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IMPROVING PHOSPHORUS NUTRITION OF COTTON

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ABSTRACT

Crop recovery of applied Phosphorus (P) fertilizer can be low, especially during season of low soil temperature, which decreases plant root growth and nutrient uptake. The $H_2PO_4^-$ or HPO_4^{-2} anions readily react with soil cations such as Calcium (Ca), Magnesium (Mg), iron (Fe) and Aluminum (Al) to produce various phosphate compounds of very limited water solubility. Specialty Fertilizer Products (SFP), Leawood, KS, USA has developed and patented a product registered as AVAIL® that is reported to attract and sequester antagonistic cations out of the soil solution leaving more of applied P in available form for plant uptake. To evaluate effectiveness of AVAIL product for cotton production, experiments were conducted in two locations in West Tennessee, Grand Junction (GJ) in Hardeman County and Ames Plantation (AP) located in Fayette County. Treatments consisted of applying Mono-Ammonium Phosphate (MAP, 11-52-0) alone or coated with AVAIL at rates of 34 or 68 kg ha^{-1} P_2O_5. A no P check was also included. An additional treatment consisting of AVAIL treated P in combination with Nutrisphere-N®, a Nitrogen (N) stabilizer product offered by SFP, was also included. At GJ site, when averaged over P rates and years, AVAIL treated MAP improved tissue P concentration and increased cotton lint yield by 157 kg ha^{-1} over untreated MAP. At AP site, when averaged over years and P rates, application of AVAIL treated MAP increased cotton lint yield by 85 kg ha^{-1} over untreated MAP. In both experiments, 34 kg ha^{-1} AVAIL treated MAP produced higher tissue P concentrations and greater yields than 68 kg ha^{-1} without AVAIL. Influencing reactions in the micro-environment around the fertilizer granule has proven to have a significant benefit on the yield and P uptake of cotton. More research is needed to determine P content in the soil and further improve fertility recommendations.

Keywords: Cotton, Avail, Phosphorus

1. INTRODUCTION

Phosphorus (P) occurs in soils mainly as inorganic P compounds. Compared to other macronutrients like Calcium (Ca), the concentration of P in the soil solution is very low, ranging from 0.001 mg L^{-1} in very infertile soils to about 1 mg L^{-1} in heavily fertilized soils (Havlin *et al*., 2005). A large fraction of P present in soils is in the mineral form as is not readily available for absorption by the plant.

Crop yields highly dependent on supply of P through mid-season. In view of the P fixation problem, Specialty Fertilizer Products (SFP), Leawood, KS has developed and patented a family of dicarboxylic co-polymers that can be used as a coating on granular or mixed into liquid phosphate fertilizers. The registered trade name of this product is AVAIL® and it is identified as a partial sodium salt of maleic-itaconic copolymer (CAS# 556055-76-6). The compound is a high-charge density polymer (cation exchange capacity of approximately 1,800 milliequilents/100 g) sequesters multivalent cations such as Ca and Magnesium (Mg) in the soil solution in high pH soils and iron (Fe) and

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Aluminum (Al) in low pH soils that normally form insoluble precipitants with applied P fertilizer. The AVAIL compounds attracts positively charged cations in the soil solution, binds them, leaving P in solution available for plant uptake (Murphy and Sanders, 2007). The objective of this research was to evaluate the use of AVAIL with P fertilizer in order to improve nutrient management in both no-tillage and conventional cotton production systems.

2. MATERIALS AND METHODS

2.1. Site Preparation and Management

Experiments were conducted in two locations in West Tennessee, USA, Grand Junction (GJ) in Hardeman County and the Ames Plantation (AP) located in Fayette County. The Grand Junction experiment was conducted during the period 2010-2012 on a Loring silt loam (fine-silty, mixed, active, thermic Oxyaquic Fragiudalfs) with a pH of 6.5 and a Mehlich I P value of 30 mg kg^{-1}. The Ames Plantation site was a Henry silt loam (coarse-silty, mixed, active, thermic Typic Fragiaqualfs) with a pH of 6.1 and a Mehlich I P value of 28 mg kg^{-1}. The AP experiment was conducted in 2012-2013.

Treatments at both sites consisted of applying P fertilizer as MAP (11-52-0) to provide 34 or 68 kg P_2O_5 ha^{-1} either treated with 0.25% AVAIL or untreated. A no P check also was included. At the GJ site, additional treatment included AVAIL treated P in combination with urea treated with Nutrisphere-N, another product offered by Specialty Fertilizer Products (SFP) that is classified as a Nitrogen (N) stabilizer.

The fertilizer was broadcast on the soil surface 7-10 days prior to planting at GJ and at planting at AP site each year. Cotton was planted without tillage in the previous year's stubble at GJ site and conventional tillage (disc followed by field cultivator) at AP site. Planting date was May 7, 12 and 10 in 2010, 2011 and 2012, respectively at GJ site and May 10 and 22 in 2012 and 2013, respectively at the AP site. The cotton variety Phytogen 499 WRE was used at both sites and all years of the experiment. Harvest occurred in early October each year. All treatments received a total of 112 kg N ha^{-1} in the form of urea and 56 kg K_2O ha^{-1} as potassium chloride regardless of P treatment. All additional fertilizer was applied just prior to planting. Plots consisted of four rows, 0.97 m row width by 9.1 m long. Each treatment was replicated four times. Fertilizer was weighed out for each plot and applied by hand.

2.2. Plant Measurements

Plant leaf samples were collected in 2011 and 2012 from the uppermost fully expanded leaf at full bloom (Aug. 8, 2011 and Aug. 1, 2012 at GJ site and Aug 1 and Aug 12 at AP site) and analyzed by Kansas State University Soil Testing Lab, Manhattan, KS. At GJ, numbers of open bolls m^{-2} were counted just before harvest in 2011 and 2012. In southwest Tennessee, twenty-year growing season (May-September) rainfall averaged 200 mm. Rainfall was 20% above normal in 2010, 10% below normal in 2011 and near normal in 2012 and 2013. The center two rows of each plot were harvested for yield and hand sample ginned on a small table-top experimental gin in order to determine lint cotton turnout.

2.3. Statistical Analysis

Data were analyzed by analysis of variance and means separated using Fisher's Least Significant Difference Test.

3. RESULTS

3.1. Yields

In spite of having what is considered adequate soil test P, good response to applied P was recorded at both sites. At GJ site, no-P check averaged 808 kg lint ha^{-1} Vs. 958 kg lint ha^{-1} for all applied P treatments (**Table 1**). When averaged over years and P rates, AVAIL treated MAP increased cotton lint yield by 157 kg ha^{-1}. Consistently greater yields were achieved with 34 kg ha^{-1} AVAIL treated MAP than 68 kg ha^{-1} untreated. Yields continued to increase with increasing P rate in untreated plots, but no additional response resulted from increasing P from 34 to 68 kg ha^{-1} in AVAIL treated plots. The greatest yields in this experiment were achieved with application of AVAIL treated P in combination with Nutrisphere-N treated urea. In this experiment, treating both N and P resulted in a yield increase of 214 kg lint cotton ha^{-1} over untreated plots and 82 kg ha^{-1} increase over AVAIL only treatment.

At AP site, when averaged over years, plots receiving P with or without AVAIL increase yield by 178 kg ha^{-1} of lint cotton over the no P check plot (**Table 2**). When averaged over rates, AVAIL increased lint cotton yield by 85 kg ha^{-1} over the P alone treatments. Similar to GJ site, consistently greater yields were achieved with 34 kg ha^{-1} AVAIL treated MAP than 68 kg ha^{-1} untreated at AP site.

3.2. Tissue Phosphorus Content and Boll Number

Tissue P concentrations followed the same trends as yield at both sites (**Table 3 and 4**). The P concentrations were greater for AVAIL treatments than untreated control, with 34 kg P_2O_5 with AVAIL giving greater P concentration than 68 kg P_2O_5 untreated. The P concentrations were lowest for the no P check. Results indicate that the use of AVAIL does result in improved P uptake by cotton.

Table 1. Lint cotton yields as affected by P-Rate and AVAIL, Grand Junction, TN

N-P_2O_5-K_2O rate	AVAIL	2010	2011	2012	Avg.
Kg ha^{-1}			kg ha^{-1}		
112-0-56	No	795.0	784.0	842.0	808.0
112-34-56	No	958.0	1040.0	937.0	978.0
112-68-56	No	997.0	1118.0	971.0	1028.0
112-34-56	Yes	1032.0	1421.0	1021.0	1158.0
112-68-56	Yes	1036.0	1442.0	1024.0	1160.0
112-68-56	Nutrisphere-N+AVAIL	1144.0	1549.0	1033.0	1242.0
LSD $_{(0.05)}$		31.0	24.0	73.0	53.0
CV%		2.8	2.7	4.9	3.3

Table 2. Lint cotton yields as affected by P-Rate and AVAIL, Ames Plantation, TN

N-P_2O_5-K_2O Rate	AVAIL	2012	2013	Avg.
kg ha^{-1}			kg ha^{-1}	
112-0-56	No	806.00	907.0	857.0
112-34-56	No	911.00	1064.0	988.0
112-68-56	No	933.00	1063.0	998.0
112-34-56	Yes	1000.0	1144.0	1073.0
112-68-56	Yes	1012.0	1151.0	1082.0
$LSD_{(0.05)}$		50.00.0	56.0	52.0
CV%		2.9.00.0	3.8	3.2

Table 3. Cotton leaf tissue P concentration as affected by P-Rate and AVAIL, Grand Junction, TN

N-P_2O_5-K_2O Rate	AVAIL	2011	2012	Avg.
kg ha^{-1}			g kg^{-1}	
112-0-56	No	2.96	3.44	3.20
112-34-56	No	3.68	3.98	3.83
112-68-56	No	4.92	4.62	4.77
112-34-56	Yes	5.26	5.51	5.39
112-68-56	Yes	5.31	5.47	5.40
112-68-56	Nutrisphere-N+AVAIL	5.42	5.44	5.43
LSD $_{(0.05)}$		0.29	0.33	0.31
CV%		3.90	5.10	4.20

Note: Uppermost fully expanded leaf at full-bloom (Aug. 8, 2011, Aug 1, 2012)

Table 4. Cotton leaf tissue P concentration as affected by P-Rate and AVAIL, Ames Plantation, TN

N-P_2O_5-K_2O rate	AVAIL	2012	2013	Avg.
kg ha^{-1}			g kg^{-1}	
112-0-56	No	3.05	3.12	3.09
112-34-56	No	3.62	3.78	3.70
112-68-56	No	4.51	4.66	4.59
112-34-56	Yes	5.02	5.12	5.07
112-68-56	Yes	5.05	5.11	5.08
LSD $_{(0.05)}$		0.32	0.33	0.33
CV%		4.10	5.00	4.40

Note: Uppermost fully expanded leaf at full-bloom (Aug. 1, 2012, Aug. 12, 2013)

Table 5. Number of harvestable bolls at maturity as affected by P-Rate and AVAIL, Grand Junction, TN

N-P_2O_5-K_2O rate	AVAIL	2011	2012	Avg.
kg ha^{-1}			number of bolls m^{-2}	
112-0-56	No	110.0	112.0	111.0
112-34-56	No	118.0	120.0	119.0
112-68-56	No	129.0	131.0	130.0
112-34-56	Yes	138.0	140.0	139.0
112-68-56	Yes	137.0	145.0	141.0
112-68-56	Nutrisphere-N+AVAIL	138.0	142.0	140.0
$LSD_{(0.05)}$		6.0	4.0	6.0
CV%		6.9	5.5	6.3

When averaged over N-Rates, application of AVAIL increased P tissue concentration by 23 and 18% at GJ and AP sites, respectively, over the P alone treatments. At both sites and all years of the experiment, use of AVAIL resulted in more P actually being taken up by plants.

At GJ site, boll number was significantly increased by addition of P fertilizer with or without AVAIL in 2011 and 2012 (**Table 5**). When averaged over years and P rates, use of AVAIL at GJ site increased harvestable boll number by 11%. Applying 34 kg P ha^{-1} treated with AVAIL resulted in 7% increase in boll number over the 68 kg P ha^{-1} rate untreated.

4. DISCUSSION

Only a small fraction of the total P in soils is available for plant uptake (Barber, 1995). Phosphorus generally occurs in soils as the anions $H_2PO_4^{-1}$ or HPO_4^{-2} depending on soil pH. These anions react readily with soil cations such as Ca, Mg, Fe and Al to produce various phosphate compounds of very limited water solubility. Crop recovery of applied P fertilizer can be quite low during the season of application (Widdowson and Penny, 1973; Cooke, 1981). The cotton plant accumulates a large portion of P that it takes up in the bolls (Ergle and Eaton, 1957). In studies of both irrigated and rain-fed cotton, P removal in the lint at harvest accounted for as much as 52% of total P taken up (Olson and Bledsoe, 1942). Mullins and Burmester (1991) reported that 21-36% of the total seasonal P uptake was accumulated during a two week period at early to mid-flower. Delayed initiation of squares, reduced flowering, decreased boll set, early senescence and delayed boll maturity of set bolls are all consequences of P deficiency in cotton (Brown and Ware, 1958). Effects of P deficiency are ultimately expressed in number of bolls set (Stewart, 1986).

This research showed that AVAIL improved leaf tissue P concentration, number of harvestable bolls and yield of cotton grown on soils not low in available P. Consistently greater yields were achieved with 34 kg ha^{-1} AVAIL treated MAP than 68 kg ha^{-1} untreated MAP.

5. CONCLUSION

This study investigated the use of AVAIL with phosphorus fertilizer in order to improve nutrient management. Phosphorus management is a key element in successful cotton production. In this experiment, AVAIL consistently improved both leaf tissue P concentration and yield of cotton grown in the Mid-South on soils not low in available P. The use of AVAIL resulted in greater number of harvestable bolls. AVAIL performed equally well in both no-tillage and conventional tillage environments. More research is needed to evaluate soil P content and improve application recommendations under different soil types and crop management practices.

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