77	60	72	41	63

+Readings higher than control in 4 of 6 replications.

This year's research explains much of the historical "potash" responses on barley in North Dakota. This year's research also opens the door to many other questions: Why does this effect occur? Is the effect osmotic? Is it due to Cl - NO_3^- antagonism? Does chloride effect the disease's metabolism only? Will more resistance varieties give the same response? What minimum rates are needed for control? Will soil test chlorides (or salts) indicate need for KCl fertilizer?

On the practical side, more site-years of response information is needed. This sort of research is tedious and time-consuming (over 7000 roots had to be individually rated to come up with Tables 3 and 4) and it will take at least another 2 years of research to begin to answer the above questions. However, much has been accomplished in this project, as a new disease-fertilizer interaction has been proven. It awaits to be determined how this interaction may be best manipulated for maximum economic yields.

III. Alfalfa Experiments.

See attached paper.

IV. PPI, FAR use of data.

The alfalfa data, since it has been accepted for publication, may be used, as long as proper credit to NDSU is given.

As can be appreciated, a primary journal article is forthcoming from the barley research. Most journals can not accept data that has been printed in essentially complete form in other media. Therefore, it is requested that Tables 3-5 not be printed in their totality in any PPI-FAR or other media. However, written summaries, averages, or partial quotations of Tables 3-5 are acceptable. The main concern is that if Tables 3-5 are reproduced in other media, then some problems with publication in refereed journals may occur.

DEEP PLACEMENT OF PHOSPHORUS INTO ESTABLISHED ALFALFA[1]

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Running Head:

Goos et al. - Deep placement of P

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ABSTRACT

Previous attempts to place phosphorus (P) fertilizer below the soil surface in established alfalfa (*Medicago sativa* L.) have not been successful because of stand disturbance and subsequent yield reduction. Three dryland experiments were conducted in western North Dakota on Pachic and Typic Haploborolls comparing surface applications of granular concentrated superphosphate to deep applications of liquid ammonium polyphosphate. The phosphorus rates were 0, 20, 40, and 80 lb P_2O_5/A (0, 10, 20, 40 kg P/ha). The liquid fertilizer was injected on 12 inch (30 cm) centers at a depth of 4 inches (10 cm) using modified thin profile anhydrous ammonia knives. Results indicate that the deleterious effects of the knifing operation on alfalfa yield were negligible at two of the three sites. The knifing operation decreased yield approximately 7% at the third site. Deep placed P promoted significantly higher yields and recoveries of fertilizer P than surface P at two of the three locations. Deep placed P was 3.4, 1.8, and 1.2 times as effective as surface P for the three sites, as estimated by plant uptake data. Procedures for knifing P into established alfalfa with minimal stand damage are discussed.

Additional index word: *Medicago sativa*.

There is great current interest in methods of phosphorus (P) fertilizer application. Much of this interest has been sparked by the successful deep placement trials of Leikam, et al. (1979, 1983). The wide publicity that these trials have received has prompted renewed research in P placement methods. Most of the trials to date have been with annual crops.

Past trials with subsurface application of P fertilizers in established grass or alfalfa (*Medicago sativa* L.) have not produced encouraging results. Leyshon (1982) applied granular P fertilizers to established alfalfa in southwest Saskatchewan with a "hoe drill" type implement. In this study, the stand damage inflicted by the application process caused a yield reduction. He concluded surface application was the only recommendable method for P fertilizer application on established alfalfa. This paper reports on the results obtained with another method of P fertilizer injection into established alfalfa.

MATERIALS AND METHODS

Four dryland experiments were established in western North Dakota in October of 1982. The sites were in either common or 'Vernal' alfalfa. All stands were over four years old. One site was lost to winterkill. The "surface P" treatments consisted of a topdressing of concentrated superphosphate at 0, 20, 40, and 80 lb P_2O_5/A. The "deep P" treatments consisted of an injected application of liquid ammonium polyphosphate at 0, 20, 40, and 80 lb P_2O_5/A. The 0 lb/A "deep P" treatment was shanked identically as the 20, 40, and 80 lb treatments, only without fertilizer addition. The "surface P" treatments were not shanked. The liquid fertilizer was metered with a ground driven John Blue[3] fertilizer pump, through a John Blue flow divider, to knives mounted on DMI spring shanks on 12 inch centers on a 3 rank tool bar. The knives were Harlan thin-profile anhydrous ammonia knives, modified for liquid fertilizer delivery (Figure 1). The knives, as modified, operated without plugging. The operation depth of the point of each knife was 4 inches, with fertilizer delivery at a depth of 3 inches. At the time of fertilizer application the fields were moist, the stands were dormant, and no problem with crown uprooting was noted.

Preliminary experiences with deep placement into alfalfa have shown that if stands are not totally denuded of leaves and dormant, there will be enough intertwining of stems to promote uprooting of crowns and subsequent stand reduction. Typically, this is not a problem in semiarid regions, as regrowth after the second cutting is minimal.

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[3]Use of trade names is only intended for reader convenience and does not imply an endorsement by North Dakota State University.

Ammonium nitrate was topdressed as appropriate so that all plots received a total of 23 lb N/A. This was to compensate for the N additions from the liquid fertilizer. A randomized complete block design with four replications was employed. One replication was abandoned at the Hettinger location because of badger damage and other soil variability. Individual plot size was 6 x 30 feet. Two harvests were made. The first harvest was at first bloom to 10% bloom and the second harvest was made at 50-75% bloom. An area of 3 x 24 feet was harvested from individual plots with a flail-type plot harvester, weighed, and subsamples taken for moisture and phosphorus analysis. Forage samples were dried at 60C, ground finely, and analyzed for total P by sulfuric acid digestion and colorimetric determination. Initial soil samples were taken from control plots to a depth of 4 feet and analyzed for standard soil test parameters (Dahnke, 1980).

RESULTS AND DISCUSSION

Pertinent soil test data, climatic data, and dates of significant field operations are found in Table 1. The Dickinson and Hettinger locations tested "low" in Olsen P and the Mandan location tested "medium," by present interpretation criteria (Dahnke et al. 1981). All sites had very low levels of available P below 6 inches. Initial stored soil moisture was above normal and growing season precipitation was near normal for western North Dakota. In general, the air temperatures were below normal from 20 April - 1 July and above normal 1 July - 1 August.

The effect of P rate and placement at the Dickinson site is shown in Table 2. First cutting yields were significantly increased by added P, and deep placed P was superior to surface P. For example, dry matter yields at 20 lb P_2O_5/A deep placed were similar to those observed at 40 lb P_2O_5/A surface placed (2110 vs. 2080 lb/A), and yields at 40 lb P_2O_5/A deep placed were similar to observed at 80 lb P_2O_5/A surface placed (2430 vs. 2370 lb/A), suggesting that the deep applications were at least twice as effective as surface P in increasing yield at this site.

First cutting P uptake was increased by P fertilization, and again deep applied P was superior to surface P. Simple linear regressions were performed on the first cutting P uptake data to further compare the two placement methods. The ratio of the linear regression slopes is an estimate of relative placement effectiveness. Results of this analysis are shown in Table 5. Deep placed P was approximately 3.4 times as effective, in terms of uptake, as equal rates of surface P at this site.

Second cut yields and P uptake were not significantly affected by P placement at the Dickinson site. This is perhaps due to the warmer than normal temperatures that prevailed after 1 July.

The effects of P rate and placement at the Hettinger site are summarized in Table 3. Although the first cutting data are more erratic than for the Dickinson site, there is a significant advantage of deep placement over surface placement in both yield and P uptake. The P uptake data for the first cutting also shows a decided superiority for deep placement. For the first cutting deep P was 1.8 times as effective as surface P (Table 5). Second cut yields and P uptake were not significantly affected by treatment at Hettinger (Table 3) although the data tends to support a superiority of deep placement.

The Mandan site gave results at variance with the other two sites (Table 4). First cutting yields were significantly lower for deep placement, although both forms of placement promoted an overall P response. Averaged across P rate the magnitude of the yield reduction was approximately 7%. This overall yield reduction is due to the tillage aspect of the deep placement and not due to a lesser availability of the deep applied P. This contention is supported by Table 5, which shows approximately equal effectiveness of these two placement methods as measured by plant P uptake. The magnitude of the tillage-induced yield decreases observed at this site are less than the decreases reported by Leyshon (1982), who observed a 20% yield decrease when alfalfa was disturbed to a one inch depth by a "hoe drill" type implement. In this present study, the soil was disturbed to 4 inches with a 7% decrease at the Mandan site and negligible decreases at the other two sites. It is not known why the alfalfa was adversely affected at only the Mandan site. This site had the oldest and thinnest overall stand of the three sites, and thus may have been more affected by the tillage operation. These yield decreases were not observed at the second cutting, however (Table 4). There were no placement differences in second cutting P uptake.

CONCLUSIONS

Deep placement of liquid P fertilizer into standing alfalfa was superior to surface broadcast application of granular fertilizer at two of the three locations. At these two sites there were negligable deleterious effects of the knifing operation on the alfalfa stand. Deep applied P was 1.8-3.4 times more effective than surface P at these two sites, as measured by first cutting plant P uptake. At a third site, a significant yield reduction (7%) from the knifing operation was observed at the first cutting, but not at the second cutting. Equal plant uptake of surface P vs. deep P was observed at this site.

The conclusion of this paper is that deep applied P to established alfalfa using modified thin profile anhydrous ammonia knives can be a very practical application technique, especially on soils testing quite low in available P. Such applications should be made in late fall or early spring when stands are dormant and very little remains of the previous year's growth. This study is being continued and results will be reported after termination of the experiment.

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LITERATURE CITED

Dahnke, W. C. (ed.). 1980. Recommended chemical soil test procedures for the North Central Region. North Dakota Agric. Exp. Stn. Bulletin No. 499 (Revised).

Dahnke, W. C., L. J. Swenson, and E. H. Vasey. 1981. Fertilizing established alfalfa and sweet clover. North Dakota Coop. Ext. Serv. Circular SF-728.

Leikam, D. F., R. E. Lamond, D. E. Kissel, and L. S. Murphy. 1979. Dual applications of N and P. Crops and Soils Magazine. 31(8): 16-19.

Leikam, D. F., L. S. Murphy, D. E. Kissel, D. A. Whitney, and H. C. Moser. 1983. Effects of nitrogen and phosphorus application method and nitrogen source on winter wheat grain yield and leaf tissue phosphorus. Soil Sci. Soc. Am. J. 47:530-536.

Leyshon, A. J. 1982. Deleterious effects on yield of drilling fertilizer into established alfalfa. Agron. J. 74:741-743.

Table 1. Characteristics of the experimental locations.

Measurement	Soil Depth	Site		
		Dickinson	Hettinger	Mandan
	in			
Olsen P, lb/A	0-6	8	5	12
	6-12	2	3	3
pH	0-6	7.1	7.2	7.4
Exch. K, lb/A	0-6	300	450	610
	6-12	180	270	620
Organic Matter, %	0-6	1.3	2.0	3.8
	6-12	1.0	1.2	2.6
Soil Series	-	Parshall	Stady	Bowdle
Classification	-	Pachic Haploboroll	Typic Haploboroll	Pachic Haploboroll
Growing season precipitation, in‡	-	6.5	7.0	6.0
Date of fertilization	-	10-20-82	10-19-82	10-18-82
Harvest dates	-	6-15-83	6-14-83	6-13-83
	-	7-26-83	7-25-83	7-25-83

‡April 20 (date of spring soil sampling) to date of second harvest.

Table 2. Effect of phosphorus rate and placement on alfalfa yield and P uptake. Dickinson site, 1983.

Phosphorus rate	Placement	First cutting Dry matter	First cutting P uptake	Second cutting Dry matter	Second cutting P uptake
lb P_2O_5/A		lb/A			
0	Surface	1890	2.5	1700	2.3
20		2070	2.8	1700	2.4
40		2080	2.7	1700	2.5
80		2370	3.2	1720	2.5
0	Deep	1880	2.4	1650	2.2
20		2110	3.0	1840	2.5
40		2430	3.6	1770	2.6
80		2650	4.6	1790	3.0
Significance of F					
P rate		**	**	NS	**
P placement		*	**	NS	NS
Rate x Placement		NS	**	NS	NS
C.V., %		8.0	12.0	5.2	8.8

*,** F significant at 0.05, 0.01, respectively.

Table 3. Effect of phosphorus rate and placement on alfalfa yield and P uptake. Hettinger site, 1983.

Phosphorus rate	Placement	First cutting Dry matter	First cutting P uptake	Second cutting Dry matter	Second cutting P uptake
lb P_2O_5/A		lb/A			
0	Surface	2450	4.7	2200	3.6
20		2330	4.3	2110	3.4
40		2490	4.9	2100	3.6
80		2670	5.9	2160	3.9
0	Deep	2350	4.1	2120	3.1
20		2710	5.5	2330	3.8
40		2710	5.8	2190	3.8
80		2830	6.8	2230	4.3
Significance of F					
P rate		*	**	NS	*
P placement		*	**	NS	NS
Rate x Placement		+	+	NS	NS
C.V., %		6.1	8.0	6.4	11.0

+,*,** F significant at 0.1, 0.05, 0.01, respectively.

Table 4. Effect of phosphorus rate and placement on alfalfa yield and P uptake, Mandan site, 1983.

Phosphorus rate	Placement	First cutting Dry matter	First cutting P uptake	Second cutting Dry matter	Second cutting P uptake
lb P_2O_5/A		lb/A			
0	Surface	2220	3.4	980	1.4
20		2450	4.0	1150	1.8
40		2470	3.9	1040	1.6
80		2450	4.0	1140	1.8
0	Deep	2030	3.4	1090	1.6
20		2260	3.6	1090	1.7
40		2330	3.7	1140	1.8
80		2340	4.0	1020	1.7
Significance of F					
P rate		*	**	NS	+
P placement		*	NS	NS	NS
Rate x Placement		NS	NS	NS	+
C.V., %		7.8	9.2	9.9	10.8

+,*,** F significant at 0.1, 0.05, 0.01, respectively.

Table 5. Effectiveness ratio calculation for deep vs. surface applied P. First cutting P uptake data, 1983.

	P surface+			P deep+			Effectiveness ratio
Site	Intercept	Slope 1	r^2	Intercept	Slope 2	r^2	(Slope 2/Slope 1)
		-	%		-	%	-
Dickinson	2.5	0.008	.86	2.4	0.027	.99	3.4
Hettinger	4.3	0.017	.76	4.5	0.031	.91	1.8
Mandan	3.6	0.006	.49	3.4	0.007	.99	1.2

+P uptake data fitted to a simple linear regression model: P uptake, lb/A = Intercept + slope (P rate, lb P_2O_5/A).

LIST OF FIGURES

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REPORT TO COOPERATING INSTITUTIONS, 1984

FIELD RESEARCH IN SOIL FERTILITY IN NORTH DAKOTA

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INTRODUCTION AND PROJECT ORIENTATION

Our field research in 1984 studied 4 subjects: 1. Phosphorus placement for established alfalfa, 2. Nitrogen needs of old alfalfa-bromegrass mixtures, 3. Chloride-repression of common root rot in barley, and 4. Evaluation of ammonium thiosulfate as a nitrification inhibitor.

Location of the field studies is shown in Figure 1. In general, the barley studies were in NW ND, the forage studies were in SW ND, and the thiosulfate studies were at or near Fargo. Soil characteristics of all sites are shown in Table 1.

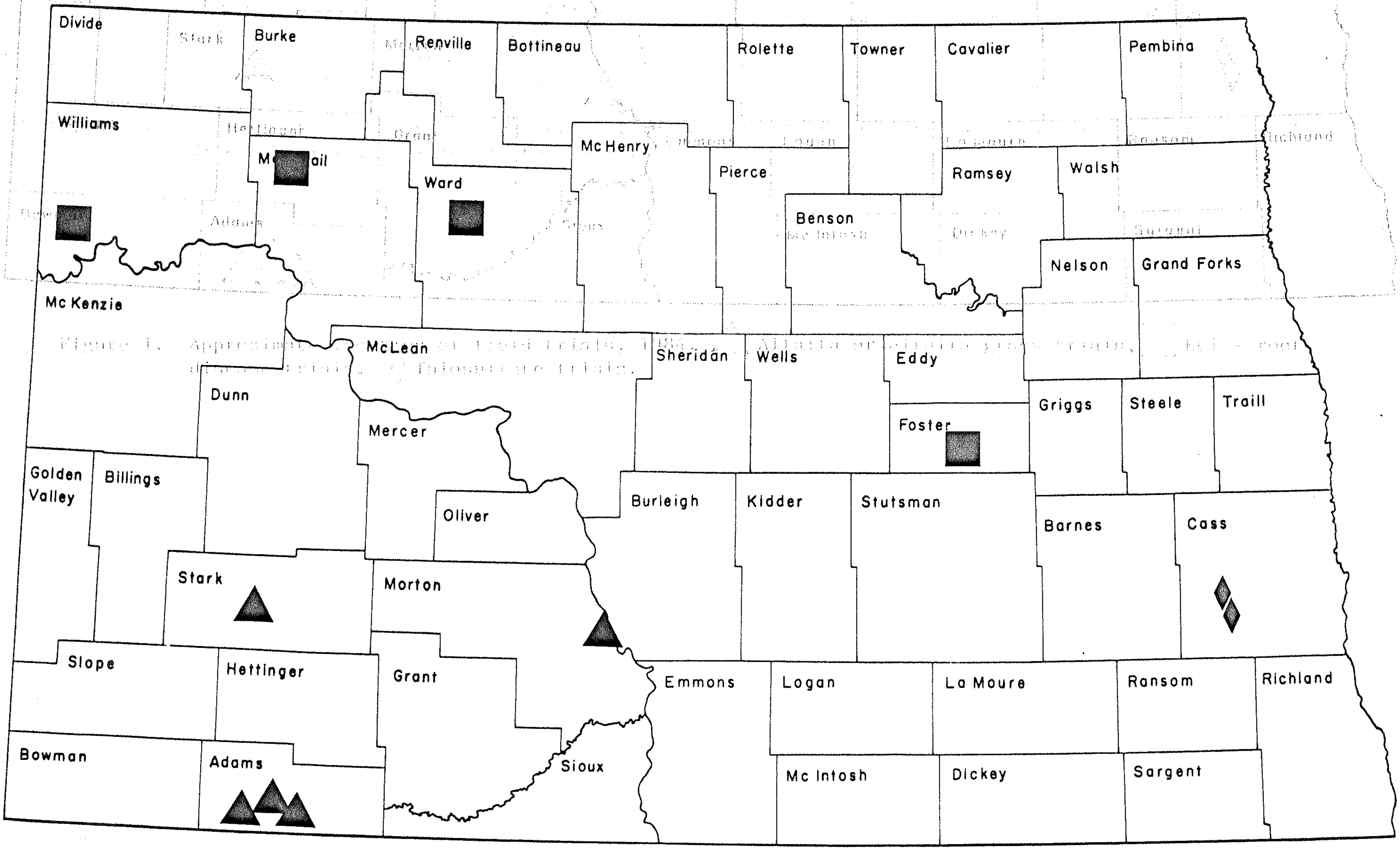

Figure 1. Approximate location of field trials, 1984. ▲ Alfalfa or alfalfa-grass trials, ■ KCl - root disease trials, ♦ Thiosulfate trials.

Table 1. Soil characteristics of the field sites.

Site	Exp.[†]	Surface texture	0-6 inch sample pH	Olsen P	Av. K	0-24" NO_3-N
			---------- lb/A ----------			lb/A
Mandan	P-A	l	6.6	16	605	-
Dickinson	P-A	fsl	6.5	8	305	-
Hettinger 1	P-A	l	6.4	8	460	-
Hettinger 2	N-AG	sil	7.1	6	900	-
Hettinger 3	N-AG	fsl	6.6	6	740	-
Carrington	K-B	l	6.5	36	480	76
Minot	K-B	l	7.0	20	840	90
Powers Lake	K-B	l	7.0	17	585	63
Williston	K-B	l	6.8	30	505	87

†P-A = phosphorus placement for alfalfa
N-AG = nitrogen needs for alfalfa-grass mixtures
K-B = KCl and barley root diseases

PHOSPHORUS PLACEMENT FOR ESTABLISHED ALFALFA

This study is a continuation of an experiment established in October 1982. The first-year results were published after a superior performance of deep-applied P over surface-P was observed (Goos, et al., 1984b). Tables 2-4 present the dry matter yields, % phosphorus and phosphorus uptake data from the 3 sites. Growing season conditions were favorable until early June and little rain was received after then. Thus, only one cutting was obtained in 1984, and yields of this cutting were depressed at the Dickinson site.

The Mandan site (Table 2) had the highest yields of the three locations. Dry matter yields tended to be increased about 10% by added P, and this increase was similar between methods of P placement. The % P and P uptake data, however clearly illustrates a superiority of deep placement. Deep-applied P was approximately twice as effective in increasing plant uptake of P as surface-applied P. It is interesting to note that the shanking involved with the deep application did not depress yields in 1984. Last year, the shanking operation promoted a small, but significant (7 %) yield decrease (Goos et al., 1984), suggesting that the harm done by the shanking operation was temporary.

Table 2. Effect of phosphorus rate and placement on alfalfa, Mandan ND, 1984.

P_2O_5 rate	P Mgmt†	D.M. yield	P Content	P uptake	Total P uptake (2-years)
lb/A		lb/A	%	-------- lb/A	------
0	Deep	1925	.23	4.4	9.4
20		2145	.23	4.9	10.2
40		2128	.26	5.5	11.0
80		2076	.28	5.8	11.5
0	Initial Sfc.	1975	.23	4.5	9.3
20		2018	.23	4.6	10.4
40		2120	.24	5.1	10.6
80		2048	.26	5.3	11.1
0	Annual Sfc.	1924	.23	4.4	9.4
10		2065	.22	4.5	9.7
20		1980	.24	4.8	10.2
40		2008	.26	5.2	10.3

†Deep = rate injected as 10-34-0 in October 1982.
Initial = rate topdressed as 0-45-0 in October 1982.
Annual = rate topdressed October 1982 and October 1983.

Yields of alfalfa were limited by drought at the Dickinson site (Table 3). Yields were consistantly increased ca. 20-30% by addition of P, but this did not translate into a large actual increase of yield. There was little difference between methods of P placement, which would be expected under low yield conditions. The previous year, deep-P was 3.5 fold more effective than surface-P at this site (Goos et al., 1984b).

Table 3. Effect of phosphorus rate and placement on alfalfa, Dickinson ND 1984.

P_2O_5 rate	P Mgmt†	D.M. yield	P Content	P uptake	Total P uptake (2-years)
lb/A		lb/A	%	-------- lb/A	------
0	Deep	1025	.19	2.0	6.6
20		1205	.19	2.2	7.8
40		1289	.19	2.5	8.7
80		1331	.21	2.8	10.4
0	Initial Sfc.	1077	.17	1.8	6.6
20		1192	.19	2.3	7.5
40		1241	.19	2.4	7.6
80		1349	.20	2.7	8.4
0	Annual Sfc.	1131	.17	1.9	6.7
10		1198	.19	2.3	7.4
20		1276	.20	2.6	7.9
40		1368	.21	2.7	8.5

†Deep = rate injected as 10-34-0 in October 1982.
Initial = rate topdressed as 0-45-0 in October 1982.
Annual = rate topdressed October 1982 and October 1983.

Yields were increased ca. 20% by P at the Hettinger site (Table 4). This site has a higher inherent variability than the other sites. Again, it is hard to distinguish a superior performance due to the deep placement in 1984.

It will be interesting to observe the continued residual effects of the added P in future years. Fertilizer uptake efficiency, averaged across all sites, illustrated a decisive advantage for deep placement (Figure 2). Even so, less than 20% of the applied fertilizer has been accounted for in forage P, suggesting that residual effects may last several years.

Table 4. Effect of phosphorus rate and placement on alfalfa, Hettinger ND 1984.

P_2O_5 rate	P Mgmt†	D.M. yield	P Content	P uptake	Total P uptake (2-years)
lb/A		lb/A	%	-------- lb/A	------
0	Deep	1820	.20	3.6	10.6
20		2080	.21	4.4	13.4
40		1802	.23	4.1	13.1
80		2041	.23	4.7	15.5
0	Initial Sfc.	1644	.20	3.3	11.4
20		1757	.21	3.7	11.4
40		1747	.21	3.8	12.0
80		1957	.22	4.3	13.6
0	Annual Sfc.	1713	.20	3.4	10.9
10		1739	.22	3.8	11.2
20		1846	.22	4.1	12.0
40		2037	.23	4.7	13.5

†Deep = rate injected as 10-34-0 in October 1982.
Initial = rate topdressed as 0-45-0 in October 1982.
Annual = rate topdressed October 1982 and October 1983.

NITROGEN NEEDS FOR OLD ALFALFA-GRASS MIXTURES

A common scene in SW ND is an old alfalfa-grass mixture where the alfalfa component is a very small percentage of the total forage. Alfalfa, being shorter-lived than crested wheatgrass or bromegrass, naturally thins with time in mixtures in our semi-arid climate. A question that has never been approached is: with respect to the need for nitrogen fertilization, what is the "critical" composition of alfalfa in the mixture? That is, what is the minimum alfalfa stand density needed for maximum yield without nitrogen fertilization? Or, stated another way, when in the natural progression of an alfalfa-grass mixture should N fertilization begin?

Because of the difficulty of manually establishing variable stand densities in old alfalfa-grass mixtures, a "transect" approach, utilizing

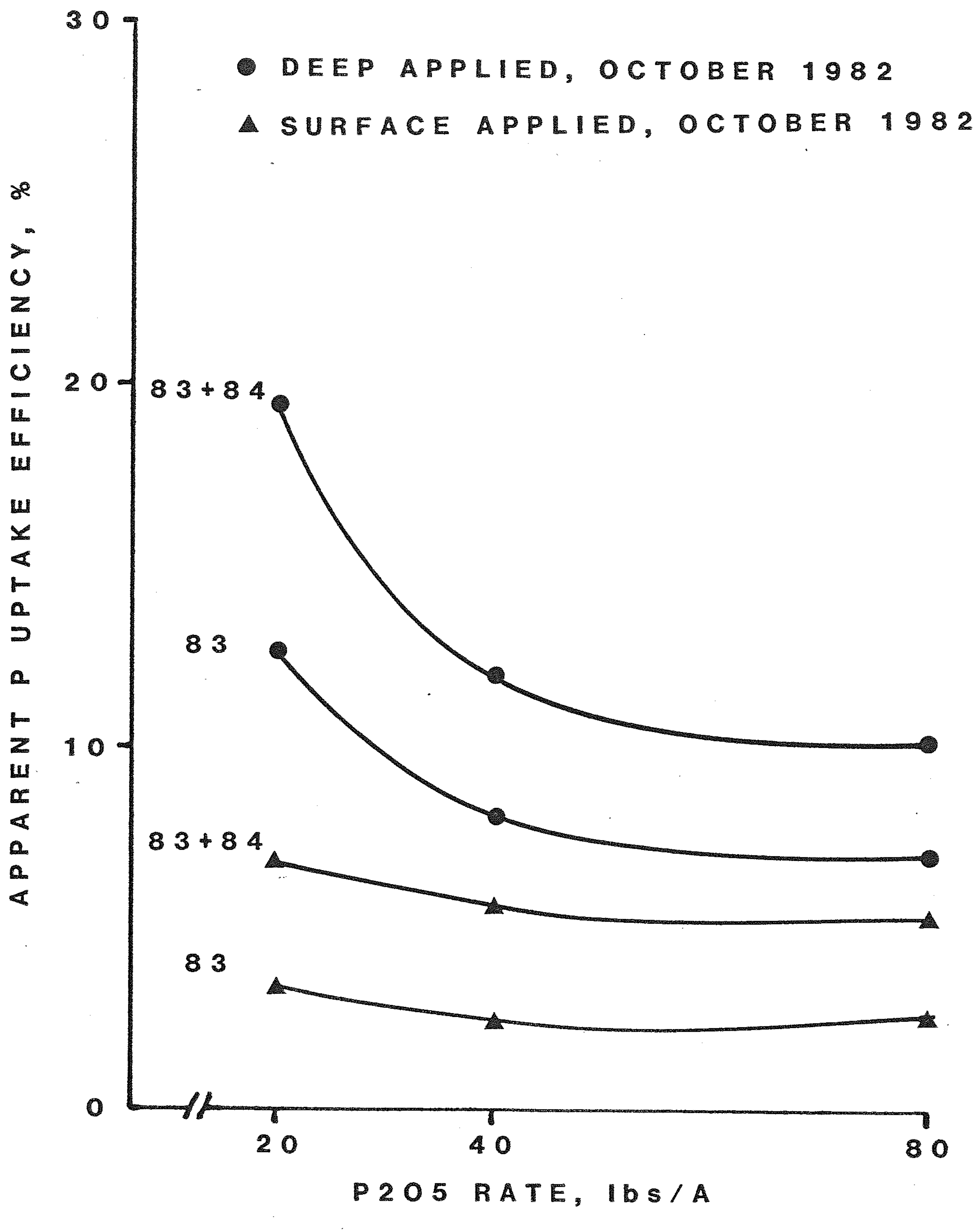

Figure 2. Effect of P rate and placement on P uptake efficiency of dryland alfalfa.

natural stand variability, was used. Several field-length transects were made across two old alfalfa-grass stands with an 8-foot wide liquid fertilizer application applying 50 lb N/A as 28-0-0 in November 1983. In early 1984, at first green-up of the mixtures, ca. 10 study areas were designated in each field selected to give a whole array of alfalfa stand densities. Four harvest areas of 3 feet by 20 feet in each study area were taken such that two replicates of plus vs. minus N could be taken per study area. The hay was harvested at full-bloom of the alfalfa and subsamples separated into the alfalfa and grass components. The change in yield due to nitrogen fertilization was related to alfalfa composition of the unfertilized areas.

The relationship between alfalfa composition and yield response of the mixture is presented in Figure 3. From 0-30% alfalfa there was a strong inverse relationship between alfalfa composition and yield increase from N fertilization. Above 30% alfalfa the results were scattered with a tendency for a slight yield increase from N. At a hay price of $40/ton and a N cost of 25¢/lb, the trade-off alfalfa composition is around 25%. That is, this year's research shows that alfalfa-grass mixtures with less than 25% of the dry matter as alfalfa should be fertilized with N. The results of this experiment have been summarized for extension use (Goos and Johnson, 1984). This experiment has been re-established for 1985 at the south site. Further research will be done into methods of thinning alfalfa-grass mixtures for future experimentation, using herbicide granules.

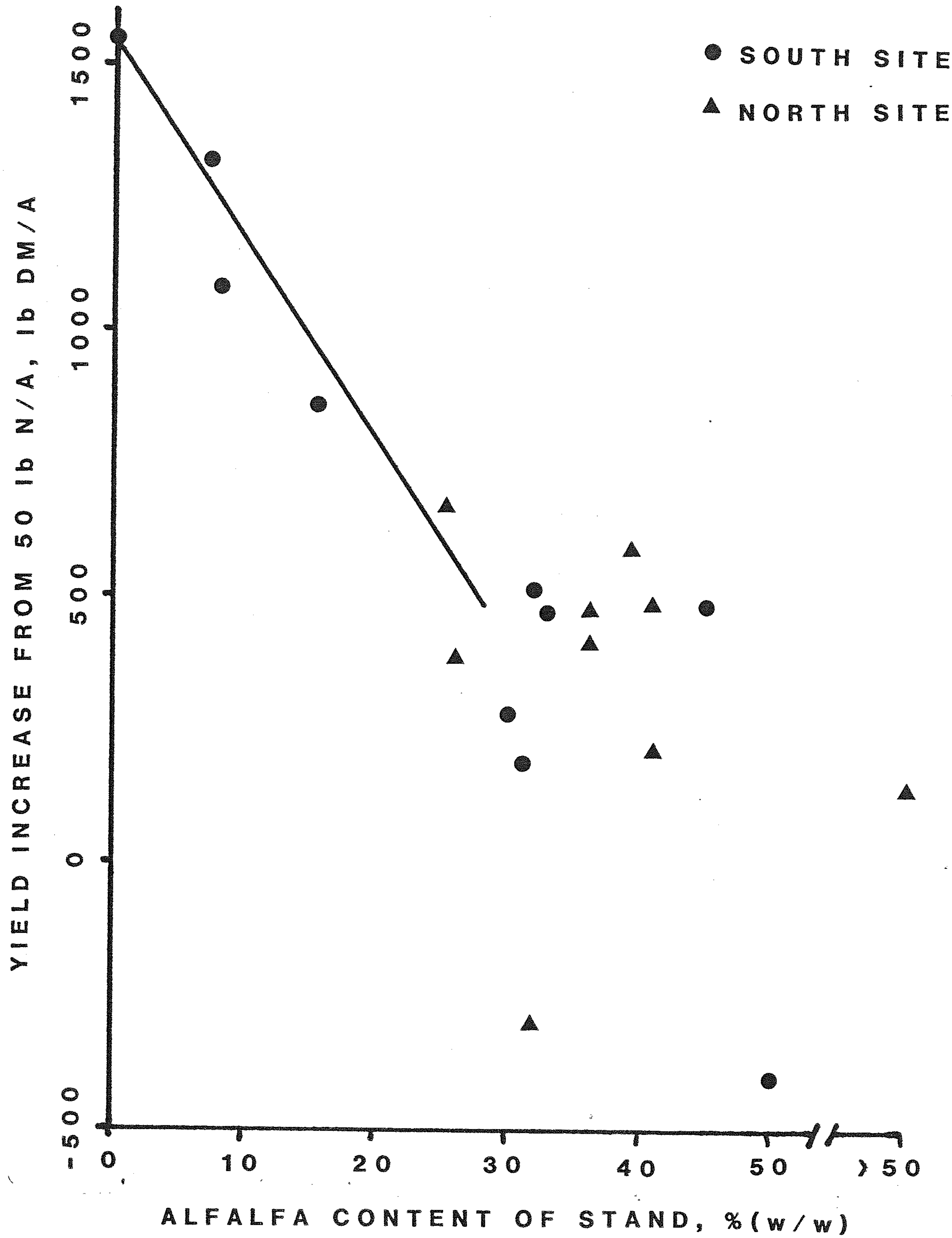

Figure 3. Relationship between alfalfa density and responsiveness of alfalfa-grass mixtures to N.

CHLORIDE-INDUCED REDUCTION OF COMMON ROOT ROT IN BARLEY

Last year it was shown that KCl applications to malting barley definitely reduces incidence and severity of common root rot (incited by Cochliobulus sativus), whereas K_2SO_4 applications in general did not (Timm et al., 1985). The purpose of the 1984 experiments was not to repeat the 1983 experiments, as KCl is the preferred chloride source for North Dakota. This year a variety x KCl rate study was initiated to compare the response of a susceptible variety (Morex) with a more tolerant type (Azure). Rates of KCl were equivalent to 0, 25, and 100 lb K_2O/A.

Two planting errors and a very large April snowfall limited the amount of reliable data available this year. Root disease ratings were not possible at Carrington because of a hard seed bed and thus the seed was placed too shallow for readable sub-crown internodes. At Williston, the experiment was seeded end-for-end as the fertilizer was applied. Thus at Williston we do not have a complete set of replicated data for rigorous statistical analysis. Only 2-4 observations per treatment remained out of the 5 intended. At Minot, a very large April blizzard occurred after seeding. Irregular drifting and severe crusting greatly increased experimental error. The Powers Lake site was completed without any unfortunate acts of God or man.

Effects of KCl and variety on disease severity at dough stage are shown in Table 5. KCl significantly reduced disease severity at Minot and Powers Lake. Application of KCl tended to reduce severity at Williston as well, even though statistical significance can not be determined. This confirms our research from 1983 which showed a significant KCl effect on disease severity. Significant varietal differences in disease severity were observed at Minot and Powers Lake. These differences were as expected, with Morex giving higher disease severity ratings than Azure. The same trend held true overall at Williston. The KCl x variety interaction was non-significant, indicating that both varieties responded similarly to KCl.

Table 5. Effect of KCl and variety on severity of root rot of barley, dough stage. North Dakota 1984.

Variety	KCl rate	Site		
		Minot	Powers Lake	Williston
	lb K_2O/A	-----------	severity index†	-----------
Morex	0	3.2	3.0	3.5
	25	2.7	2.8	3.0
	100	2.6	2.6	3.1
Azure	0	2.8	2.7	3.5
	25	2.6	2.5	2.7
	100	2.4	2.2	3.0
LSD (.05)		0.4	0.2	
Significance of F				
Variety		+	**	-
KCl rate		**	**	-
Variety x KCl		NS	NS	-

†1 = none, 2 = slight, 3 = moderate, 4 = severe.
+, ** significant at the 0.1 and 0.01 level, respectively.

The effect of KCl and variety on grain yield are shown in Table 6. Yields were not significantly influenced by KCl or variety at Carrington or Minot, although Azure tended to be more productive than Morex at Carrington. Even though some large numerical differences appear in the Minot data, there were no significant effects of KCl or variety. It was extremely difficult to obtain adequate harvest areas at this site, because of the irregular stand. However, it was less difficult to obtain 24 random plants from areas of good stand, and thus the data for disease severity at Minot (Table 5) was of higher reliability than the yield data (Table 6).

Grain yields were significantly increased by the highest rate of KCl at Powers Lake. This is the second year that a significant yield increase from KCl fertilization was observed at this site. It is not known why the lower rate did not give a yield increase. Perhaps even higher rates of KCl should be studied. However, at rates greater than, say, 50 lb K_2O/A there would have to be significant chloride residual effects for the practice to be economically feasible. The response obtained at Powers Lake this year, 3-4 bu/A, doesn't quite pay for the 100 lb K_2O/A applied. Lower rates (15-30 lb K_2O/A) have produced profitable responses in eastern ND (Bauer and Vasey, 1964; Zubriski et al., 1970).

Table 6. Effect of KCl and variety on barley yields. North Dakota, 1984.

Variety	KCl rate	Site: Carrington	Minot	Powers Lake	Williston
	lb K_2O/A	bu/A			
Morex	0	85.0	84.0	63.1	37.2
	25	86.3	80.9	62.3	39.1
	100	87.1	89.7	66.7	38.5
Azure	0	95.3	83.3	64.1	38.3
	25	91.4	87.6	64.4	37.8
	100	93.1	104.8	66.9	38.5
LSD (.05)		5.8	22.1	3.6	--
Significance of F					
Variety		NS	NS	NS	--
KCl rate		NS	NS	**	--
Variety x KCl		NS	NS	NS	--

FIELD EVALUATION OF AMMONIUM THIOSULFATE AS A NITRIFICATION INHIBITOR

Recent laboratory studies (Goos, 1985b) have shown that the thiosulfate ion ($S_2O_3^{=}$) can inhibit the conversion of ammonium (NH_4^+) to nitrate

(NO_3^-). Such a concept would have widespread application if similar levels of inhibition were obtained in the field. To test this hypothesis, field experiments were set out at two locations in 1984 with field-scale equipment to compare the effectiveness of ammonium thiosulfate (ATS), ammonium polysulfide (APS), and nitrapyrin (N-Serve) as nitrification inhibitors in conjunction with both anhydrous ammonia (AA) and urea-ammonium nitrate (UAN). Both sites were ca. 40 miles from Fargo. The north site was on a Glyndon silt loam and the south site was on a Embden fine sandy loam. All applications were made at a 5 inch injection depth with standard anhydrous ammonia knives modified for dual placement. The fertilizer retention zones were sampled periodically as weather permitted. Three cores per plot were taken, mixed and sieved in the field, and two subsamples were taken per plot for analysis. The samples were frozen or refrigerated as necessary and analyzed for ammonium-N or (urea + ammonium)-N as appropriate. The samples were analyzed wet, with correction made for water content.

The major complicating factor for this experiment was a ca. 6 inch rain that fell just before the first scheduled sampling date. This large rainfall probably limited the utility of this experiment, as will be shown later. The effect of treatment on soil ammonium-N for the north site is presented in Table 7. This site was severely impacted by the rainfall. Water stood on the field for over 1 week after the rain and was too wet to sample for about two weeks after the rainfall (although several abortive attempts were made). N-Serve was the only inhibitor to significantly delay nitrification. ATS and APS gave no indication of nitrification inhibition activity. It is conjectured that the ponding of water and subsequent leaching was adequate to separate the retention zones of ammonium and thiosulfate. A few anomolies exist in the data, which is expected for a larger-scale study of this sort. For example, for the 6/18 sampling it is not known why the ammonium value obtained with UAN + N-Serve (39 ppm) was similar than the appropriate control (UAN w/o inhibitor) (32 ppm).

Table 7. Effect of nitrification inhibitor and date of sampling on soil ammonium concentration. North site, 1984.

N rate	N source	Inhibitor type	Inhibitor rate†	Sampling date 6/18	6/29	7/12
lb/A			lb/A	--------	ppm NH_4-N	-------
0	--	--	--	26	4	1
120	AA	--	--	40	21	3
120		N-Serve	0.5	90*	30*	21*
120		ATS	10	37	14	1
120		ATS	20	47	13	2
120		APS	10	30	4	2
120		APS	20	50	11	3
120	UAN	--	--	32	15	2
120		N-Serve	0.5	39	58*	12*
120		ATS	10	39	8	2
120		ATS	20	29	26	2

†Rates are expressed as lb/A of active ingredient for N-Serve and lb/A of actual sulfur applied for ATS and APS. Observations marked * are significantly greater than the appropriate control (0.05 level) by Dunnett's test.

The effect of treatment at the south site is shown in Table 8. Again, N-Serve consistently retarded nitrification of both AA and UAN. ATS at the 20 lb S/A rate also significantly retarded nitrification of AA at the 6/11 sampling. This is our first indication that ATS may retard nitrification under field conditions. The same trend existed for ATS to retard nitrification of UAN at the 6/11 sampling date, but the trend could not be declared statistically significant.

Table 8. Effect of nitrification inhibitor and date of sampling on soil ammonium concentration. South site, 1984.

N rate	N source	Inhibitor type	Inhibitor rate†	Sampling date 6/11	6/25	7/9
lb/A			lb/A	ppm NH_4-N		
0	--	--	--	2	14	1
120	AA	--	--	13	15	2
120		N-Serve	0.5	52*	37*	16*
120		ATS	10	20	14	1
120		ATS	20	40*	13	2
120		APS	10	17	10	0
120		APS	20	25	14	1
120	UAN	--	--	15	16	1
120		N-Serve	0.5	59	49*	10*
120		ATS	10	29	13	1
120		ATS	20	32	13	1

†Rates are expressed as lb/A of active ingredient for N-Serve and lb/A of actual sulfur applied for ATS and APS. Observations marked * are significantly higher than the appropriate control (no inhibitor) at the 0.05 level by Dunnett's test.

In summary:

1) N-Serve consistently retarded nitrification.

2) ATS gave an indication of nitrification inhibition of anhydrous ammonia at one sampling date at one site. This observation shows that it is hypothetically possible to obtain adequate co-retention of anhydrous and ATS through common "double shooting" techniques.

3) APS gave no indication of any nitrification inhibition.

This research will be repeated in 1985 using micro-plot techniques so that rainfall interception and experimental error can be controlled to a fuller degree.

To study the leaching characteristics of thiosulfate, a non-replicated preliminary leaching column study was performed. Three PVC cylinders (4 inch diameter by 12 inches tall) were filled with 10 inches of Embden fsl soil, covered with a piece of filter paper, brought to field capacity, and allowed to drain for several days. To each cylinder a spot application of 1 ml of mixed fertilizer was placed in the center of the column at a depth of one inch. The mixed fertilizer consisted of 90 ml of aqua ammonia and 10 ml of ATS. One cylinder received no leaching, one cylinder received the equivalent of one 2 inch leaching and the third received the equivalent of two 2-inch leachings separated in time by one day. Four days after the leaching treatments were applied the cylinders were pushed from the pipes and cut into various depth increments. The soils were frozen until they were analyzed for thiosulfate and ammonium. The results are shown in Figure 4. Without leaching and with one leaching the thiosulfate was maintained in the top 2 inches of soil, where over 90% of the ammonium was held. However, with two leachings the thiosulfate was significantly moved out of the 0-1 inch layer and into the 2-4 inch layer, away from most of the ammonium.

This simple study does much to explain the erratic behavior of ATS as a nitrification inhibitor in the field in 1984. However, there is a need to test ATS as an inhibitor on more acid soils with a significant anion retention capacity. For example, chloride is normally thought to be very leachable. However, chloride has been shown to significantly inhibit nitrification on an acid soil in Oregon (Neil Christensen, personal communication). In Dr. Christensen's research the effect of chloride was eliminated by liming, suggesting a pH-anion retention phenomena. Thiosulfate may be a more reliable nitrification inhibitor under such conditions.

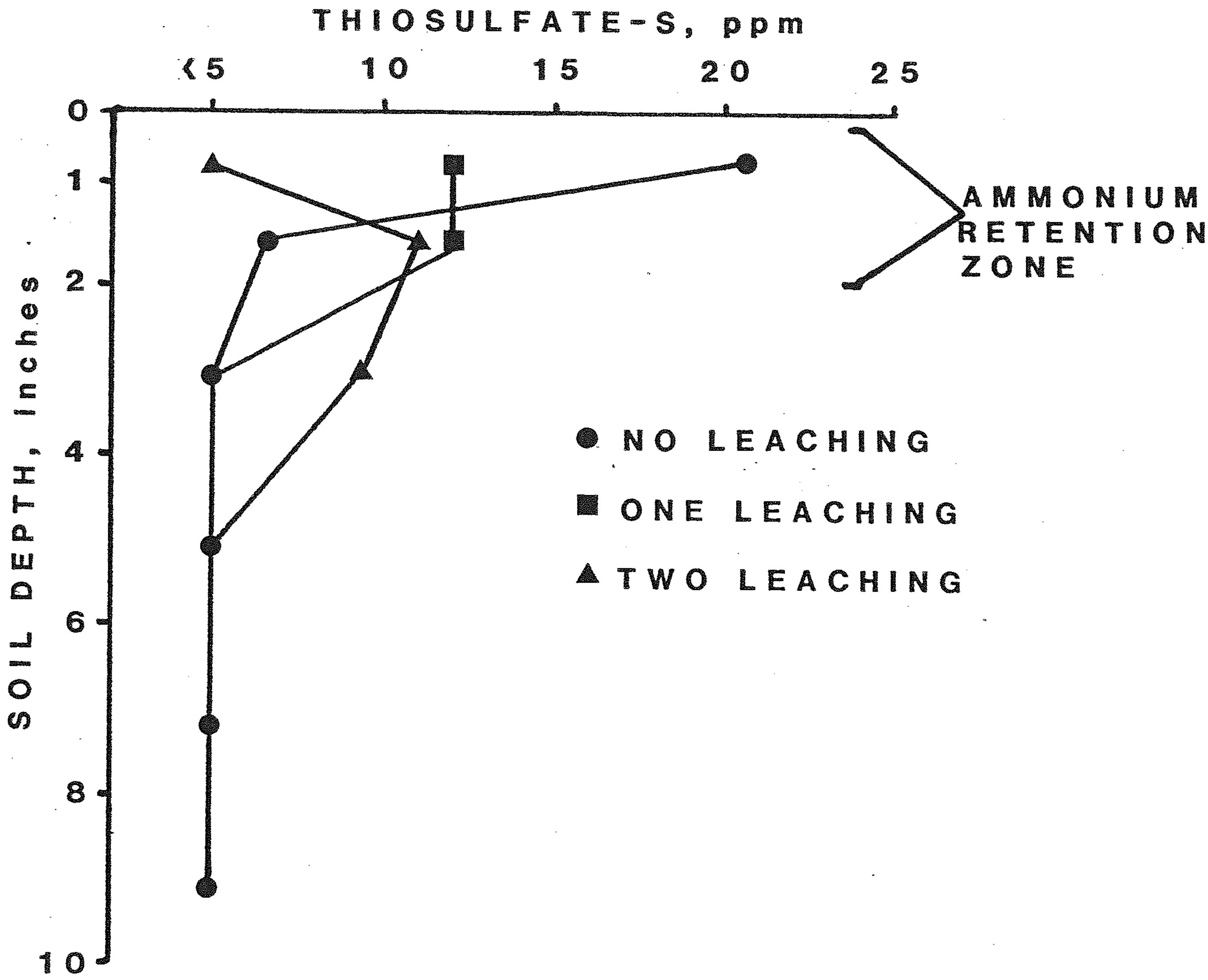

Figure 4. Effect of leaching on vertical position of thiosulfate.

SUMMARY OF OTHER STUDIES

A summary of the soil water requirements for summerfallow elimination for spring wheat was published (Goos et al., 1984a). This paper outlines easy-to-interpret guidelines for farmers to decide whether to fallow or recrop. A farmer in western ND can reduce his odds of crop failure from near 50% to 10% by following the guidelines in this paper.

A summary of the post-harvest technique for evaluating a farmer's nitrogen program for wheat was published (Goos, 1984b). Diagnostic criteria for winter wheat, spring wheat, and durum wheat were given.

A study of the urease properties of small grain residues will be published in early 1985 (Goos, 1985a). In short, the urease activity of wheat or rye stubble is very low at harvest - within the range observed for soils. However, after 1-2 months of field exposure and concomitant fungal colonization, the urease activity increases to 15-20 fold higher than observed for any U.S. soil. Perhaps this finding should be taken into account on deciding when to apply urea to no-till soils.

We have been vigorously researching ammonia losses from soil as influenced by ATS. These results will be summarized by 1 February 1985 and they will be circulated to you at this time.

Thank you for your support in 1984.

LITERATURE CITED

Bauer, A. and E. Vasey. 1964. Potassium fertilizer for barley. North Dak. Farm Res. 23(4):19-22.

Goos, R. J. 1985a. Effect of assay conditions and field exposure on the urease activity associated with cereal residues. Comm. Soil Sci. Plant Anal. (In press).

Goos, R. J. 1985b. Identification of ammonium thiosulfate as a nitrification and urease inhibitor. Soil Sci. Soc. Am. J. (in press).

Goos, R. J. 1984. Post-harvest evaluation of nitrogen management - a new way of promoting soil testing to wheat farmers. J. Agron. Educ. 13:103-106.

Goos, R. J. and B. E. Johnson. 1984. Nitrogen fertilization of alfalfa-grass mixtures in southwestern ND. In 1985 ND Crop Prod. Guide. ND Agric. Ext. Ser. Spec. Pub.

Goos, R. J., B. E. Johnson, F. J. Sobolik, and R. P. Schneider. 1984a. Stored soil water and the fallow-recrop decision - a critical level approach. Soil Sci. Soc. Am. J. 48:1134-1137.

Goos, R. J., B. E. Johnson, and C. A. Timm. 1984b. Deep placement of phosphorus fertilizer into established alfalfa. J. Fert. Iss. 1:18-22.

Timm, C. A., R. J. Goos, B. E. Johnson, F. J. Sobolik, and R. W. Stack. [1985]. Effect of potassium fertilizers on malting barley infected with common root rot. Agron. J. (In preparation).

Zubriski, J. C., E. H. Vasey, and E. B. Norum. 1970. Influence of nitrogen and potassium fertilizers and date of seeding on yield and quality of malting barley. Agron. J. 62:216-219.