N and P Placement and Timing of Dryland Winter Wheat Varieties

K. J. Larson and L. Herron [1]

Nitrogen fertilizer is commonly applied to winter wheat in the High Plains to achieve moderate to high yields. Typically, anhydrous N is applied in the summer or early fall with a tillage operation. Some growers apply liquid N in the spring if winter and spring moisture are high to take advantage of higher yielding condition. Phosphate fertilizer is less frequently used on winter wheat than N fertilizer. There are two main methods of P fertilization for calcareous soils: banding with the seed (seedrow) and banding with a knife (chisel). Banding N and P together is referred to as dual placement. We studied these common methods and timing of N and P fertilization (chisel N in fall, surface banding liquid N in spring, dual placement of N and P in fall, chisel P in fall, seedrow P at planting, and no fertilizer) on three varieties of winter wheat in Southwestern Kansas to determine which treatment produces the highest yield and variable net income. We included a comparison of with and without carpramid (Amisorb), a polymer reported to increase nutrient adsorption (Murphy and Sanders, 1998; Thompson, 2000), to the high rate dual placement P and N.

Wheat yield response to timing of N fertilization varies with moisture. Spring application of N was reported to increase wheat yields in higher moisture areas such as Illinois (Welch et al., 1966). In drier areas there tended to be little yield difference between fall and spring N applications, when using low or nonvolatile N fertilizers (Christensen and Meints, 1982; Kolberg et al., 1993). A three-year study conducted in Eastern Colorado reported yield and income advantage to spring-applied N compared to fall-applied N (Vaughan et al., 1990). Residual soil moisture and plant residue from the preceding crop also affected wheat yield response to N timing: wheat following grain sorghum produced the highest yields with a split N application (fall and late winter); whereas, when wheat followed soybean, preplant N produced higher yields than split N application (Kelley and Sweeney, 2000). Wheat fertilization recommendations state the advantages of fall-applied N (less expensive N source, applied with common tillage operation) and the advantages of spring-applied N (higher grain yield, increase in protein, timed to moisture conditions) (Sander, 1988; Davis et al., 1996).

Banding P fertilizer is recommended compared to broadcasting and incorporating P (Sander, 1988). The two most frequently used P banding methods are applying P with the seed at planting (seed) and knife application. Sander and Eghball (1999) reported that both P banding methods worked similarly with optimum wheat planting date, but seed placement produced higher yields than knife when planting was delayed.

Materials and Methods

The experimental design for our study was split-split-plot with three replications. We tested eight N and P placement and timing treatments as main plots (Table 1). Three winter wheat varieties: Akron, Lamar, and TAM 107 were the subplots. The variety subplots were further split into with and without seedrow 20 P_2O_5 (seedrow applied 5 gal 10-34-0/A) as the sub-subplots. We applied our chisel treatments using a 30 ft. dual placement N and P applicator chisel with 18 in. spaced knives during summer fallow prior to wheat planting. Seedrow P was applied at planting with the seed at 5 gal/A of 10-34-0 (20 P_2O_5/A, 6 lb N/A).

Table 1. Main Plot Treatments for Dryland Winter Wheat at Manter, 1997-2000.

Treatment	Timing	N Rate	P_2O_5 Rate	Treatments Applied 1997	1998	1999	2000
		lb/A	lb/A				
Chisel 50 N & 40 P_2O_5	Fall	62 [1]	40	--	--	x	x
Chisel 50 N & 40 P_2O_5 + 1 qt Amisorb	Fall	62 [1]	40	--	x [3]	x	x
Chisel 50 N & 20 P_2O_5	Fall	56 [2]	20	x	x	x	x
Chisel 50 N	Fall	50	0	x	x	x	x
Stream 50N	Spring	50	0	x	x	x	x
Chisel 20 P_2O_5	Fall	6	20	--	x	x	x
Chisel	Fall	0	0	x	x	x	x
No Fertilizer	None	0	0	x	x	x	x

[1] Total N is 62 lb N/A; 50 lb N/A from NH_3 and 12 lb N/A from 10-34-0.

[2] Total N is 56 lb N/A; 50 lb N/A from NH_3 and 6 lb N/A from 10-34-0.

[3] Chisel 50 N & 40 P_2O_5 + 1 qt Amisorb for 1998 was Chisel 50 N & 20 P_2O_5 + 1 qt Amisorb.

We planted the 10 ft. by 60 ft. plots during the last week of September – first week of October at 45 lb seed/A with three varieties of winter wheat: Akron, Lamar, and TAM 107. We applied the stream N treatment using 28-0-0 with a 40 ft. spray applicator with 18 in. spacing in March. We harvested the plots in late June and early July with a self-propelled combine equipped with a digital scale. We adjusted the seed yields to 12% seed moisture content. We randomly sampled the soil at 6 to 8 sites at 0 to 8 in. and 8 to 24 in. depths and sent them to the CSU Soil Testing Lab for 1997 and 1998, and for 1999 and 2000 we sent them to the Servi-Tech Laboratory for analysis. To determine phosphorus availability, the CSU Soil Testing Laboratory uses the AB-DTPA test and the Servi-Tech Laboratory uses the Mehlich-3 test. The soil was a Richfield Silty Loam. The soil test recommendation for our 40 bu/A yield goal ranged from 0 to 40 lb N/A, and 40 lb P_2O_5/A was recommended each year. No other nutrients were required. The soil test analysis is as follows:

Table 2. Soil Analysis.

Year	pH	Salts mmhos/cm	OM %	N	P	K	Zn	Fe	Mn	Cu
				ppm						
1997	7.9	0.5	1.3	9	1.5	413	0.5	4.4	14.2	2.1
1998	8.0	0.6	1.3	28	1.6	305	0.4	7.0	18.1	4.3
1999	7.9	0.7	1.0	9	11	518	0.3	--	--	--
2000	7.9	0.6	1.1	10	13	488	0.4	--	--	--

N is from 0 to 24 in. depth; all other values are from 0 to 8 in. soil depth.

<u>Results and Discussion</u>

The soil test revealed a high residual N in 1998 (Table 2) and recommended that no N was needed for our 40 bu/A yield goal. There was only a 1 bu/A difference between the no N check and all the treatments with applied N. The chisel (without N) treatment was the only treatment that produced significantly less than the no N check. Therefore, we eliminated the 1998 results from our economic analysis, because of the high residual N and lack of response from applied N. The lack of N response in 1998 demonstrates the importance of soil sampling for determining fertilization needed to meet yield goals. The application of N to the high residual soil nitrate-N levels in 1998 did not increase grain yield, although the N fertilizer no doubt increased grain protein levels (Hartman et al., 2000; Vaughan et al., 1990; Westfall et al., 1996).

N and P Application and Timing Treatments

There were very highly significant yield differences between the application treatments for all years; however none of the interactions for the application treatments and varieties and seedrow P were significant (Table 3). The non-significant interactions suggest that the varieties and seedrow P responded similarly for all application treatments.

Table 3. Analysis of variance for winter wheat grain yield for 1997-2000 as affected by variety (V), seedrow P (P), and application treatment (T).

	Grain Yield			
Variable	1997	1998	1999	2000
Variety (V)	**	**	***	†
Seedrow P (P)	**	NS	***	***
P X V	†	NS	NS	**
Application Treatment (T)	***	***	***	***
T X V	NS	NS	NS	NS
T X P	NS	NS	NS	NS
T X P X V	NS	NS	NS	NS

>0.1, not significant (NS); †, 0.1; *, 0.05; **, 0.01; and ***, 0.001 probability levels.

We used these variable costs and price for the economic analysis: chisel application, \$5.00/A; stream application, \$3.50/A; anhydrous ammonia (NH_3), \$0.15/lb of N; urea ammonium nitrate (28-0-0), \$0.25/lb of N; poly ammonium phosphate (10-34-0), \$0.34/lb of P_2O_5; Amisorb, \$6.00/qt; and a wheat price of \$2.47/bu. Chisel 50 N provided the highest average variable net income, \$15.49/A, of all the application treatments tested (Table 4). Chisel 50 N & 20 P_2O_5 and chisel 50 N & 40 P_2O_5 produced the next highest variable net incomes, \$12.50/A and \$10.95/A, respectively. The average yield of the chisel 50 N & 40 P_2O_5 treatment was 2 bu/A more than the chisel 50 N & 20 P_2O_5 treatment, but the additional 20 lbs of P_2O_5/A fertilizer cost more than the 2 bu/A increase in yield obtained.

Grain yield and variable net income were higher for 50 lb N/A fall-applied than spring-applied (Table 4). The fall-applied (summer fallow-applied) chisel 50 N treatment averaged 3.5 bu/A more yield and $9.26/A more net income than the spring-applied stream 50 N treatment. A three-year, winter wheat study conducted in Eastern Colorado (Vaughan et al., 1990) reported grain yield, protein, and net return increases with spring-applied N compared to fall-applied N. We did not measure grain protein content for our study. In our area, protein premiums are only available during low protein years: high moisture, high yield years. For the four years of our study, the only protein premium year was 1999 (personal communication with local grain elevator managers). Grain yield from our study in 1999 was twice as high as the average of the other study years. Presumably, with a two-fold increase in yield and low soil residual nitrate-N (Table 2), the grain protein content for our 1999 crop would have been below 12% (Hartman et al., 2000) and probably similar to the average protein percentage harvested for the 1999 Kansas wheat crop of 11.5% (Kansas Agricultural Statistics Service, 1999). Therefore, for the four years of our study, no protein premium would have been available, or our harvested wheat crop would not have qualified for a protein premium.

Table 4. N and P Placement and Timing of Dryland Wheat at Manter, KS for 1997, 1999, and 2000.

Treatment	Timing	1997 Grain Yield	1999 Grain Yield	2000 Grain Yield	Treatment Cost	1997 Variable Net Income	1999 Variable Net Income	2000 Variable Net Income	Average Variable Net Income
		---------bu/A--------			----------------------------$/A----------------------------				
Chisel 50 N & 40 P_2O_5	Fall	--	83	43	26.10	--	6.01	15.89	10.95
Chisel 50 N & 40 P_2O_5 + Amisorb 1Qt/A	Fall	--	81	43	32.10	--	-4.93	9.89	2.48
Chisel 50 N & 20 P_2O_5	Fall	45	80	42	19.30	15.28	5.40	16.82	12.50
Chisel 50 N (NH_3 gas)	Fall	42	78	41	12.50	14.67	7.26	24.55	15.49
Stream 50 N (28-0-0)	Spring	39	79	36	16.00	3.76	6.23	8.70	6.23
Chisel 20 P_2O_5 (10-34-0)	Fall	--	73	26	11.80	--	-4.39	-11.80	-8.10
Chisel	Fall	31	69	25	5.00	-5.00	-7.47	-7.47	-6.65
No N Check		31	70	26	0.00	0.00	0.00	0.00	0.00
Average		38	77	35					
LSD 0.05		1.5	2.1	1.5					

N applied: Chisel N (NH_3 gas, incorporated), June; Stream N (liquid 28-0-0, surface banded), March.
Treatment Cost: Chisel, $5/A; Stream, $3.50/A; NH_3, $0.15/lb; 28-0-0, $0.25/lb; 10-34-0, $0.34/lb; Amisorb, $6/qt. Wheat Price, $2.47/bu.

There was no grain yield increase with the addition of Amisorb to the high fertilizer application (chisel 50 & 40 P_2O_5) (Table 4). Since Amisorb, a fertilizer additive reported to increase the cation exchange capacity around the roots (Murphy and Sanders, 1998), provided no grain yield response at the 1 qt/A application rate tested, and costs $6.00/qt, it had a lower average variable net income than the same fertilizer application without Amisorb. In contrast to our lack of grain yield response from the addition of Amisorb, Thompson (2000) reported that the addition of Amisorb to seed-banded and foliar-sprayed fertilizers significantly increased winter wheat grain yields in all five of his study sites in Central Kansas. Reports similar to our results of no response from Amisorb, but on multiple crops, comes from studies in Eastern South Dakota on winter wheat, spring wheat, soybean, and corn that concluded the addition of Amisorb to fertilizer applications did not influence grain yields (Woodward et al., 1996 and 1997).

Two treatments, chisel 20 P_2O_5 and chisel, consistently had negative variable net incomes compared to the no N check (Table 4). The chisel treatment without fertilizer application was included to test tillage affects from chiseling. The chisel treatment reduced yield by less than 1 bu/A compared to the no N check and the chisel operation cost $5.00/A. The slight decrease in yield from chisel may be due to moisture loss from tillage.

Seedrow P

Seedrow P compared to no seedrow P produced very significant grain yield differences for all fertilizer responsive years (Table 3). The seedrow 20 P_2O_5 treatment produced 4 to 5 bu/A more and increased average variable net income by $3.38/A more than without seedrow P (Table 5). The grain yield response to seedrow P for our study is less than that reported for winter wheat in Southeastern Nebraska of 11 bu/A (Sander and Eghball, 1999). The 11 bu/A increase is derived from the two-year average of seed-applied P for September planting date to the no P fertilizer check.

Table 5. Grain Yield and Variable Net Income of Seedrow P Fertilizer on Dryland Wheat at Manter, KS, 1997, 1999, and 2000.

	Grain Yield				Average Variable Net
Placement	1997	1999	2000	Treatment Cost	Income
	---------------bu/A--------------			$/A	$/A
Seedrow 20 P_2O_5	40	79	37	6.80	3.38
No Seedrow P Fertilizer	35	75	33	0.00	0.00
Average	38	77	35		
LSD 0.05	2.4	1.6	0.6		

Seedrow P was applied at planting with the seed at 5 gal 10-34-0/A (20 lb P_2O_5/A).
Treatment Cost: P_2O_5, $0.34/lb. Wheat Price, $2.47/bu.

Seedrow P at 20 lb P_2O_5/A was a profitable fertilizer application: however, applying the same P rate with a chisel, chisel 20 P_2O_5, produced the lowest average variable net income of all the application treatments tested (Table 4). Since the chisel 20 P_2O_5 treatment was applied with knives spaced 18 in. apart to a depth of 6 in., the probability of wheat roots intercepting this band of P fertilizer is far less than when P fertilizer is banded with the seed (Sander and Eghball, 1999).

The interactions between variety and seedrow P produced significant grain yield differences in 1997 and 2000 (Table 3). This interaction between variety and seedrow P suggests that the varieties responded differently to seedrow P application. Akron had a greater grain yield response to seedrow P than TAM 107 or Lamar in 1997; grain yields of all three varieties responded similarly to seedrow P in 1999; grain yield response to seedrow P for Lamar was less than that for TAM 107 or Akron in 2000 (Fig. 1). The reason for grain yield response differences to seedrow P for the wheat varieties tested is unclear.

Winter Wheat Varieties

There were grain yield differences between the varieties for all four years of our study (Table 3). In two of four years (1997 and 1999), Akron produced significantly higher yield than Lamar (Table 6). For all four years of our study, TAM 107 produced higher yield than Akron and Lamar. These varietal yield rankings were reflected in the winter wheat variety studies conducted at the Plainsman Research Center in Southeastern Colorado at Walsh. The dryland winter wheat variety strips for forage and grain yield studies conducted at Walsh, Colorado from 1997 to 2000 reported that the grain yield of TAM 107 was either significantly greater than Lamar, or there was no significant difference between TAM 107 and either Lamar or Akron (data not shown).

Table 6. Grain Yields of Wheat Varieties Across N and P Placement and Timing Applications, Manter, KS, 1997-2000.

	Grain Yield			
Variety	1997	1998	1999	2000
	----------------------bu/A--------------------			
TAM 107	39	43	84	36
Akron	38	40	76	34
Lamar	35	39	70	35
Average	38	41	77	35
LSD 0.05	2.4	1.9	3.2	1.3

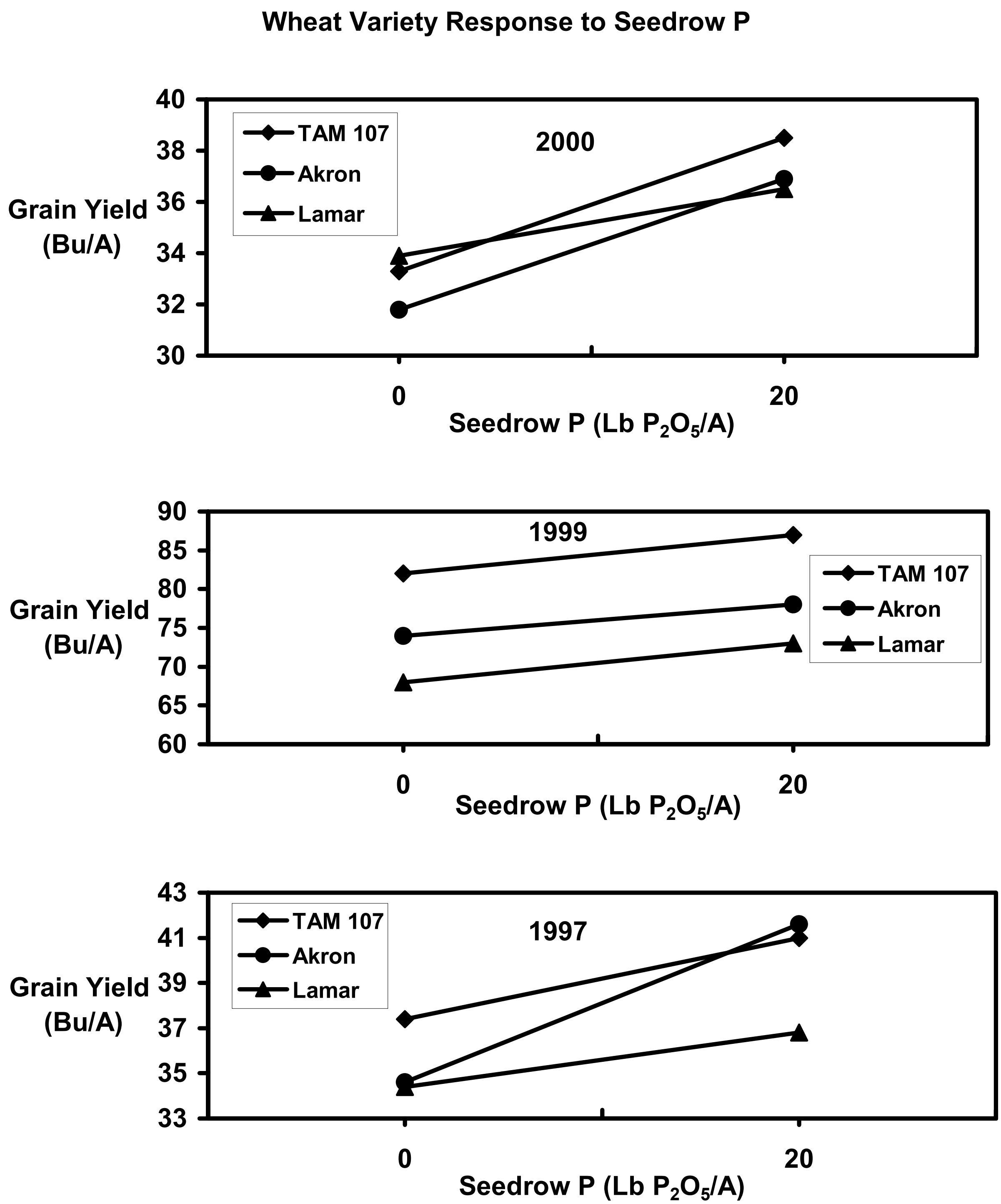

Fig. 1. Wheat variety response with and without seedrow P. Poly ammonium phosphate was applied with the seed at planting at 5 gal 10-34-0/A (20 lb P_2O_5/A, 6 lb N/A) to three hard red winter wheat varieties: TAM 107, Akron, and Lamar.

Conclusion

Amisorb did not increase winter wheat grain yields in our studies. There appears to be no economic advantage for adding Amisorb to fertilizers.

Of the three winter wheat varieties that we tested, TAM 107 was consistently higher yielding than Akron and Lamar.

The fall-applied chisel N application provided the highest variable net income of all the application methods tested. Fall-applied chisel N produced higher average yield and net income than spring-applied stream N. Multiple studies (Goos et al., 1982; Hartman et al., 2000; Sander, 1988; Vaughan et al., 1990; Westfall et al., 1996) report that spring-applied N increases wheat protein. Nonetheless, protein premiums are only available in our area when average protein levels are low, that is, high-precipitation, high-yield years. Protein premiums are not available for average and dry years when protein levels are high. The hard red winter wheat crop from Kansas and surrounding area determines the national protein premiums. There is little or no opportunity for N fertilization management for protein for the hard red winter wheat area of Kansas and surrounding area. We believe it is economically unwise to annually fertilize solely for potential protein premiums in our area. However, protein premiums for the hard red spring wheat crop of the Northern Plains can be a manageable, economically viable option (Hartman et al., 2000). The hard red winter wheat crop of Kansas and the surrounding area is harvested months before the hard red spring wheat crop of the Northern Plains, thus protein levels are known and N fertilization for protein premiums can be a practical and beneficial tool for wheat growers in the Northern Plains.

Dual placement of N and P produced high variable net incomes, second only to chisel N. The soil test analysis for our study site recommended a broadcast application of 40 lb P_2O_5/A. With dual N and P placement, the 20 lb P_2O_5/A rate, half the recommended rate, produced a higher variable net income than the 40 lb P_2O_5/A rate. With our low P soil analysis, as little as one-third the recommended broadcast rate may have been a sufficient P rate if seed-banded (Peterson et al., 1981). Banding P makes more P available for roots than broadcast P, especially in calcareous soils where lime binds the P.

The seedrow P application was a more effective P fertilizer banding method than chisel P. The probability of the roots coming into contact with seedrow-applied P is much greater than with chisel P (Sander and Eghball, 1999). Seedrow P averaged 4 to 5 bu/A more than no seedrow P. The combination of TAM 107, seedrow P, and chisel N produced the highest variable net income of the application treatments and varieties tested.

References

Christensen, N. W. and V. W. Meints. 1982. Evaluating N fertilizer sources and timing for winter wheat. Agron. J. 74:840-844.

Davis, J. G., D. G. Westfall, J. J. Mortvedt, and J. F. Shanahan. 1996. Fertilizing winter wheat. Fact Sheet 0.544. Colorado State Univ. Coop. Ext., Fort Collins.

Goos, R. J., D. G. Westfall, A. E. Ludwick, and J. E. Goris. 1982. Grain protein content as an indicator of N sufficiency for winter wheat. Agron. J. 74:130-133.

Hartman, M., R. McKenzie, and R. Andreiuk. 2000. High protein wheat production. Agdex 112/20-4. Alberta Agriculture, Food and Rural Development. http://www.agric.gov.ab.ca/agdex/100/112_20-4.html.

Kansas Agricultural Statistics Service. 1999. Wheat quality bulletin, 1999. NASS, USDA, KASS, and KDA. http://www.nass.usda.gov.81/ipedb/.

Kelley, K. W. and D. W. Sweeney. 2000. Effects of previous crop, nitrogen rate, and nitrogen method on nitrogen requirement for winter wheat. Kansas Fertilizer Research, 1999. Report of Progress 847. AES, CE, Kansas State Univ., Manhattan.

Kolberg, R. L., D. G. Westfall, G. A. Peterson, N. R. Kitchen, and L. Sherrod. 1993. Nitrogen fertilizer of dryland cropping systems. Colorado State Univ. Agric. Exp. Stn. Tech. Bull. TB 93-6.

Murphy, L. S. and J. L. Sanders. 1998. Amisorb in Great Plains crop production. Great Plains Soil Fertility Conference Proceedings, 1998. Denver, March 3-4, 1998. Vol. 7:214-219.

Peterson, G. A., D. H. Sander, P. H. Grabouski, and M. L. Hooker. 1981. A new look at row and broadcast phosphate recommendations for winter wheat. Agron. J. 73:13-17.

Sander, D. N. 1988. How to apply fertilizer to wheat. NebGuide G88-889-A. Coop. Ext., Institute of Agric. and Nat. Res., Univ. of Nebraska-Lincoln.

Sander, D. H. and B. Eghball. 1999. Planting date and phosphorus fertilizer placement effects on winter wheat. Agron. J. 91:707-712.

Thompson, C. A. 2000. Effects of liquid Amisorb on winter wheat in central Kansas. Kansas Fertilizer Research, 1999. Report of Progress 847. AES, CE, Kansas State Univ., Manhattan.

Vaughan, B., D. G. Westfall, and K. A. Barbarick. 1990. Nitrogen rate and timing effects on winter wheat grain yield, grain protein, and economics. J. Prod. Agric. 3:324-328.

Westfall, D. G., J. L. Havlin, G. W. Hergert, and W. R. Raun. 1996. Nitrogen management in dryland cropping systems. J. Prod. Agric. 9:192-199.

Woodard, H. J., A. Bly, and D. Winter. 1996. The effect of Amisorb applications on growth and yield parameters of corn, soybean, and hard red spring wheat in Eastern South Dakota. Project no. 23696A and B, 24196, and 24596. SDSU Soil Fertility Project Website. South Dakota State Univ., Brookings. http://www.plantsci.sdstate.edu/woodardh/soilfert.

Woodard, H. J., A. Bly, and D. Winther. 1997. Influence of Amisorb fertilizer additive in hard red winter wheat, hard red spring wheat, and corn during 1997. Project no. 26197, 24097, and 26697. SDSU Soil Fertility Project Website. South Dakota State Univ., Brookings. http://www.plantsci.sdstate.edu/woodardh/soilfert.

[1] L. Herron is a dryland wheat farmer in Southwestern Kansas at Manter.

K.J. Larson is a Research Scientist for Colorado State University Agricultural Experiment Station at the Plainsman Research Center in Walsh, Colorado.

For e-mail comments, contact the authors at Kevin.Larson@colostate.edu

Published - March, 2003