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Phosphorus Fertilization of Rice

Charles E. Wilson, Jr.
Extension Agronomist - Rice

Nathan A. Slaton
Assistant Professor of Agronomy and Director of Soil Testing

Richard J. Norman
Professor of Agronomy

Jeff W. Branson
Area Extension Agronomist - Rice

Introduction

Direct phosphorus (P) fertilization of rice was not recommended in Arkansas prior to 1992. Phosphorus fertilization of crops grown in rotation with rice generally provided adequate P for rice because P is converted to a soluble form under flooded conditions, which makes P more available to rice. In some cases, growers have omitted or reduced P fertilization rates to crops grown in rotation with rice in order to reduce production costs. Recent research shows that direct P fertilization of rice can increase yields on soils that have inherently low soil test P levels and/or on soils that have limited P availability due to high soil pH (pH > 6.5). Numerous reports of P deficiencies in rice have been documented since 1989.

Recent results from the University of Arkansas Soil Testing Laboratory (2002 and 2003) indicate that 31 percent of the Arkansas rice acreage, particularly silt loam soils, tests very low in P using a modified Mehlich III extraction procedure (Table 1). Phosphorus fertilizer is recommended on 56 percent of the rice soils in Arkansas. The top 10 rice-producing counties have in excess of 30 percent of their rice acreage testing very low in P and requiring P fertilization, according to University of Arkansas recommendations. The top four rice-producing counties have in excess of 50 percent of the rice acreage needing P fertilization (Table 2). The soil test recommendations were modified in 1998 to include soil pH as a factor, in addition to soil test P, in determining the recommended P fertilizer rate (Table 3). Soils that have a pH greater than 6.5 and less than 30 lbs/acre of soil test P receive recommendations for 60 lbs P_2O_5/acre P fertilizer. Also, 40 lbs P_2O_5/acre is recommended on rice soils that have recently been precision graded.

Role of Phosphorus in the Plant

Phosphorus is an essential element required for energy storage and transfer within the plant. At maturity, a high-yielding rice crop contains 60 to 80 lbs P_2O_5/acre, with about 70 percent of the P contained in the rice panicles. Phosphorus is a major component in ATP, the molecule that provides "energy" to the plant for such processes as photosynthesis, protein synthesis, nutrient translocation, nutrient uptake and respiration. Phosphorus is also a component of other compounds necessary for protein synthesis and transfer of genetic material (DNA, RNA). In addition, P has been observed to increase root growth and influence early maturity, straw strength, crop quality and disease resistance.

Deficiency Symptoms

Severe foliar P deficiency symptoms are occasionally observed in commercial rice fields. When present, the deficiency symptoms are usually very subtle and difficult to identify. However, absence of deficiency symptoms does not necessarily indicate

Table 1. University of Arkansas 2002 and 2003 Soil Test Results Illustrating Distribution of Rice Acreage as a Function of Soil Test P and Soil pH Levels

Soil Test Phosphorus	Percentage of Sampled Rice Acreage				
	pH < 6.0	pH 6.0-6.5	pH 6.6-7.0	pH > 7.0	Total
lbs P/acre	% of acres				
< 30	4.13	8.31	8.42	10.48	**31.35**
30-50	4.05	9.32	10.36	14.56	**38.29**
> 50	3.41	6.79	8.46	11.70	**30.36**
Total	**11.60**	**24.43**	**27.23**	**36.74**	

Data based on 2002 and 2003 soil test results: 377,404 sampled rice acres in 2002; 437,174 sampled rice acres in 2003.

Table 2. Percentage of Rice Acreage in the Top 10 Rice-Producing Counties That Had P Fertilizer Recommendations

County	Total Rice Acreage		Rice Acreage Needing P Fertilizer[1]
	2002	2003	
	acres		%
Poinsett	131,273	126,683	65.3
Arkansas	113,182	111,154	62.8
Cross	109,238	105,919	59.7
Lawrence	89,472	94,864	55.9
Jackson	82,983	82,292	48.7
Craighead	79,462	78,110	49.2
Clay	76,991	77,709	44.9
Lonoke	73,984	77,046	36.3
Greene	62,039	61,662	34.6
Prairie	68,192	57,031	65.7

[1]Based on percentage of acres sampled for soil testing by the University of Arkansas Soil Test Lab for 2002 and 2003.

Table 3. Phosphorus and Potassium Fertilizer Recommendations for Rice Based on University of Arkansas Soil Test Results

Soil pH	P Soil Test Level[1] (lbs/A)	K Soil Test Level[1] (lbs/A)		
		> 175	175-125	< 125
< 6.5	> 30	X-0-0[2]	X-0-60	X-0-90
< 6.5	#30	X-20-0	X-20-60	X-20-90
∃ 6.5	> 50	X-0-0	X-0-60	X-0-90
∃ 6.5	31-50	X-40-0	X-40-60	X-40-90
∃ 6.5	#30	X-60-0	X-60-60	X-60-90

[1]University of Arkansas soil test levels for P and K by the modified Mehlich 3 extract.
[2]N-P_2O_5-K_2O (lbs/A).

that the P level in rice plants is adequate. Plants generally suffer from deficiency prior to exhibiting symptoms. This phenomenon, known as "hidden hunger," occurs when the soil nutrient level is low enough to limit the plants' yield potential but high enough to sustain growth. Hidden hunger may lead to reduced yields. Subsequently, when plants do exhibit deficiency symptoms, major yield losses and added production expenses can be expected. Precautions (such as soil testing on a regular basis) should be taken to prevent the deficiency.

Phosphorus deficiency symptoms on seedling rice may include moderate to severe stunting; small, very erect, dark green leaves; small stem diameter; reduced or no tillering and delayed plant



development; or lack of vigorous growth after N fertilization and flooding. Because P is mobile in the plant, deficiency symptoms may appear in older leaves first. As a result, mature leaves and tillers may die when P is limiting plant growth. If these symptoms are present, tissue analysis of plant leaf blades from the affected area and from outside the affected area should be performed to correctly diagnose the nutritional problem. The normal range of P in the plant leaf blade at tillering is 0.14 to 0.27 percent. Generally, whole tillering rice plants with P concentrations > 0.20 percent are capable of producing high grain yields.

Approximately 50 lbs P_2O_5/acre (0.31 lbs P_2O_5/bushel) is removed in the rice grain at harvest with a grain yield of 150 bu/acre and can exceed 62 lbs P_2O_5/acre when yields exceed 200 bu/acre. With the same grain yield, the straw contains approximately 15 to 20 lbs P_2O_5/acre. Similarly, a soybean yield of 60 bu/acre will remove approximately the same amount of P in the grain.

Phosphorus-Soil Relationships

Available P is present in the soil as an anion (PO_4^{-3}, HPO_4^{-2} or $H_2PO_4^{-}$) (anion = negatively charged), such as nitrate or sulfate, but it is not as readily leached from the soil as other anions. Phosphorus combines very easily with other elements such as iron (ferric phosphates or ferrous phosphates), aluminum (aluminum phosphates) and calcium (calcium phosphates) in the soil. Much of the P in these P compounds is not immediately available for plant uptake. Soil test P levels are indications of available P for plant uptake. While the numbers closely resemble the amount of P required by the plant, they are an index of available P, not total P. Total soil P encompasses P tied up in soil organic matter and many mineral forms that are not available for plant uptake.

Flooding the soil increases the amount of P in solution, thus increasing the amount of P available for plant uptake. When the soil is flooded, ferric (iron) phosphate is converted to ferrous phosphate, which is more soluble in water. This process, called reduction, occurs because oxygen is depleted from the soil after flooding. The rate at which this process occurs governs the amount of available P in the soil. On low pH soils, this reaction occurs relatively quickly. However, on alkaline soils, the process is much slower. While deficiency may be present on these soils soon after flooding, sufficient P may be released later in the season to produce normal yields. When the soil is drained and the soil dries, P may again form compounds that are less soluble than prior to flooding. Because of this, wheat following rice in the rotation is highly susceptible to P deficiency and usually requires P fertilization for the production of maximum yields. Phosphorus is most available for plant uptake when soil pH is between 6.0 and 6.5. Availability decreases outside of this range.

Phosphorus fertilizer can be applied to fields either in the fall, immediately prior to planting or preflood. Fall applications of P fertilizer to P-deficient soils are generally discouraged because the P may become fixed into forms that are not available for plant uptake, especially if fields are to be flooded during the winter for waterfowl or weed control. Poultry litter and other manures are excellent sources of P, but cost and availability comparisons should be used to determine if they are economical substitutes for commercial fertilizer sources, such as triple superphosphate (0-46-0) or diammonium phosphate (18-46-0).

Remember that soil test P is an index of P availability to plants and represents only a fraction of the total soil P content. Also note that soil test P is expressed as P rather than P_2O_5, which is used in the fertilizer industry. To convert elemental P to P_2O_5, multiply P by 2.29; to convert P_2O_5 to elemental P, multiply P_2O_5 rates by 0.437.

Research Results

Recent research data has indicated that rice yields can be increased by P fertilizer applications on some soils. Several experiments have been conducted in Arkansas to evaluate P fertilizer rates and timing

since 1989. Research has demonstrated that soil pH appears to be a significant factor, in addition to soil test P levels, in determining the need for P (Figure 1). Soil P availability usually increases after flooding to provide sufficient P for the rice crop. The influence of flooding on soil P availability is one reason P was rarely recommended for rice prior to 1990, despite low soil test levels. However, research results illustrated in Figure 1 demonstrate that on high pH soils, the P availability does not increase rapidly enough to meet the needs of the rice plant during tillering. Therefore, soil pH was added to the soil test recommendation thresholds for P (Table 3).

Phosphorus application to soils with low soil pH should be made with caution. Even with low soil test P levels, some cases of decreased yields have been measured (Figure 1). On these soils, excessive P can increase the plant's vigor and vegetative growth but can lead to mutual shading and lodging that can decrease yield. The University of Arkansas recommends a small amount of P for these soils (20 lbs P_2O_5/acre) to help compensate for crop removal of P.

Phosphorus fertilizers are typically applied in the spring prior to planting. Because some farmers were experiencing P deficiency in spite of P fertilizer applications, research to evaluate the influence of P fertilizer application timing was initiated. Results from several studies suggest that the optimum time to apply P fertilizer may be immediately prior to flooding, particularly on extremely high soil pH fields (Table 4). Although yields are not always different between preplant and preflood, P uptake by the plant is almost always greater when the P is applied preflood (Table 5). However, single preflood applications may not be cost effective. For fields that have a history of P deficiency or require a large P application (i.e., 60 lbs P_2O_5/acre), split applications have worked effectively. Apply half preplant blended with other preplant fertilizers, and apply the other half as diammonium phosphate (DAP) alone or blended with the preflood urea. The DAP provides the extra benefit of containing a small amount of nitrogen at a cost very similar to triple superphosphate.

Phosphorus is also recommended on soils that have recently been precision graded, particularly on those with deep cuts. Research indicates that although poultry litter is an effective means of increasing productivity on these soils, addition of P with the poultry litter provides the optimum benefit (Table 6). Generally, as the soils are cut, topsoil is removed. Soil P content generally decreases and the potential for P fixation increases as soil depth increases. Therefore, as the topsoil is removed, the exposed subsoil contains less available P for plant uptake. Poultry litter provides some P, but additional P fertilizer is often needed for adequate plant growth.

Crop rotation is important in determining the P fertilizer required for rice. Because flooding and subsequent draining affects soil P availability, the amount of available P measured is dependent upon when in the rotation the soil samples are collected. Soil test P levels remain low immediately following rice, regardless of the amount of P applied to the rice crop. In contrast, soil test P in samples collected after

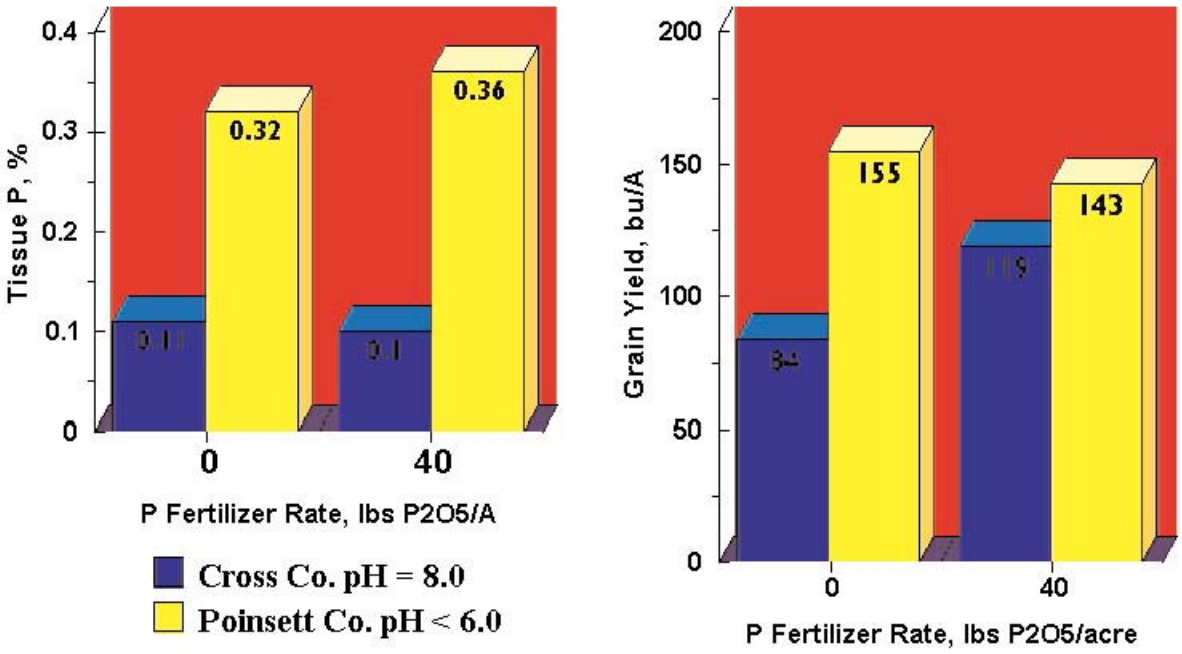

Fig. 1. Rice response to P fertilizer on two soils with low soil test P.

Table 4. Influence of P Fertilizer Application Timing on Total Dry Matter, P Concentration and Grain Yield of Rice During 2001					
P Application Timing	Total Dry Matter		P Concentration		Grain Yield
	28 DAF	Maturity	28 DAF	Maturity	
	lbs/acre		%		bu/acre
None	1,197	7,957	0.175	0.143	157
Emergence	1,355	7,933	0.190	0.145	163
Preflood	1,418	10,105	0.219	0.161	166
Midseason	--	8,518	--	0.162	161
Late Boot	--	7,816	--	0.166	154
LSD(0.05)	n.s.	1,258	0.035	0.018	8
Source: N. Slaton et al., 2002. *Ark. Rice Res. Series 495*.					

Table 5. Influence of P Fertilizer Application Timing on Uptake of P by Rice 55 and 68 Days After Seeding					
Time After Seeding	Total P Uptake			Fertilizer P Uptake	
	None	Preemerge	Preflood	Preemerge	Preflood
days	lbs P/acre			% of applied	
55	0.5	0.7	0.9	0.7	1.7
68	2.1	2.6	3.1	2.0	3.8
Source: N. Slaton et al., 2002. *Ark. Rice Res. Series 495.*					

Table 6. Rice Yields on Precision-Graded Soils Following Applications of Composted Poultry Litter and Phosphorus Fertilizer				
Treatment	Grain Yield			
	Huey Farm	Lewis Farm	Conner #1 Farm	Conner #2 Farm
rate/acre	- (bushels/acre) -			
Control	72	40	106	88
46 lbs P_2O_5	113	73	113	144
2,000 lbs litter	116	114	129	142
46 lbs P_2O_5 + 2,000 lbs litter	137	116	133	160

the soybean crop tend to increase as the amount of P applied to the soybean crop increases. Thus, soil test P, as well as other soil test parameters, fluctuates across time and depends to a large extent on the previous crop and P fertilization practices. Therefore, when collecting soil samples from fields with rice in the rotation, always be consistent in the timing. The preferred timing would be after the soybean crop, in the fall or spring prior to the rice crop.

Summary and Recommendations

Recent work by University of Arkansas researchers shows that rice will respond to P applications on some soils. The four situations when P fertilizer is recommended are:

1. The University of Arkansas soil test report indicates soil test P level 30 to 50 lbs P/acre and the soil pH is 6.5 or greater (apply 40 lbs P_2O_5/acre).
2. The University of Arkansas soil test report indicates soil test P level is less than 30 lbs P/acre and the soil pH is 6.5 or greater (apply 60 lbs P_2O_5/acre).
3. The University of Arkansas soil test report indicates soil test P level is less than 30 lbs P/acre and the soil pH is less than 6.5 (apply 20 lbs P_2O_5/acre).
4. The field has recently been precision graded (apply 40 lbs P_2O_5/acre).

For precision-leveled soils, apply 40 lbs P_2O_5/acre, unless the soil test report calls for more. If the field has been precision graded and poultry litter will be applied, also apply P fertilizer.

Soil samples should be collected at least every three years to ensure proper fertilizer recommendations, preferably after soybean and before the rice crop. Collect samples from several areas within the field to a depth of 4 inches (plow depth). Samples should be mixed to make one general composite sample. However, this sample should not represent more than 20 acres. **Remember: The soil test values and subsequent fertilizer recommendations are only as good as the soil samples.** Therefore, soil samples should be representative of the entire area in the field the samples were collected.

Care should be taken if P is applied to soils with a high pH (greater than 6.5) because of the possibility of aggravating a Zn deficiency. Make certain to apply Zn also if soil test results indicate the need for Zn. Be careful not to over-fertilize with P on soils with low pH. Excessive P applied when the crop does not need it can result in reduced yields due to mutual shading and lodging (Figure 1).

If you have questions about a possible P deficiency or you have other questions, contact your local county Cooperative Extension Service office.

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DR. CHARLES E. WILSON, JR., is Extension agronomist - rice**,** and **JEFF BRANSON** is area Extension agronomist - rice with the University of Arkansas Cooperative Extension Service, located at the Rice Research and Extension Center, Stuttgart.
DR. NATHAN A. SLATON is assistant professor of agronomy and director of soil testing, and **DR. RICHARD J. NORMAN** is professor of agronomy in the department of Crop, Soil and Environmental Sciences, University of Arkansas, Fayetteville.

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