

Final Report

Arizona Grain Research and Promotion Council

October, 2009

Response of wheat and barley varieties
to phosphorus fertilizer

Mike Ottman
University of Arizona

Response of wheat and barley varieties to phosphorus fertilizer, 2009

M. J. Ottman

Summary

Phosphorus fertilizer represents a significant portion of the cost of producing small grains. Some evidence exists that there are differences in the ability of small grain varieties to take phosphorus up from the soil and utilize this nutrient in the grain. The objective of this study is to determine if barley and wheat varieties grown in Arizona differ in their response to phosphorus fertilizer. A study was initiated at the Maricopa Agricultural Center testing the response of 7 barley and 13 wheat (12 durum wheat and 1 bread wheat) varieties to 2 phosphorus rates (0 and 100 lbs P₂O₅/acre). The grain yield increase due to phosphorus application averaged across varieties was 474 lbs/acre for barley and 613 lbs/acre for wheat. The barley varieties differed in their grain yield increase due to phosphorus fertilizer and the greatest increase for the commercial varieties tested was 906 lbs and the smallest increase was 245 lbs. We have no statistical evidence that wheat varieties differed in their response to phosphorus fertilizer. The lack of response to phosphorus fertilizer for a particular variety may save production costs if the fertilizer is not applied, but a significant response to phosphorus fertilizer may pay for the fertilizer cost and increase profits. In this study, the higher yielding varieties tended to have a greater response to phosphorus fertilizer, particularly for the barley. This test will be repeated in 2010 to see if the results obtained this year can be duplicated.

Introduction

Phosphorus fertilizer costs have increased dramatically in the past few years. In small grain production, fertilizer represents a significant proportion of the cost of production. The availability of soil P can be influenced by root exudates, which are under genetic control (Rengel, 2002). Small grain varieties may differ in their response to phosphorus fertilizer due to the presence or absence of these exudates or other factors (Davies et al., 2002). Citric acid is one of the root exudates that have been identified and related to phosphorus availability. The objective of this study is to determine if wheat and barley varieties grown in Arizona differ in their response to phosphorus fertilizer.

Procedure

A study was conducted at the University of Arizona Maricopa Agricultural Center to determine if wheat and barley varieties respond to phosphorus fertilizer differently. The soil type was a Casa Grande sandy loam with a preplant soil phosphate level of 4.3 ppm P. P fertilizer treatments were applied before planting at rates of 0 and 100 lbs P₂O₅/acre using triple super phosphate (0-45-0) as a fertilizer source. The P fertilizer was applied by hand to plots 5 ft x 20 ft in size. The seed was planted with a cone planter in seven rows spaced 7 inches apart and 20 ft long. The seeding rate was approximately 100 lbs/acre for durum varieties and 85 lbs/acre for barley varieties. The experimental design of the P x Variety Study was a split plot with varieties (9 barley and 13 wheat [12 durum wheat and 1 bread wheat]) as main plots and P rate (0 and 100 lbs P₂O₅/acre) as subplots. A P Rate Study with a wider range of P rates (0, 25, 50, 75, 100, and 150 lbs P₂O₅/acre) and a single variety (Gustoe barley and Kronos durum)

was also conducted to determine if the P rate of 100 lbs P₂O₅/acre is adequate for optimum yield. Cultural practices are listed in Table 1. The following data was collected: grain yield, test weight, plant height, lodging, heading, flowering, physiological maturity, grain P, grain protein, HVAC, biomass and light interception on Feb 3 at the 5 leaf stage, and light interception on Apr 4 at the milky kernel stage. Grain was harvested with a small plot combine and yields are expressed on an “as is” moisture basis. HVAC was determined from 10 g of seed. Grain protein was calculated using the combustion method to obtain total N, which was multiplied by 5.7 to obtain protein content and expressed on a 12% moisture basis. Flowering is defined as when about half of the heads are shedding pollen and physiological maturity is defined as when the glumes turn brown. Biomass was determined from a pair of rows each 18 inches in length. Light interception was determined by dividing the average of six readings from a sunflecks ceptometer at ground level by incident light level. Abbreviations for the sources of varieties are: APB = Arizona Plant Breeders, WPB = Western Plant Breeders, WWW = World Wide Wheat, UC = University of California.

Results and Discussion

This growing season was characterized by above average temperature and low rainfall (Table 2). Temperatures were especially warm during the months of January and May. Temperatures during April were below average.

P rate study (6 P rates and 1 barley and 1 wheat variety):

Grain yields of Gustoe barley and Kronos durum were increased by phosphorus rates from 0 to 150 lbs P₂O₅/acre (Table 3). Yield of Gustoe were increased even at the 150 lbs/acre rate whereas yield of Kronos reached a plateau at about 75 lbs P₂O₅/acre. The seed of Gustoe germinated poorly resulting in poor stand establishment, which may explain the lack of a yield plateau for this variety. A different source of seed for Gustoe with better germination was used in the P x Variety study to be discussed below. P rate also increased plant height; decreased time to heading, anthesis, and maturity; increased grain P content; decreased wheat protein; and increased barley biomass and light interception measured on Feb 3.

P x variety study (2 P rates and 9 barley and 13 wheat varieties)

We measured a P response to most variables (Tables 4-7). P increased yield, test weight, plant height (barley), grain phosphorus, biomass and light interception; decreased time to heading, anthesis, and maturity; but had no effect on plant height (wheat), grain P, and protein.

The varieties responded to an application of 100 lbs P₂O₅/acre in a similar manner for most of the variables measured (Tables 4-7). However, the P application response was different for barley varieties for grain yield and light interception on Feb 3 and for wheat varieties for heading, anthesis, and light interception on Feb 3.

The barley grain yield response to P application ranged from -272 to 906 lbs/acre. The grain yield response to P application was correlated with absolute yield. The variety that had the greatest response to P also had the highest yield, and the variety that had the negative response to P had the lowest yield. The increase in light interception on Feb 3 due to P application ranged from 15 to 28% for barley and 6 to 28% for wheat. The increase in light interception on Feb 3 for the varieties was not necessarily related to yield. Lack of P application delayed heading and anthesis dates in wheat by as much as 4 to 6 days for certain varieties, but this delay did not affect maturity and was not related to yield.

In summary, a small or negligible response to phosphorus fertilizer for a particular variety may save production costs if the fertilizer is not applied, but a significant response to phosphorus fertilizer may pay for the fertilizer cost and increase profits.

Acknowledgments

Financial support for this project was received from the Arizona Grain Research and Promotion Council and the Arizona Crop Improvement Association. The technical assistance of Mary Comeau and Mike Sheedy is greatly appreciated.

References

Davies, T.G.E., J. Ying, Q. Xu, Z.S. Li, J. Li, and R. Gordon-Weeks. 2002. Expression analysis of putative high-affinity phosphate transporters in Chinese winter wheats. *Plant, Cell and Environment*. 25:1325-1339.

Rengel, Z. 2002. Genetic control of root exudation. *Plant and Soil* 245:59-70.

Table 1. Cultural practices for the small grain phosphorus trial at Maricopa.

Previous crop	Corn
Soil texture	Sandy loam
Planting date	12/12/08
Irrigations	7 12/12, 1/28, 2/25, 3/13, 3/27, 4/9, 4/22
Nitrogen (lbs N/a)	246 12/12: 46 as 46-0-0 1/28: 50 as 32-0-0 2/25: 50 as 32-0-0 3/13: 50 as 32-0-0 3/27: 50 as 32-0-0
Phosphorus (lbs P ₂ O ₅ /acre)	0 or 100
Pesticides	None
Harvest date	6/3

Table 2. Climatic data from AZMET for Maricopa during the 2008-09 growing season compared to the long-term average.

Climate variable	Unit	Year(s)	Dec	Jan	Feb	Mar	Apr	May	Dec-May
Max Temp.	°F	2009	65	70	72	79	84	98	78
	°F	Avg	65	66	70	77	85	95	76
Min Temp.	°F	2009	38	38	39	45	49	66	46
	°F	Avg	35	36	39	44	51	60	44
Ppt.	inches	2009	1.06	0.11	0.52	0.00	0.08	0.15	1.92
	inches	Avg	0.62	0.72	0.85	0.79	0.26	0.20	3.43

Table 3. Phosphorus rate effect on grain yield and other plant characteristics for ‘Gustoe’ barley and ‘Kronos’ durum.

P rate	Yield	Test Weight	Plant Height	Head-ing	Anth-esis	Mat-urity	Grain Phos-phorus	Grain Protein	HVAC	Bio-mass	Light inter-ception	Light inter-ception
lbs/A	lbs/A	lbs/bu	inches				%	%	%	(Feb 3) lbs/A	(Feb 3) %	(Apr 2) %
<u>Barley</u>												
0	6687	51.3	27.5	3/29	3/27	5/04	0.278	13.9	---	355	20	95
25	6944	51.2	28.5	3/27	3/25	5/04	0.284	14.1	---	386	31	97
50	7195	51.6	29.3	3/28	3/26	5/04	0.301	13.1	---	554	28	97
75	7030	51.3	28.8	3/28	3/26	5/04	0.276	12.9	---	516	32	97
100	7380	51.7	28.5	3/27	3/25	5/04	0.315	13.3	---	510	35	97
150	7897	51.7	27.5	3/27	3/26	5/03	0.358	13.7	---	585	35	97
All	7189	51.5	28.3	3/27	3/26	5/04	0.302	13.5	---	484	30	97
P rate	*	*	NS	NS	NS	NS	**	NS	NS	*	*	NS
Linear	**	*	NS	+	NS	+	**	NS	NS	**	**	NS
Quad	NS	NS	*	NS	NS	NS	*	NS	NS	NS	NS	NS
Cubic	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	+
<u>Durum</u>												
0	6051	62.5	32.8	3/17	3/21	4/28	0.296	14.0	100.0	610	46	90
25	6881	62.4	34.8	3/16	3/20	4/27	0.318	14.1	99.9	753	60	94
50	6874	62.6	34.5	3/16	3/20	4/27	0.35	14.2	99.9	784	59	93
75	7195	62.8	34.8	3/16	3/20	4/27	0.353	13.5	99.8	821	58	93
100	7073	62.9	33.5	3/16	3/20	4/28	0.365	13.7	99.7	703	60	94
150	7168	63.1	34.0	3/16	3/20	4/28	0.346	13.5	99.7	790	56	92
All	6874	62.7	34.0	3/16	3/20	4/27	0.338	13.8	99.8	744	56	93
P rate	**	**	NS	**	NS	NS	**	NS	NS	NS	**	NS
Linear	**	**	NS	**	*	NS	**	+	NS	NS	+	NS
Quad	*	NS	NS	*	NS	+	**	NS	NS	NS	**	NS
Cubic	NS	NS	+	*	NS	*	NS	NS	NS	NS	+	NS

Table 4. Grain yield, test weight, and plant height of barley and wheat varieties as affected by phosphorus fertilizer rates of 0 and 100 lbs P₂O₅/acre. "Response" refers to the difference between the phosphorus rates. The wheat varieties are durums except for Yecora Rojo, which is a bread wheat.

Entry	Source	Grain Yield			Test Weight			Plant Height		
		Phosphorus								
		0 lb/A	100 lb/A	Response	0 lb/A	100 lb/A	Response	0 lb/A	100 lb/A	Response
		lbs/A			lbs/bu			inches		
		<u>Barley</u>								
Chico	WPB	6544	7355	811	50.5	51.2	0.7	25.4	26.3	0.9
Cochise	WPB	6798	7083	285	50.3	51.0	0.7	27.0	27.9	0.9
Gustoe	WPB	7050	7578	528	50.9	51.1	0.2	27.2	27.6	0.4
Nebula	WPB	7216	7698	482	51.3	51.6	0.3	29.6	31.5	1.9
Commander	WWW	7170	7676	506	50.3	50.7	0.4	28.9	29.4	0.5
Max	WWW	7763	8669	906	49.7	50.9	1.2	28.0	29.4	1.4
Baretta	APB	6972	7217	245	50.6	51.7	1.1	27.5	29.3	1.8
ARGBA2042	WWW	6130	5858	-272	52.5	52.6	0.1	36.3	35.8	-0.5
Unknown	APB	6480	6642	162	52.9	53.5	0.6	34.5	34.3	-0.2
Avg	---	6995	7469	474	50.8	51.4	0.6	28.7	29.6	0.9
LSD _{.05} *		499	499	487	0.7	0.7	NS	1.3	1.3	NS
Entry		**			**			**		
P rate		**			**			**		
Entry x P		NS			NS			NS		
		<u>Wheat</u>								
Alamo	WPB	5536	6344	808	63.6	64.0	0.4	35.1	35.3	0.2
Havasu	WPB	6009	6756	747	63.7	63.8	0.1	34.0	33.9	-0.1
Orita	WPB	5821	6995	1174	60.5	61.3	0.8	33.9	33.9	0.0
WPB-881	WPB	6236	6736	500	62.3	62.6	0.3	33.9	35.1	1.2
Crown	WWW	5974	6526	552	60.2	60.6	0.4	36.4	35.9	-0.5
Duraking	WWW	6459	7144	685	62.8	63.3	0.5	33.3	33.4	0.1
Q-Max	WWW	5021	6012	991	58.9	60.1	1.2	36.9	36.1	-0.8
Kronos	APB	6407	6845	438	62.4	62.6	0.2	33.0	33.1	0.1
Sky	APB	6269	6606	337	61.4	61.9	0.5	30.3	30.8	0.5
Ocotillo	APB	5636	6162	526	62.6	62.8	0.2	36.4	35.8	-0.6
Westmore	APB	6348	6900	552	63.1	63.4	0.3	32.9	32.4	-0.5
Maestrals	Allstar	5767	6411	644	62.9	62.3	-0.6	36.8	36.1	-0.7
Yecora Rojo	Public	6277	6581	304	62.9	62.9	0.0	29.1	30.6	1.5
Avg	---	5990	6603	613	62.1	62.4	0.3	34.0	34.0	0.0
LSD _{.05} *		492	492	NS	0.7	0.7	NS	1.1	1.1	NS
Entry		**			**			**		
P rate		**			**			NS		
Entry x P		NS			NS			NS		

* LSD.05 = least significant difference between means within a column with a 5% or less probability the difference is due to chance.

Table 5. Heading, anthesis, and physiological maturity of barley and wheat varieties as affected by phosphorus fertilizer rates of 0 and 100 lbs P₂O₅/acre. "Response" refers to the difference between the phosphorus rates. The wheat varieties are durums except for Yecora Rojo, which is a bread wheat.

Entry	Source	Heading			Anthesis			Physiological Maturity		
		Phosphorus								
		0 lb/A	100 lb/A	Response	0 lb/A	100 lb/A	Response	0 lb/A	100 lb/A	Response
<u>Barley</u>										
Chico	WPB	3/23	3/20	-3	3/21	3/18	-3	4/30	4/29	-1
Cochise	WPB	3/14	3/10	-4	3/13	3/09	-4	4/21	4/21	0
Gustoe	WPB	3/26	3/22	-4	3/24	3/21	-3	5/01	4/30	-1
Nebula	WPB	3/21	3/17	-4	3/19	3/16	-3	4/26	4/26	0
Commander	WWW	3/25	3/23	-2	3/23	3/21	-2	5/01	4/28	-3
Max	WWW	3/24	3/21	-3	3/23	3/19	-4	5/05	5/03	-2
Baretta	APB	3/23	3/20	-3	3/21	3/19	-2	4/27	4/25	-2
ARGBA2042	WWW	3/13	3/10	-3	3/12	3/10	-2	4/20	4/19	-1
Unknown	APB	3/19	3/15	-4	3/17	3/14	-3	4/22	4/20	-2
Avg	---	3/21	3/18	-3	3/20	3/17	-3	4/28	4/26	-2
LSD _{.05} *		2	2	NS	2	2	NS	2	2	NS
Entry		**			**			**		
P rate		**			**			**		
Entry x P		NS			NS			NS		
<u>Wheat</u>										
Alamo	WPB	3/18	3/17	-1	3/22	3/21	-1	4/30	4/30	0
Havasu	WPB	3/18	3/17	-1	3/22	3/21	-1	4/28	4/26	-2
Orita	WPB	3/24	3/23	-1	3/29	3/27	-2	5/04	5/03	-1
WPB-881	WPB	3/18	3/17	-1	3/22	3/21	-1	4/29	4/28	-1
Crown	WWW	3/24	3/20	-4	3/29	3/23	-6	5/04	5/02	-2
Duraking	WWW	3/23	3/19	-4	3/27	3/23	-4	5/02	5/01	-1
Q-Max	WWW	3/27	3/24	-3	3/31	3/29	-2	5/05	5/04	-1
Kronos	APB	3/16	3/15	-1	3/21	3/19	-2	4/29	4/27	-2
Sky	APB	3/19	3/17	-2	3/23	3/22	-1	5/03	5/02	-1
Ocotillo	APB	3/18	3/17	-1	3/22	3/21	-1	5/01	4/30	-1
Westmore	APB	3/18	3/17	-1	3/22	3/21	-1	4/29	4/29	0
Maestrals	Allstar	3/20	3/18	-2	3/24	3/22	-2	4/28	4/28	0
Yecora Rojo	Public	3/17	3/16	-1	3/21	3/20	-1	4/25	4/26	1
Avg	---	3/20	3/18	-2	3/24	3/22	-2	4/30	4/30	0
LSD _{.05} *		2	2	2	2	2	2	2	2	NS
Entry		**			**			**		
P rate		**			**			**		
Entry x P		**			**			NS		

* LSD.05 = least significant difference between means within a column with a 5% or less probability the difference is due to chance.

Table 6. Grain phosphorus, grain protein, and percentage of kernels “hard and vitreous and of amber color” (HVAC) of barley and wheat varieties as affected by phosphorus fertilizer rates of 0 and 100 lbs P₂O₅/acre. “Response” refers to the difference between the phosphorus rates. The wheat varieties are durums except for Yecora Rojo, which is a bread wheat.

Entry	Source	Grain Phosphorus			Grain Protein			HVAC		
		Phosphorus								
		0 lb/A	100 lb/A	Response	0 lb/A	100 lb/A	Response	0 lb/A	100 lb/A	Response
		%			%			%		
		<u>Barley</u>								
Chico	WPB	0.31	0.35	0.03	13.3	13.3	0.0	---	---	---
Cochise	WPB	0.31	0.36	0.05	12.6	12.9	0.3	---	---	---
Gustoe	WPB	0.27	0.33	0.07	13.4	13.1	-0.3	---	---	---
Nebula	WPB	0.31	0.35	0.04	13.9	15.0	1.1	---	---	---
Commander	WWW	0.30	0.35	0.05	13.5	13.4	-0.1	---	---	---
Max	WWW	0.27	0.32	0.05	13.0	12.5	-0.5	---	---	---
Baretta	APB	0.29	0.33	0.04	13.6	12.6	-1.0	---	---	---
ARGBA2042	WWW	0.28	0.32	0.04	13.7	13.7	0.0	---	---	---
Unknown	APB	0.29	0.38	0.09	14.4	15.2	0.8	---	---	---
Avg	---	0.29	0.34	0.05	13.4	13.4	0.0	---	---	---
LSD _{.05} *		0.03	0.03	NS	1.0	1.0	NS	---	---	---
Entry		NS			**			---		
P rate		**			NS			---		
Entry x P		NS			NS			---		
		<u>Wheat</u>								
Alamo	WPB	0.30	0.35	0.06	14.8	14.7	-0.1	100	100	0
Havasu	WPB	0.30	0.33	0.03	14.4	14.0	-0.4	100	100	0
Orita	WPB	0.31	0.34	0.03	14.2	13.6	-0.6	100	100	0
WPB-881	WPB	0.32	0.39	0.07	14.2	13.8	-0.4	100	99	-1
Crown	WWW	0.28	0.30	0.02	13.6	13.3	-0.3	100	100	0
Duraking	WWW	0.29	0.33	0.04	14.0	13.2	-0.8	100	100	0
Q-Max	WWW	0.28	0.34	0.06	13.6	13.7	0.1	100	100	0
Kronos	APB	0.32	0.32	0.01	14.0	14.3	0.3	100	100	0
Sky	APB	0.30	0.37	0.07	13.2	14.1	0.9	100	100	0
Ocotillo	APB	0.32	0.35	0.03	14.3	13.1	-1.2	100	100	0
Westmore	APB	0.31	0.33	0.02	14.4	13.7	-0.7	100	100	0
Maestrале	Allstar	0.29	0.32	0.03	14.6	14.8	0.2	100	100	0
Yecora Rojo	Public	0.27	0.29	0.02	14.4	14.4	0.0	100	100	0
Avg	---	0.30	0.34	0.04	14.1	13.9	-0.2	100	100	0
LSD _{.05} *		0.03	0.03	NS	0.9	0.9	NS	NS	NS	NS
Entry		NS			NS			**		
P rate		**			+			NS		
Entry x P		+			NS			NS		

* LSD.05 = least significant difference between means within a column with a 5% or less probability the difference is due to chance.

Table 7. Biomass on Feb 3 and light interception by the crop on Feb 3 and Apr 2 of barley and wheat varieties as affected by phosphorus fertilizer rates of 0 and 100 lbs P₂O₅/acre. "Response" refers to the difference between the phosphorus rates. The wheat varieties are durums except for Yecora Rojo, which is a bread wheat. The growth stage was about 5 leaf on Feb 3 and milky kernel on Apr 2.

Entry	Source	Biomass (Feb 3)			Light interception (Feb 3)			Light interception (Apr 2)		
		Phosphorus								
		0 lb/A	100 lb/A	Response	0 lb/A	100 lb/A	Response	0 lb/A	100 lb/A	Response
		lbs/A			%			%		
		<u>Barley</u>								
Chico	WPB	342	541	199	38	57	19	95	97	2
Cochise	WPB	579	1014	435	41	69	28	93	94	1
Gustoe	WPB	---	---	---	---	---	---	---	---	---
Nebula	WPB	498	784	286	49	75	26	96	97	1
Commander	WWW	529	778	249	49	64	15	95	97	2
Max	WWW	492	933	441	53	68	15	98	99	1
Baretta	APB	492	940	448	42	66	24	96	98	2
ARGBA2042	WWW	---	---	---	---	---	---	---	---	---
Unknown	APB	---	---	---	---	---	---	---	---	---
Avg	---	488	832	344	45	67	22	96	97	1
LSD _{.05} *		188	188	NS	6	6	9	2	2	NS
Entry		**			*			*		
P rate		**			**			**		
Entry x P		NS			*			NS		
		<u>Wheat</u>								
Alamo	WPB	367	585	218	38	55	17	94	94	0
Havasu	WPB	504	672	168	43	55	12	92	93	1
Orita	WPB	510	709	199	47	53	6	96	96	0
WPB-881	WPB	579	896	317	46	60	14	95	96	1
Crown	WWW	280	492	212	31	46	15	95	97	2
Duraking	WWW	355	597	242	40	55	15	94	95	1
Q-Max	WWW	187	280	93	17	30	13	91	95	4
Kronos	APB	392	772	380	41	52	11	92	92	0
Sky	APB	361	591	230	33	54	21	90	94	4
Ocotillo	APB	311	554	243	39	49	10	94	96	2
Westmore	APB	585	647	62	44	59	15	90	93	3
Maestrале	Allstar	373	498	125	31	52	21	91	95	4
Yecora Rojo	Public	635	890	255	45	73	28	93	97	4
Avg	---	418	629	211	38	53	15	93	95	2
LSD _{.05} *		178	178	NS	8	8	11	4	4	NS
Entry		**			**			NS		
P rate		**			**			**		
Entry x P		NS			+			NS		

* LSD.05 = least significant difference between means within a column with a 5% or less probability the difference is due to chance.