Wheat Grain Yield Response to Phosphorus and Potassium Fertilizer Rate

N.A. Slaton, R.E. DeLong, M. Mozaffari, S. Clark, C. Allen, and R. Thompson

BACKGROUND INFORMATION AND RESEARCH PROBLEM

Phosphorus (P) is a common yield-limiting nutrient for winter wheat (*Triticum aestivum* L.) grown in Arkansas. Because wheat frequently shows P deficiency and responds favorably to P fertilization, numerous research trials have been performed to improve P fertilization recommendations. In contrast, few studies have been conducted to determine how wheat responds to K fertilization. Sweeney et al. (2000) reported that potassium (K) fertilization increased yields and reduced leaf rust severity of wheat cultivars rated as susceptible to leaf rust. Snyder and Mascagni (1998) reported similar benefits of P and K fertilization on wheat yields and disease suppression in Louisiana. According to a USDA survey of Arkansas wheat growers, P and K fertilizers were applied to 28% of the soft red winter wheat acreage in Arkansas with an average application rate of 37 lb P_2O_5 and 48 lb K_2O $acre^{-1}$ (USDA-NASS, 2001).

Soil-test results are used by many farmers to determine whether P and K fertilizers should be applied to wheat. Soil-test-based fertilizer recommendations must be adequately researched to determine the range of soil-test nutrients within which wheat responds to P and K fertilization and to calibrate the optimum fertilizer rates needed to produce maximum yields for P- and K-deficient soils. A large number of fertilization trials must be conducted to provide accurate fertilization recommendations. During the 2006 to 2007 growing season, P and K fertilization trials were established with the ultimate objectives of i) identifying the critical soil P and K availability index (Mehlich-3) values for which winter wheat requires fertilization, and ii) calibrating the appropriate fertilizer rates that should be recommended for each soil-test level.

PROCEDURES

Field studies were established during the fall of 2006 to evaluate the effect of P and K fertilization rate on wheat yield. Tests were located in commercial production fields on a Dundee silt loam in Poinsett County (Trumann) following corn (*Zea mays* L.) and a Hillemann silt loam in Poinsett County (White Hall) following soybean [*Glycine max* (Merr) L.]. The tillage practices, wheat cultivar, previous crop, and dates of agronomic importance for each site are listed in Table 1.

Individual plots consisted of 9 or 10 rows of wheat that were 20-ft long and separated from adjacent plots by a 12- to 24-inch-wide alley. A composite soil sample (0- to 4-inch depth, $n = 6$) was taken from each replicate at each site to determine soil chemical properties. Soil was oven-dried, crushed, and passed through a 2-mm sieve for measurement of Mehlich-3-extractable nutrients, organic matter by weight loss on ignition, and soil, water, and salt pH. Mean values of selected soil chemical properties are listed in Table 2.

Planting, pest control, and N fertilization of wheat were performed by each cooperating grower and were identical to the management practices applied to the field surrounding each test. Wheat was drill seeded at the Trumann site and broadcast and incorporated at White Hall. Potassium fertilizer (100 lb muriate of potash/acre) was applied to P trials and P fertilizer (130 lb triple superphosphate/acre) was applied to K trials in the fall or early winter to ensure these nutrients were not yield-limiting factors. Phosphorus fertilizer treatments were applied to the soil surface after wheat was seeded at rates of 0, 30, 60, 90, or 120 lb P_2O_5/acre as triple superphosphate. Potassium fertilizer treatments were applied to the soil surface at rates of 0, 40, 80, 120, or 160 lb K_2O/acre as muriate of potash.

Whole, aboveground plant samples were taken at Feekes stage 10.1 (early heading) at both sites to determine whole-plant P and K concentrations. For the Trumann site, a 3-ft section of the first inside row was cut at the soil surface, placed in a paper bag, oven-dried at 60°C to a constant weight, and ground to pass a 1-mm sieve. Because the White Hall site was broadcast seeded, a sample of wheat plants was collected from an area near the edge of each plot. A 0.25 g sub-sample was digested in concentrated HNO_3 and 30% H_2O_2 and analyzed for nutrient concentration. At maturity, grain yields were measured by harvesting the middle rows of each plot with a small-plot combine. Grain yields were adjusted to a uniform moisture content of 13% moisture.

For each experiment, fertilizer rates were arranged in a randomized complete block design with six replicates per treatment. Each experiment was analyzed separately. Analysis of variance procedures were conducted with the PROC GLM procedure in SAS v9.1 (SAS Institute, Inc., Cary, N.C.). Mean separations were performed using Fisher's Protected Least Significant Difference method at a significance levels of 0.05 and 0.10.

RESULTS AND DISCUSSION

The soil-test level associated with the average Mehlich-3-extractable P was classified as 'Very Low' (<16 ppm) at White Hall and 'Optimum' (36 to 50 ppm) at Trumann (Table 2). Based on the University of Arkansas fertilizer guidelines for winter wheat, the recommended P-fertilizer rates were 100 lb P_2O_5/acre for White Hall and 0 lb P_2O_5/acre for Trumann. The revised recommendations were designed to build and maintain soil-test P concentrations in the 'Medium' (26 to 35 mg P/kg) soil-test category for wheat yields of 70 bu/acre. For K trials, the average Mehlich-3-extractable K was 'Medium' for White Hall (91 to 130 ppm) and 'Optimum' (131 to 175 ppm) for Trumann. The recommended rates of K fertilizer were 60 lb K_2O/acre for White Hall and 0 lb K_2O/acre for Trumann.

Whole-plant P and K concentrations of wheat at early heading were not affected significantly by P or K rate for wheat grown at Trumann (Table 3), which contained optimum soil-test P and K levels (Table 2). However, P and K concentrations of wheat grown at White Hall were significantly affected by P and K fertilizer rate (Table 3). Phosphorus concentrations declined significantly as P rate increased. Although wheat dry matter production was not measured in this study, visual observations of wheat growth among P rates clearly indicated that P fertilization increased wheat growth dramatically in all replications. The decline in tissue P concentrations was likely due to increased dry matter production, which is known as a 'dilution effect'. Late-planted wheat has been shown to respond more readily to P fertilization than wheat planted at optimal dates and has potential to offset some of the negative influence of late seeding (Blue et al., 1990). In contrast to P, wheat K concentrations increased as K rate increased (Table 3). Potassium fertilization had no visually detectable influence on wheat dry matter production like P. Plant tissue samples were taken after freezing temperatures (-2 to -4°C or 24 to 28°F in northeast Arkansas) occurred on 7 and 8 April.

Wheat yield potential at both sites was affected negatively by the freezing temperatures in early April. Reports throughout Arkansas indicated that early planted and well-fertilized wheat may have suffered the greatest damage from the freezing temperatures. Wheat yields in these studies (Table 4) would be considered 'below average' in most years, however, for the 2006 to 2007 production year, these yields were considered average or better than average.

Wheat yields were affected significantly by fertilizer treatments only in the P-rate study at White Hall (Table 4). Grain yield declined significantly when >30 lb P_2O_5/acre were applied to the Hillemann soil with very low soil-test P. This was surprising because visual observations indicated that wheat vegetative growth and tillering increased dramatically as P rate increased. The increased growth may have promoted early maturity and increased wheat yield potential which subsequently increased yield loss due to freeze damage. Wheat at White Hall had not yet headed when the freezing temperatures occurred, but P may have accelerated plant development such that wheat plants receiving P were at a growth stage more sensitive to freezing temperatures than wheat receiving no P or only low rates of P. Although wheat yields at the Truman site or the K-rate trial in the Hillemann soil were not affected significantly by fertilizer treatments, they also showed that numerical wheat yields tended to decline as fertilizer rate increased. These data hint, but do not conclusively prove, that well fertilized wheat, especially with P, may be more susceptible to freeze damage.

PRACTICAL APPLICATION

The potential benefits of providing sufficient P and K for wheat, as well as other plants, often include promoting early plant maturity, resistance to diseases and other pests, stalk strength, tillering, vigorous growth, and improved yield. During the 2006 to 2007 growing season some of these potential benefits (e.g., early maturity) were realized, but were offset by the abnormally cold temperatures that damaged developing wheat grain in early April. Data collected from P and K rate trials during the 2006 to 2007 growing year will not be used in the database being developed to correlate soil-test recommendations and calibrate fertilizer rates for P and K due to significant damage from freezing temperatures that influenced wheat yield potential. Although these data do not aid in developing soil-test-based recommendations they may be useful at some future time for evaluating wheat response to fertilization in abnormal climatic conditions.

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Table 1. Selected agronomic information for P-rate trials with winter wheat conducted during the 2006 to 2007 growing season.

			Tillage/	Date of event		
Site	Soil series	Cultivar	previous crop	Plant	P applied	Harvest
				---------- (month/day) ----------		
White Hall	Hillemann	DK 9577	Conv/Soybean	Nov 27	Dec 18	June 8
Trumann	Dundee	Armor 3035	Conv/Corn	Oct 16	Dec 18	June 8

Table 2. Selected soil chemical property means (n = 6) of phosphorus and potassium fertilization trials conducted during the 2006 to 2007 growing season .

		Soil	Mehlich-3-extractable nutrients										
Nutrient site	SOM	pH	P[z]	K[x]	Ca	Mg	S	Na	Fe	Mn	Cu	Zn	B
	(%)		---------- (ppm) ----------										
Phosphorus													
White Hall	2.8	7.7	10	106	2029	285	22	32	257	153	1.7	1.9	1.0
Trumann	2.3	6.9	36	134	2101	356	13	22	262	38	2.2	4.9	0.9
Potassium													
White Hall	2.8	7.5	10	98	1775	281	23	31	253	151	1.5	1.7	0.8
Trumann	2.5	6.7	47	154	1954	344	12	16	268	46	2.0	5.0	0.9

[z] Standard deviation (n=6) of soil-test P in P trials was 1.7 ppm for the Hillemann soil at White Hall and 4.1 ppm for the Dundee soil at Trumann.

[y] Standard deviation (n=6) of soil-test K in K trials was 9.4 ppm for the Hillemann soil and 29.7 ppm for the Dundee soil.

Table 3. Winter wheat whole-plant P and K concentrations at Feekes stage 10.1 as affected by P and K fertilizer application rates at two sites during the 2006 to 2007 growing season.

Phosphorus trials			Potassium trials		
P rate	Trumann	White Hall	K rate	Trumann	White Hall
(lb P_2O_5/acre)	---------- (% P) ----------		(lb K_2O/acre)	---------- (% K) ----------	
0	0.25	0.30	0	2.07	1.32
30	0.27	0.27	0	2.27	1.46
60	0.28	0.28	80	2.36	1.58
90	0.28	0.26	120	2.20	1.83
120	0.28	0.24	160	2.28	1.90
P-value	0.1273	0.0050	*P*-value	0.2121	0.0024
LSD(0.10)	NS[z]	0.023	LSD(0.10)	NS	0.240

[z] NS = not significant (P>0.10).

Table 4. Winter wheat grain yields as affected by P and K fertilizer application rate at two sites during the 2006 to 2007 growing season.

Phosphorus trials			Potassium trials		
P rate	Trumann	White Hall	K rate	Trumann	White Hall
(lb P_2O_5/acre)	---------- (bu/acre) ----------		(lb K_2O/acre)	---------- (bu/acre) ----------	
0	0.25	0.30	0	2.07	1.32
0	50	39	0	50	39
30	48	42	40	52	38
60	47	36	80	51	31
90	47	35	120	49	37
120	46	33	160	48	37
P-value	0.1326	0.0178	*P*-value	0.6527	0.2702
LSD(0.05)	NS[z]	5	LSD(0.05)	NS	NS
LSD(0.10)	NS	4	LSD(0.10)	NS	NS

[z] NS = not significant (P>0.10).