Variable Rate Phosphorus Fertilization in Cotton on the Texas High Plains

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Introduction

We cannot always predict how cotton will respond to phosphorus fertilizer, even with soil tests. Phosphorus is probably the third limiting factor in crop growth on the Texas High Plains, behind water (first) and nitrogen (second).

There have not been many studies on how cotton responds to phosphorus fertilizer, using a landscape (topography) scale. Differences in nitrogen and phosphorus response and overall productivity may be attributed to landscape position, due to re-distribution of water to low-lying landscape positions.

Our objectives in this study were to: (1) compare variable-rate-phosphorus and blanket-rate-phosphorus applications on phosphorus accumulation and lint yields at two 27-acre irrigated cotton and (2) determine how landscape position and soil properties may affect P fertilizer response and lint yields.

Experiment design

We conducted our studies at two sites, using a randomized complete block design with three replicates (repeats); each replicate was within the span of a center pivot sprinkler. The studies compared zero phosphorus, blanket-rate phosphorus application and variable-rate phosphorus application. Each plot contained 16 rows, each 40-inches wide, and was up to 1,000 yards long.

We applied phosphorus as phosphoric acid (0-34-0) near planting, placing it 4 inches deep and 4 inches from the seed row. We used a blanket rate of 45 pounds of P_2O_5 per acre at Lamesa, and 30 pounds of P_2O_5 per acre at Ropesville, during both years of the study. This rate was based on Mehlich-3-P recommendations for samples taken from the zero to six-inch deep topsoil layer.

We applied phosphorus at variable rates with the ground rig used for blanket-rate applications, after it was fitted with an Agchem/Soil Tec., Inc., Fertilizer Applicator Local Controls Operating Network (FALCON™). This network consists of variable-rate servo valves, a field-duty computer, control software, ground speed radar, centrifugal pumps driven by hydraulic motors, flow meters and shut-off valves.

We also used a submeter accurate SATLOC® differential global positioning system (GPS) receiver with the FALCON™ system. The FALCON™ software used the inverse-distance method of interpolation to calculate and generate its variable-rate application maps (Figure 1, Lamesa site).

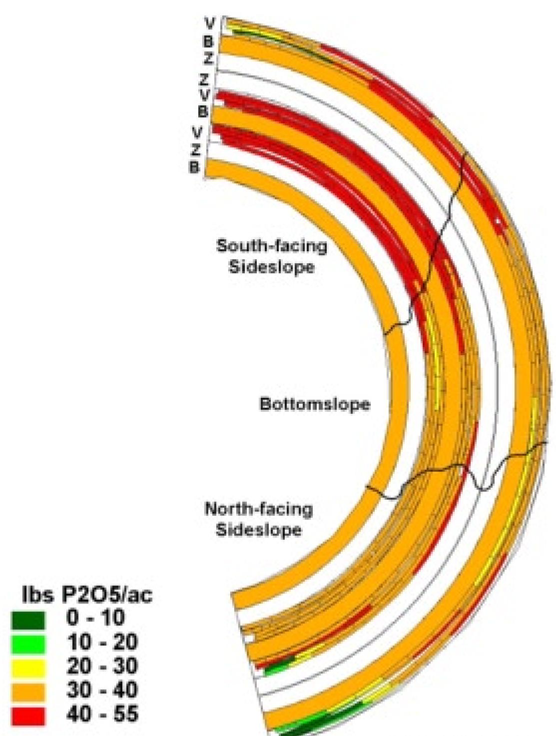

Figure 1

Background

Lamesa

The soil is an Amarillo sandy/sandy clay loam. In March, 2000, we took soil samples at 63 GPS-referenced points in this 27-acre site. We also took 10 subsamples by hand soil probe, at a depth of zero to six inches, and analyzed for Mehlich-3-P and nitrate. We also took two subsamples from the six to 24-inch depth, for nitrate analysis.

Our blanket nitrogen fertilizer application was based on a nitrogen requirement of 120 pounds of nitrogen per acre for a two-bale yield goal, taking into consideration existing nitrate in the zero to 24-inch depth. We planted PaymasterR Roundup ReadyR 2326 cotton (PM 2326 RR) on 40-inch rows on May 10, 2000.

We hand harvested the lint from 22 feet of row at each GPS-referenced point. Seed cotton was ginned, and we obtained a lint weight for each sample.

In 2001, we repeated this experiment identically, but we planted the same variety on May 28 instead of May 10.

Ropesville

This site contains two soil series (types): an Amarillo sandy/sandy clay loam, and a Portales sandy clay/sandy clay loam. In March, 2000, we took soil samples at 60 GPS-referenced points at this site, in the same manner as in Lamesa, and analyzed the samples for nitrate and Mehlich-3-P.

On May 6, 2000, we planted PM 2326 RR cotton in 40-inch rows. We applied blanket nitrogen fertilizer based on the zero to 24-inch nitrate. We hand-harvested 22 feet of row per GPS point on Sept. 29.

We planted the same variety on May 2, 2001, but a hail storm with six inches of rain destroyed the crop on May 25.

Results

Lamesa

We found a negative correlation between relative elevation and slope with the row, and cotton biomass, phosphorus accumulation and lint yield (data not shown). In other words, low-lying areas in the field produced the greatest yields while higher landscape positions produced lower yields. In fact, soil properties did not have much affect on cotton in 2000 or 2001.

Greater yields on the low-lying bottomslope at this site were previously reported. In our early studies, we measured more soil moisture in the bottomslopes, presumably due to runoff of rain and irrigation. Therefore, we delineated bottomslope from sideslope using slope-with-the-row data (derived from elevation data).

The bottomslope had the lowest slope-with-the-row (less than 0.4 percent). Landscape position, and landscape/phosphorus treatment, was incorporated into the statistical analysis.

Cotton biomass and phosphorus accumulation at early squaring were not affected by phosphorus fertilizer, but both were greater in the bottomslope than in the sideslopes (data not shown). The highest lint yield occurred in the bottomslope, in both years of our study (Table 1). In 2000, lint yield in the north-facing sideslope was less than in the south-facing sideslope.

As mentioned above, water is apparently redistributed to the bottomslope in this location, resulting in greater plant growth.

Response to phosphorus fertilizer was less consistent than landscape position. Lint yields responded to variable-rate-phosphorus in 2000, averaged across landscape position. In any particular landscape position, however, phosphorus did not affect lint yields. In 2001, the blanket-rate phosphorus application produced a lint yield response only in the south-facing sideslope (Table 1).

Table 1. Lint yield as affected by phosphorus fertilization and landscape position, Lamesa, TX, 2000 and 2001.

Phosphorus treatment	North-facing sideslope	Bottomslope	South-facing sideslope	Mean
	---------------------------- lb/ac ------------------------------			
	2000			
Variable-rate-P	687 a†	762 a	575 a	675 a†
Blanket-rate-P	602 a	690 a	564 a	619 ab
Zero-P	604 a	671 a	521 a	598 b
Average	631 b‡	707 a	553 c	
	2001			
Variable-rate-P	892 a†	1047 a	866 ab	935 a†
Blanket-rate-P	963 a	1013 a	885 a	953 a
Zero-P	896 a	1021 a	769 b	896 a
Mean	916 b‡	1026 a	840 b	

† Means in a column followed by the same letter are not significantly different by pairwise t test (P=0.05)

‡ Means in a row followed by the same letter are not significantly different by pairwise t test (P=0.05)

In 2000, we applied more phosphorus to the variable-rate plots (an average of 38 pounds of P_2O_5 per acre) than to the blanket plots (Table 2). We applied less phosphorus in 2001 to the variable-rate plots (an average of 16 pounds P_2O_5 per acre), despite similar soil phosphorus levels.

Ropesville

We observed a strong negative correlation between phosphorus accumulation, biomass at early squaring and soil calcium (data not shown) at this site. High soil calcium levels were associated with the calcareous Portales soil on the west half of this site. Cotton growth was suppressed in high-calcium areas, compared to other areas in the field with normal soil calcium.

Table 2. Cost and returns of phosphorus fertilizer applications, Ropesville, 2000 and Lamesa, TX, 2000-2001

	Lint yield (lb/ ac)	Lint income† ($/ac)	Lint income above zero-P	Ave rate of P_2O_5 (lb/ac)	Cost of P_2O_5 ‡ ($/ac)	Net return to P fertilizer ($/ac)
	Ropesville, 2000					
Variable-rate-P	643	321.50	35.50	41.9	14.66	20.84
Blanket-rate-P	623	311.50	25.50	45.0	15.72	9.78
Zero-P	572	286.00		0	0	
	Lamesa, 2000					
Variable-rate-P	675	337.50	38.50	38.4	13.44	25.06
Blanket-rate-P	618	309.00	10.0	30.0	10.50	-0.50
Zero-P	598	299.00		0	0	
	Lamesa, 2001					
Variable-rate-P	935	467.50	19.50	15.9	5.57	13.93
Blanket-rate-P	953	476.50	28.50	30.0	10.50	18.00
Zero-P	896	448.00		0	0	

† $ 0.50/lb lint
‡ $ 0.35/lb P_2O_5

Unlike Lamesa, we found no correlation between elevation or slope-with-the-row and plant measurements. We therefore delineated the two soil types in our data sets, and incorporated soil type, and soil type/phosphorus treatment into our statistical analysis.

Phosphorus accumulation (Table 3) and biomass (data not shown) at early squaring were lower in the Portales soil than in the Amarillo soil. Blanket-rate and variable-rate phosphorus treatments affected phosphorus accumulation and biomass,

Table 3. Cotton phosphorus accumulation at early squaring, and lint yield as affected by phosphorus fertilization and soil type, Ropesville, TX, 2000.

Phosphorus treatment	Amarillo sandy loam	Portales clay loam	Mean
	Phosphorus accumulation		
	---------- lb P_2O_5/ ac ------------		
Variable-rate-P	5.2 a†	3.4 a	4.3 a†
Blanket-rate-P	5.0 a	2.7 a	3.9 ab
Zero-P	3.4 b	3.2 a	3.2 b
Mean	4.5 a‡	3.2 b	
	Lint yield		
	----------- lb/ac -----------		
Variable-rate-P	663 a†	622 a	643 a†
Blanket-rate-P	646 a	600 a	623 a
Zero-P	538 b	606 a	572 a
Mean	616 a‡	609 a	

† Means in a column followed by the same letter are not significantly different by pairwise t test (P=0.05)

‡ Means in a row followed by the same letter are not significantly different by pairwise t test (P=0.05).

relative to plots receiving zero phosphorus, only in the Amarillo soil. Soil phosphorus and added phosphorus were apparently less available in the calcareous Portales soil.

We observed a lint yield response to blanket-rate and variable-rate phosphorus treatments only in the Amarillo soil (Table 3). When averaged across phosphorus treatments, lint yield was similar between both soil types. We applied less phosphorus, on average, in our variable-rate treatments than in our blanket-rate treatments, despite similar soil-test phosphorus levels (Table 2).

Costs/returns of phosphorus fertilization

Our costs and returns analysis for blanket-rate and variable-rate phosphorus fertilization is shown in Table 2. However, this analysis does not include the extra costs we incurred with variable-rate treatments, compared to blanket-rate treatments.

These extra costs include: grid soil sampling; additional laboratory analyses of a larger number of soil samples; and retro-fitting a liquid fertilizer rig with variable-rate equipment, GPS, and ground speed radar.

A liquid fertilizer rig, designed for variable-rate application, with spoke applicators. Note the cotton seedlings growing in the crop residue.

Compared to zero phosphorus application, blanket-rate phosphorus fertilization produced a positive cash return in 2000 at Ropesville, and in 2001 at Lamesa. It produced a negative cash return in 2000 at Lamesa (Table 3).

Variable-rate phosphorus applications produced positive cash returns in all three site-years. However, in 2001 at Lamesa, our blanket-rate treatment produced a higher cash return ($18 per acre) than our variable-rate treatment ($13.93 per acre).

A field-duty computer -- part of the FALCON™ variable-rate control system used in our study. The screen on this computer shows a map of variable-rate applications made in this field.

Summary

Cotton's response to phosphorus fertilization was not consistent in this study. At the same time, we conclude that variable-rate fertilizer applications can theoretically match soil-test phosphorus and phosphorus fertilizer rate in all areas of a field better than conventional, blanket fertilization.

Our study compared variable-rate, blanket-rate, and zero phosphorus applications on two 27-acre irrigated sites, using similar soil-test methods as a basis for phosphorus application rates.

When averaged across landscape position, lint yields at Lamesa showed a positive response to variable-rate phosphorus applications in 2000. In 2001, Lamesa lint yields responded to blanket-rate phosphorus applications only in the south-facing sideslope.

At Ropesville in 2000, cotton biomass and phosphorus uptake at early squaring was less in a calcareous soil than in a non-calcareous soil. At the same time, we observed a lint response to variable-rate phosphorus applications only on the non-calcareous soil.

In summary, responses to variable-rate and blanket-rate phosphorus treatments were inconsistent. However, one of the most significant results from our study was that in two of three site-years, less phosphorus was applied with the variable-rate approach than with a recommended blanket-rate. Still, landscape position/slope at Lamesa, and soil type/soil calcium at Ropesville, had a greater impact

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