EFFECTS OF PHOSPHORUS FERTILIZER PLACEMENT AND RATE ON YIELD AND FIBER QUALITY IN ARIZONA COTTON PRODUCTION SYSTEMS

E. R. Norton
T. McFarland
University of Arizona, Safford, AZ

Abstract

A set of field trials were established during the 2007 and 2008 seasons in an effort to examine if precise placement of phosphorus (P) fertilizer directly under the seed row prior to planting may improve fertilizer efficiency over and above the standard practice of side dress in-season applications. The trial was conducted at the Safford Agricultural Center in southeastern Arizona on a Pima clay loam soil. Treatments consisted of varying rates of 0 to 100 lbs P_2O_5/acre applied either (1) deep banded pre-plant directly under the seed row, or (2) side dress applied when the crop reached the 2-3 true leaf stage. Results in 2007 indicated a strong positive response to applied P fertilizer over the control with a slight advantage of the precisely placed P band at the 60 lbs P_2O_5/acre rate. Significant differences in fiber strength were also observed with increased P applied. Residual soil P levels were significantly higher in the pre-plant injected treatments with the higher applied P_2O_5 rates. Results from 2008 were less obvious with no significant response to the applied P fertilizer under any comparison of rates or placement methods. Soil residual P levels were similar to those observed in 2007. This project will continue to be carried out with slight modifications. Original plots will be sub-divided in half where one half will continue to receive the same P treatments and the other half will no longer receive P fertilizer. Yield, fiber quality, and soil residual P levels will continue to be monitored over the next few years.

Introduction

Phosphorus (P) is one of the major nutrients required for growth and development in all higher plants. Major physiological processes within the plant require sufficient levels of P for proper function. These processes include energy storage and the synthesis of structural components of the plant including nucleic acids. Sufficient levels of P within the plant are critical for the proper development of root systems (Borkert and Barber, 1985; and Yao and Barber, 1986). Specifically in Upland cotton (*Gossypium hirsutum* L.) systems, root growth stimulation has been observed with the addition of P fertilizers (Mullins, 1993). Deficiency of P in cotton is generally manifested by stunted growth and dark green foliage while extreme P deficiencies may result in the expression of anthocyanin pigments resulting in a purple coloration of the older leaf tissue. A delay in the onset of fruiting forms in cotton may also be attributed to deficient levels of P within the plant. Fiber quality may also be affected by P deficiency resulting in shortened fiber length and decreased seed weight (Mikkelsen and Hoover, 1952).

As with any other nutrient in crop production, P fertilizer management is critical to achieving optimum yields. Research has shown that approximately 11 lbs. P/acre are required by a cotton crop to produce one bale (490 lbs.) of lint (Unruh and Silvertooth, 1996). The P taken up by a cotton crop must come from either native soil P or from supplemental fertilizers. Therefore, an assessment of plant-available soil P is important in determining the P supplying power of the soil. This may be accomplished through the process of obtaining a soil sample and having the sample appropriately analyzed for extractable P.

Phosphorus is a very dynamic nutrient in the soil-plant system. Numerous reactions can occur in the soil environment that affects P availability to the plant. Precipitation of soluble phosphates to insoluble complexes with Fe, Al, or Ca can result in soil P forms that are not available for plant uptake. Many soil P reactions are strongly dependent upon the dominant chemical environment of the soil. Arizona soils are dominated by the basic cations (calcium (Ca), magnesium (Mg), potassium (K), and sodium (Na) which can contribute to the formation of insoluble P complexes, predominately with Ca. In order for a cotton plant to utilize P from the soil solution, the preferable form for uptake is orthophosphate (HPO_4^{2-}). Both the pyro and polyphosphate fertilizers must first break down to orthophosphate prior to plant uptake. Insoluble complexes of either Ca or Mg phosphates are entirely unavailable for plant uptake and utilization. Therefore, total soil P levels are not necessarily indicative of plant-available P levels.

Due to the inherently low availability of soil P in Arizona soils, supplemental P is often required to meet crop demands. Soil critical levels are a valuable and useful technique for determining the need for P fertilization. The extraction technique for soil test P analysis that has proven most effective in calcareous, high pH soils is sodium bicarbonate ($NaHCO_3$, Olsen et. al., 1954). Soil test correlation and calibration research performed in the cotton producing regions of California have revealed a critical soil P level of 5 ppm ($NaHCO_3$ extractable) for cotton production (Reisenauer, et al., 1978).

Management of phosphorus (P) fertilizer in cotton production systems of Arizona has been studied for many years. Critical levels of soil test P have been developed and validated for desert Arizona cotton production systems at 5 parts per million (ppm) $NaHCO_3^-$ extractable P (Norton and Silvertooth, 2006). This critical level was developed from a series of experiments involving side-dress banded applications made to cotton at the 2-3 true leaf stage approximately six inches to the side of the seed row and six inches deep. Under Arizona cotton production systems rows are listed in the late winter prior to pre-irrigation. Growers have begun injecting a band of P fertilizer at the time of listing directly under the seed-bed. This precise placement is thought to enhance availability of the P for crop uptake improving the fertilizer efficiency.

A research trial was begun in 2007 to evaluate the effects of deep placement bands of P fertilizer at varying rates on crop yield and fiber quality as compared to the traditional side-dress application. The introduction of sub-inch accurate auto-steer GPS systems has allowed for another component of precise placement of P fertilizer to be examined. The ability to return to the exact location within an inch tolerance allowing growers to exploit better the zone of fertilizer placement from the previous year. Residual P from applied fertilizer now becomes a more critical factor to consider when making recommendations for P fertilizer applications (Mallarino and Borges, 2006).

Materials and Methods

A research trial was conducted during the 2007 and 2008 cotton growing season at the University of Arizona Safford Agricultural Center located in the Upper Gila River Valley in southeastern Arizona at approximately 2900 feet elevation. The soil type located on the Center is a Pima clay loam soil. An initial soil sample from the field site was collected in the winter of 2006 to gain a baseline of soil chemical characteristics with results presented in Table 1. Treatments in this trial included a control, receiving no fertilizer P and a series of rates of P_2O_5 applied per acre as either a side-dress application at the 2-3 leaf stage or a pre-plant injected band directly under the seed row. Table 2 outlines treatments and rates of application for 2007 and 2008.

Plots were arranged in a randomized complete block design with four replications. Each plot was four, 38-inch rows wide and extended the full length of the irrigation run of 220 feet. Plots were planted on 4 April and 21 April in 2007 and 2008 respectively to the Upland cotton cultivar Phytogen PH745WRF. Plots were managed in an optimal fashion with respect to all other cultural inputs including irrigation and nitrogen management, pest control, and defoliation.

Plant measurement data including plant height, number of mainstem nodes, position of first fruiting branch, and nodes above white flower, were collected on an interval of approximately 15-20 days to document any differences in plant growth and development. Yield was estimated each year by mechanically harvesting the center two rows of each plot and weighing the seed cotton in a boll buggy equipped with load cells. Sub samples of seed cotton were collected from each treatment and ginned to obtain percent lint estimates. Lint samples were also collected from the ginned cotton and sent to the USDA-AMS Phoenix Classing Office in Phoenix, AZ for fiber quality determinations.

All yield and fiber quality data was subjected to analysis of variance and a Fisher's Least Significant Difference means separation test according to procedures outlined by the SAS institute (SAS, 2008) and Steele and Torrie (1980).

Results and Discussion

2007

Lint yield and fiber quality results comparing the injected treatments to the control are presented in Tables 3 and 4 respectively. A significant response to applied P_2O_5 was observed in both application techniques. The highest yielding treatment was the injected 60 lbs P_2O_5/acre treatment with the 100 lbs P_2O_5/acre side dress application producing a slightly lower yield. No significant difference was observed when comparing the two application techniques at 40 lbs P_2O_5/acre treatment. A nearly 90 lbs lint/acre advantage was observed when comparing the two application techniques at the 60 lbs P_2O_5/acre rate. At the 100 lbs P_2O_5/acre rate the advantage was observed in the side dress application with an increase of nearly 70 lbs lint/acre. No significant differences were observed in fiber quality with the exception of strength. A significant increase in strength was observed with increasing P applied (Tables 3 and 4). Residual soil P levels are presented in Table 7. These samples were collected directly in the seed row to a depth of approximately 18 inches across all treatments and analyzed for $NaHCO_3^-$ extractable P. Mean soil test levels are presented in Table 7 and indicate a strong increasing concentration of residual P with increasing application rates. This trend was not observed in the side dress treatments. Samples were also taken to the side of the bed in an attempt to locate increased levels of residual P from the side dress treatments but none was observed (data not shown). No significant differences were observed in any of the plant measurement data and so it is also not presented.

2008

Results from the 2008 season were much less dramatic. No significant differences were observed in lint yield as a function of P fertilizer applied (Tables 5 and 6). There were also no differences between the two application methods at a given P application rate. At the time of this writing fiber quality data was not yet available and is not presented here. Again, as in 2007, no significant differences were observed in plant measurement data so it also is not presented in this article. Residual soil test P levels again showed increasing residual P with increasing applied P fertilizer (Table 8). In 2008 samples were collected to a depth of 2 feet by one foot increments and were collected across replications and composited by treatment.

Conclusions

After two years of experiments conclusions are yet unclear whether or not an increase in efficiency may be obtained through precise placement of deep banded P directly below the root zone. This project will continue with some slight modifications. Figure 1 outlines one of the four replications employed in the trials in 2007 and 2008. For the 2009 growing season, these plots will be split in half and will extend a length of approximately 80 feet (Figure 2). One half of the original plot will continue to receive fertilizer treatments while the second half will no longer receive any P fertilizer. Soil test P levels will be monitored along with yield and fiber quality under this new treatment scheme. A closer examination of the ability of residual P to supply a portion of the P required for proper crop growth development and yield will be a goal of the new treatment regime.

Literature Cited

Borkert, C.M. and S.A. Barber. 1985. Soybean shoot and root growth and phosphorus concentration as affected by phosphorus placement. Soil Sci. Soc. Am. J. 46:152-155.

Mallarino and Borges, 2006. Phosphorus and potassium distribution following long-term deep-band fertilization in different tillage systems. Soil Sci. Soc. Am. J. 70:702-707 (2006).

Mikkelson, D.S., and M. Hoover. 1952. Cotton fertilization. *Calif. Agric.* Aug., pp. 3-4.

Mullins, G.L. 1993. Cotton root growth as affected by P fertilizer placement. Fert. Res. 34:23-26.

Norton, E.R. and J.C. Silvertooth. 2006. A review of 10 years of phosphorus fertility research in Arizona. In Cotton: A College of Agriculture and Life Sciences Report. Series P-141 pp. 289-298.

Olsen, S.R., C.V. Cole, F.S. Watanabe, and L.A. Dean. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. U.S. Dep. of Agric. Circ. 939.

Reisenauer, H.M., J. Quick, R.E. Voss, and L.A. Brown. 1978. Chemical soil tests for soil fertility evaluation. In H.M. Reisenauer (ed.), *Soil and plant tissue testing in California*, pp. 39-41. Berkeley: University of California, Division of Agricultural Science, Bulletin 1879.

SAS Institute. 2008. SAS Procedures Guide. Version 9.2, SAS Inst., Cary, NC

Steel, R.G.D., and J.H. Torrie. 1980. Principles and procedures of statistics. McGraw-Hill, New York.

Unruh, B.L. and J.C. Silvertooth. 1996. Comparisons between an upland and a Pima cotton cultivar. II. Nutrient uptake and partitioning. Agron. J. 88:589-595.

Yao, J. and S.A. Barber. 1986. Effect of one phosphorus rate placed in different soil volumes on P uptake and growth of wheat. Commun. Soil Sci. Plant Anal. 17:819-827.

Table 1. Initial soil test results from field site collected in early spring 2007 for the P placement by rate experiment, Safford, AZ.

Test	Method	Result	Units
pH	1:1	8.5	---
Electrical Conductivity	1:1	1.2	dS/m
Calcium	NH_4OAc (pH 8.5)	3,900	ppm
Magnesium	NH_4OAc (pH 8.5)	420	ppm
Sodium	NH_4OAc (pH 8.5)	1,400	ppm
Potassium	NH_4OAc (pH 8.5)	340	ppm
Nitrate-N	Cd Reduction	15	ppm
Phoshate-P	Olsen	4.9	ppm
Sulfate-S	Hot Water	56	ppm
ESP	Calculated	20.3	Percent
CEC	Calculated	30.0	meq/100g

Table 2. Treatment rate and application technique utilized in the P placement by rate experiment in 2007 and 2008 in Safford, AZ.

Treatment	Application Technique	Rate (lbs. P_2O_5/Acre)	
		2007	2008
1	Control	0	0
2	Injected†	40	30
3	Injected	60	60
4	Injected	100	90
5	Side Dress‡	40	30
6	Side Dress	60	60
7	Side Dress	100	90

Table 3 Lint yield and fiber quality results from the injected treatments of the P placement by rate experiment, Safford, AZ, 2007

Treatment	Rate	Lint Yield	Percent Lint	Micro	Staple	Strength	Uniformity
	lbs P_2O_5/acre	lbs lint/acre			32nds	g / tex	Percent
Control	0	1407.4 b*	33.0	4.1	37	29.2	83.0
Injected	40	1463.8 b	33.0	4.2	38	31.7	83.2
	60	1542.7 a	33.0	4.1	37	32.1	82.5
	100	1458.7 b	33.0	3.6	37	33.5	82.0
LSD¶		69.2	--	NS	NS	NS	NS
OSL†		0.0115	--	0.4939	0.6858	0.4435	0.1835
CV‡		2.9	--	10.4	3.3	7.4	0.5

Table 4 Lint yield and fiber quality results from the side dress treatments of the P placement by rate experiment, Safford, AZ, 2007

Treatment	Rate	Lint Yield	Percent Lint	Micro	Staple	Strength	Uniformity
	lbs P_2O_5/acre	lbs lint/acre			32nds	g / tex	Percent
Control	0	1407.4 b*	33.0	4.1	37	29.2 b	83.0 a
Side Dress	40	1463.3 ab	33.0	4.0	38	32.0 a	83.1 a
	60	1437.2 b	33.0	4.0	38	32.3 a	83.2 a
	100	1516.0 a	33.0	4.1	37	32.9 a	83.5 a
LSD¶		76.6	--	NS	NS	1.6	NS
OSL†		0.0552	--	0.9460	0.6858	0.0167	0.8746
CV‡		3.3	--	6.0	3.3	1.6	0.8

Table 5 Lint yield and fiber quality results from the injected treatments of the P placement by rate experiment, Safford, AZ, 2008

Treatment	Rate	Lint Yield	Percent Lint	Micro	Staple	Strength	Uniformity
	lbs P_2O_5/acre	lbs lint/acre			32nds	g / tex	Percent
Control	0	1558.3	36.6				
Injected	30	1565.6	37.0				
	60	1526.7	36.1				
	90	1544.4	35.2				
LSD¶		NS	NS				
OSL†		0.7577	0.1414				
CV‡		3.5	2.8				

Table 6 Lint yield and fiber quality results from the side dress treatments of the P placement by rate experiment, Safford, AZ, 2008

Treatment	Rate	Lint Yield	Percent Lint	Micro	Staple	Strength	Uniformity
	lbs P_2O_5/acre	lbs lint/acre			32nds	g / tex	Percent
Control	0	1558.3	36.7				
Side Dress	30	1545.6	36.7				
	60	1581.3	37.0				
	90	1560.5	36.5				
LSD¶		NS	NS				
OSL†		0.9265	0.5742				
CV‡		4.8	1.4				

Table 7. Soil test results taken from each treatment in the fall of 2007 to a depth of one foot, Safford, AZ

Treatment	0-1 ft
	ppm
Control	5.5
40 INJ	6.1
60 INJ	7.4
100 INJ	18.0
40 SD	6.3
60 SD	6.1
100 SD	6.4

Table 8. Soil test results taken from each treatment in the fall of 2008 to a depth of two feet in one foot increments, Safford, AZ

Treatment	0-1 ft	1-2 ft
	ppm	ppm
Control	12.1	6.0
30 INJ	6.6	9.5
60 INJ	7.7	7.8
90 INJ	11.0	7.8
30 SD	4.0	6.1
60 SD	3.7	6.2
90 SD	6.3	6.3

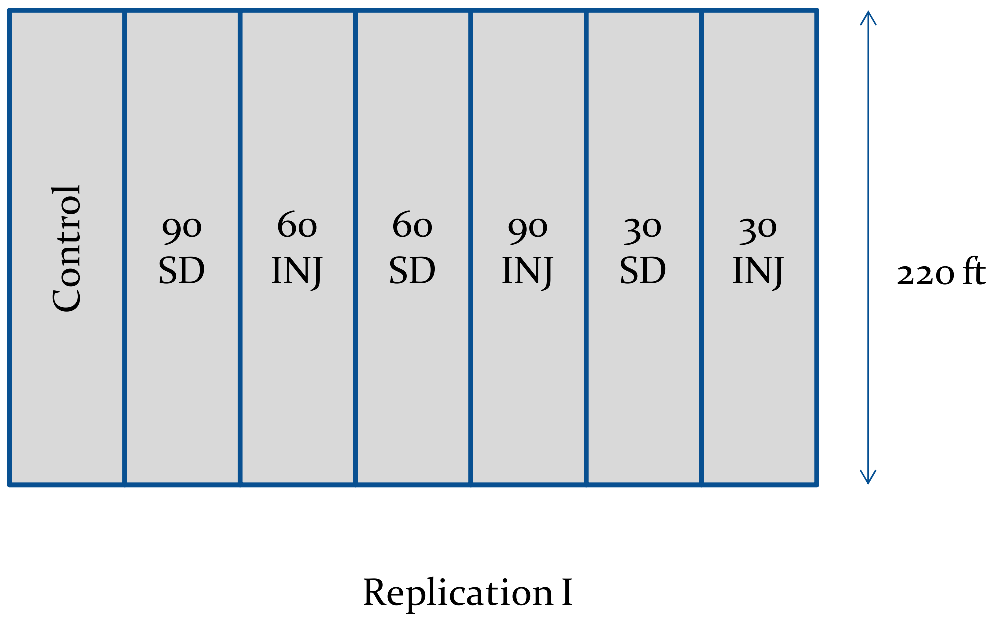

Figure 1. Plot layout of one replication for P placement by rate experiment in 2007 and 2009, Safford, AZ.

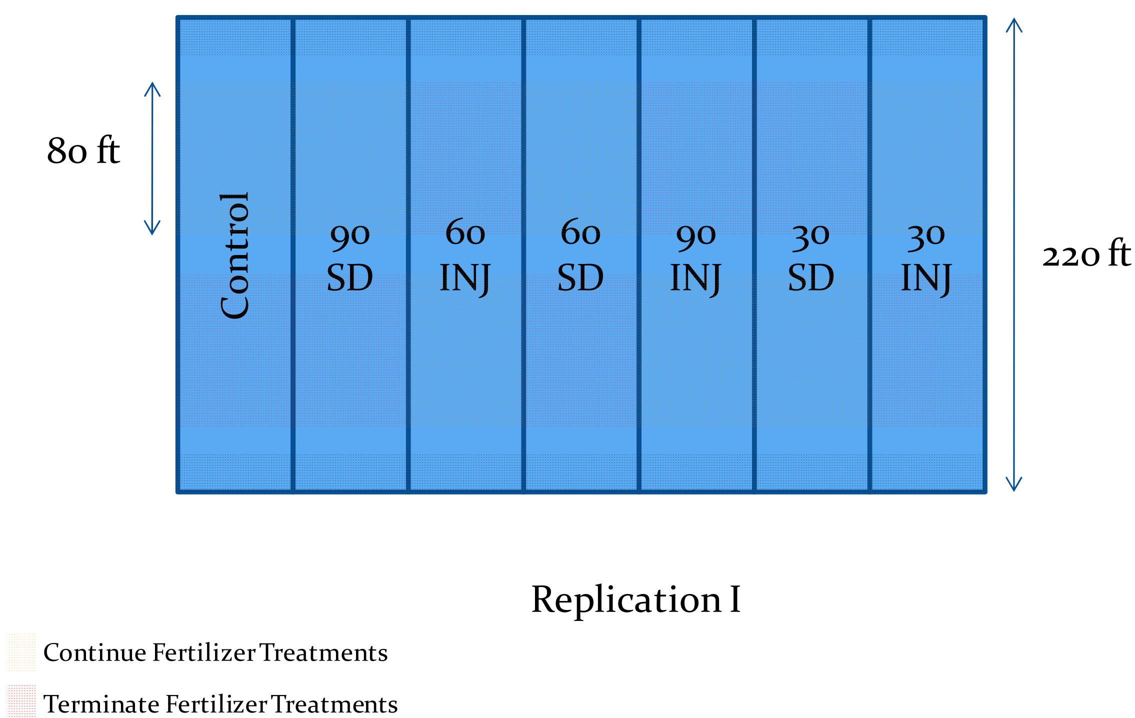

Figure 2. Plot layout for P placement by rate trial beginning in 2009 and beyond, Safford, AZ.