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INFLUENCE OF PHOSPHORUS APPLICATION WITH AVAIL ON FOLLOWING SOYBEANS IN SOUTHEASTERN COASTAL PLAINS

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ABSTRACT

Application of Phosphorus (P) in combination of with polymer Avail to previous crop may affect soybeans [*Glycine max* (L.) Merr.] under dryland conditions. The objective of this study was to determine the effect of two P rates (45 and 90 kg P_2O_5 ha^{-1}) with and without Avail applied to winter wheat (*Triticum aestivum* L.) previous crop on growth and yields of dryland soybeans near Blackville, SC from 2011 to 2012. Soybeans were evaluated for Leaf Area Index (LAI), plant Normalized Difference Vegetation Index (NDVI), plant height, grain moisture, seed weight and grain yields. Compared to untreated control, P applications at 45 kg and 90 kg ha^{-1} with Avail to winter wheat significantly increased soybean grain yields by 12.3% and 20.2%, respectively. Phosphorus applied to previous crop at 45 kg and 90 kg P ha^{-1} with polymer Avail, improved soybean yields by 8.1 and 4.0% over P treatments not treated with Avail, respectively. Soybean LAI significantly increased by 22.8% at 3 months after planting with application of P at 90 kg ha^{-1} and polymer Avail to winter wheat previous crop compared to untreated control. Lower P rate of 45 kg ha^{-1} with Avail to winter wheat increased soybean LAI by 11.8%. Applications of 45 kg and 90 kg P ha^{-1} with Avail to previous crop improved plant NDVI at 3 months after soybean planting by 1.8% and 2.5%, respectively. Based on significant linear relationship, increasing plant NDVI by 0.1 improved soybean yields by 126.1 kg ha^{-1}. Applications of P with Avail to winter wheat did not affect soybean LAI and NDVI at 2 months after planting, plant height, grain moisture and seed weight. Results from this study indicate that P applications with Avail to previous crop significantly improved plant LAI and NDVI at 3 months after planting and increased soybean yields.

Keywords: Soybean, Polymer, Avail, Phosphorus, Normalized Difference Vegetation Index (NDVI), Leaf Area Index (LAI)

1. INTRODUCTION

Reduced yield potential of soybeans is a result of low soil Phosphorus (P) (Liu *et al*., 2010) and insufficient water availability (Zheng *et al*., 2010). Many areas in the World are deficient in available P (McLaughlin *et al*., 2011). Improved soybean yields have been shown with improved nodulation after P application and Rhizobium inoculation (Abbasi *et al*., 2010) and with P and potassium (K) applications, which also improved seed protein content (Abbasi *et al*., 2012). Phosphorus fertilization was effective in reducing the impact of drought and therefore improving yields in studies conducted by Zheng *et al*. (2010).

Fertilizer recommendations depend on determination of nutrients supplied and immobilized in the soil, which is very important for a site-specific nutrient management (Anthony *et al*., 2012). Qiao (2012) pointed out that soil P distribution is essential to improve nutrient uptake. McBeath *et al*. (2012) indicated that most P available to plants was in the topsoil, but adding P improved uptake of nutrient from the subsoil. They also reported that P fertilizer applied below seeds increased nutrient uptake from the subsoil. According to McBeath *et al*. (2011), P should be applied at early stages of crop growth. Compared to untreated control, applying P fertilizer near seeds increased plant weight, nutrient uptake and content in plants, therefore placing fertilizer close to seeds should be a recommended management practice in crop production (Rehm and Lamb, 2010).

Phosphorus availability is not only affected by nutrient management, but also cropping system (Nunes *et al*., 2011), which can help with the sustainability of agricultural production (Steiner *et al*., 2012). Phosphorus in plant residues from previous crop may be utilized by following crops (Noack *et al*., 2012). Under no-till system, P released from plant residues and concentrated in the soil surface helps to improve nutrient availability of following crops (Olibone and Rosolem, 2010). Hassan *et al*. (2012) noted that P uptake improved in cereal crops following legumes. Continued cereal systems required P application every other year, while after soybean P was required in one out of three years in studies conducted by Kihara *et al.* (2010).

Alternative fertilization may help to reduce nutrient loss, especially in sandy soils subjected to nutrient leaching (Yang *et al*., 2012). Using technologies to improve P efficiency is a good alternative in crop production (De Figueiredo *et al*., 2012). According to McLaughlin *et al*. (2011), slow release P products improve nutrient use efficiency in soils with leaching problems. They also indicated that soil P placement is important in improving P use efficiency. Guareschi *et al*. (2011) reported that soybean yields increased with superphosphate coated polymer applied at 15 days prior to planting; however, there was no significant difference between coated and uncoated fertilizer application at planting.

Little research focused on the effect of P coated with polymer Avail applied to previous crop on following soybean crop under insufficient rainfall. McLaughlin *et al*. (2011) indicated that P use efficiency is generally low in first year and residual effect is important for the following crop. Moreover, polymer-coated fertilizer should be evaluated for improving nutrient efficiency (De Figueiredo *et al*., 2012). Therefore, objective of this study was to evaluate polymer coated P applied to winter wheat previous crop on soybeans under dryland conditions in Southeastern Coastal Plains.

2. MATERIALS AND METHODS

2.1. Site Preparation and Management

This study was conducted on Faceville loamy sand (Fine, kaolinitic, thermic Typic Kandiudults) at Clemson University, Edisto Research and Education Center (REC) near Blackville, SC (33° 21' N, 81°18' W) under dryland conditions in 2011 and 2012. These are well drained soils with moderate permeability and soil pH was 6.6. Treatments consisted of 2 rates of P (45 and 90 kg P_2O_5 ha^{-1}) with and without Avail applied to winter wheat previous crop and an untreated control.

Prior to planting winter wheat previous crop, all treatments with Diammonium Phosphate (DAP) (18-46-0 of N-P_2O_5-K_2O fertilizer with and without Avail) were applied separately in each plot using a handheld spreader. Soybean cv. 'Pioneer 97M50' was planted after harvest of winter wheat at 272,000 seeds ha^{-1} in strip-till using Univerferth Ripper-Stripper (Unverferth Mtg. Co., Inc., Falida, OH) implement and John Deere 1700 MaxEmerge XP vacuum planters (John Deere Co., Moline, IL) on 27 May 2011 and 13 June 2012. The plot size was 9.1 m long by 4.0 m wide with four soybean rows. Pest control was based on the South Carolina Extension recommendations.

2.2. Plant Measurements

Plant measurements were conducted in the center of each plot. Normalized Difference Vegetation Index (NDVI) was measured using handheld GreenSeeker™ (NTech Industries, Inc. Ukiah, CA) instrument and the Leaf Area Index (LAI) LAI-2000 (Li-Cor, Lincoln, NE) meter was used to measure plant index at 8 and 12 weeks after soybean planting. Ten random plants were selected for height measurements from the ground to the top of the plant prior to soybean harvest.

Soybeans were harvested from the entire length of plot using Kinkaid 8XP small plot combine (Kinkaid Equip. Mtg, Haven, KS) on 8 November 2011 and 29 October 2012. Grain samples from all harvested plots were evaluated for weight and tested for moisture content using a Burrows Model 750 Digital Moisture Computer (Seedburo Equip. Co., Chicago, IL). Seed weight was determined after counting seeds using the Agriculex electronic seed counter model ESC-1 (Agriculex Inc., Guelph, Ont., Canada). Grain yield was converted to 15.5% moisture content. Additionally, weather data (air temperature and precipitation) were recorded during soybean vegetation using a weather station located near the experimental site.

2.3. Statistical Analysis

The study design was a Randomized Complete Block with eight replications. Data were analyzed using the general linear models in SAS (2011) by analysis of variance and means were separated using Fisher's Least Significant Difference Test at $p \le 0.05$. A linear regression model was fit using PROC REG (SAS, 2011) after contrast analyses indicated a significant ($p \le 0.05$) response.

3. RESULTS

3.1. Weather Conditions

Monthly average temperature, precipitation and average from the 30-yr average are shown in **Table 1**. The average monthly air temperature was generally similar to 30-yr average, except for June and July 2011 and August 2012 when temperature was 2.3, 1.3 and 1.1°C higher and October 2011 and June 2012 when temperature was 2.3 and 1.4°C lower than 30-yr average, respectively.

Precipitation was 151 mm higher during soybean growing season in 2011 and 15 mm higher in 2012 than 30-yr average (**Table 1**). Insufficient precipitation was observed in June in two soybean growing seasons and also July, September and October in 2012. Compared to multiyear rainfall data, higher precipitation was recorded in August in 2011 and 2012 and July, September and October in 2011.

3.2. Plant Leaf Area Index (LAI) and Normalized Difference Vegetation Index (NDVI)

Table 2 shows that plant LAI significantly increased by 22.8% with high rate of P at 90 kg ha^{-1} and polymer Avail application to winter wheat previous crop compared to untreated control at 3 months after soybean planting. Applying P fertilizer at 45 kg ha^{-1} with polymer Avail improved soybean LAI by 11.8% over control. Soybean LAI increased by 4.5% and 10.2% with P in combination with Avail applied at 45 kg and 90 kg ha^{-1} to winter wheat, respectively. Plant LAI was not significantly affected by treatment application at 2 months after soybean planting.

Compared to untreated control, treatment with P and polymer Avail applied to winter wheat previous crop significantly improved plant NDVI at 3 months after planting of soybean (**Table 2**). Plant NDVI increased by 1.8 and 2.5% over untreated control at 45 and 90 kg P ha^{-1} with polymer Avail. Phosphorus and Avail applications to winter wheat did not affect soybean NDVI at 2 months after planting soybeans.

3.3. Plant Height, Grain Moisture, Seed Weight and Grain Yield

Compared to the untreated control, application of P with polymer Avail to winter wheat previous crop significantly improved grain yields of following soybean crop (**Table 3**). Soybean yields increased by 12.3% over untreated control with P rate of 45 kg ha^{-1} and Avail applied to winter wheat and 20.2% at P rate of 90 kg ha^{-1} with Avail compared to control. Compared to P fertilizer without Avail, addition of Avail to P improved soybean yields by 8.1and 4.0% with 45 kg and 90 kg P ha^{-1} applied to wheat previous crop. Plant height, grain moisture and seed weight of soybeans were not significantly affected by P with polymer Avail applications to winter wheat previous crop.

Table 1. Monthly average air temperature and precipitation during soybean growth near Blackville, SC from 2011 to 2012

	Month					
Year	June	July	Aug.	Sep.	Oct.	Average/total
Temperature (°C)						
2011	27.4	28.0	18.0	23.2	15.9	21.3
2012	23.8	27.7	18.8	22.7	18.4	21.9
30-yr avg.	25.2	26.8	17.8	23.4	18.2	21.6
Precipitation (mm)						
2011	58.0	140.0	182.0	142.0	111.0	575.0
2012	80.0	97.0	309.0	19.0	14.0	439.0
30-yr avg.	129.0	130.0	122.0	92.0	80.0	524.0

Table 2. Influence of Phosphorus (P) and Avail applied to winter wheat previous crop on soybean Leaf Area Index (LAI) and Normalized Difference Vegetation Index (NDVI) at 2 and 3 months after planting near Blackville, SC from 2011 to 2012.

	Leaf Area Index (LAI) (months after planting)		Normalized Difference Vegetation Index (NDVI) (months after planting)	
P rate (kg ha^{-1})	2	3	2	3
Control	2.90	4.97	0.6085	0.8830
45	3.05	5.36	0.6593	0.8991
45+Avail	3.07	5.60	0.6478	0.8995
90	3.16	5.69	0.6279	0.8997
90+Avail	3.22	6.27	0.6357	0.9057
$LSD_{(0.05)}$	NS	0.90	NS	0.0145

Table 3. Influence of Phosphorus (P) and Avail applied to winter wheat previous crop on plant height, grain moisture, weight of 100 seeds and grain yield of soybeans near Blackville, SC from 2011 to 2012

P rate (kg ha^{-1})	Plant height (cm)	Grain moisture (%)	100 seed weight (gms)	Grain yield (Mg ha^{-1})
Control	85.5	12.5	12.9	1.87
45	85.5	12.6	13.5	2.10
45 + Avail	83.4	12.9	13.2	2.27
90	86.9	12.8	13.6	2.23
90 + Avail	84.7	12.3	13.1	2.32
$LSD_{(0.05)}$	NS	NS	NS	0.22

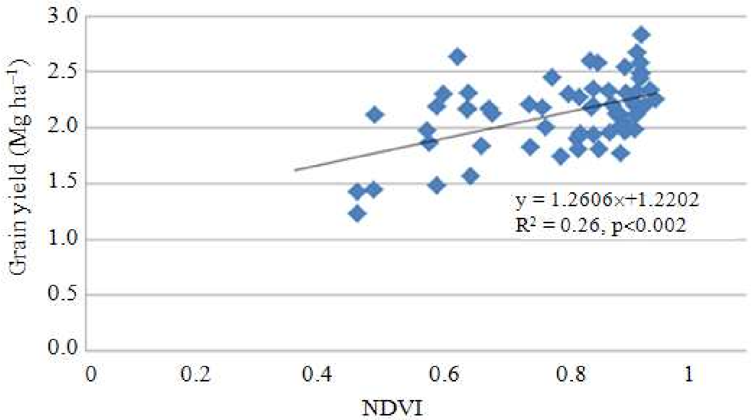

Fig. 1. Relationship between plant Normalized Difference Vegetation Index (NDVI) at 2 months after planting and grain yield of soybeans from 2011 to 2012

3.4. Relationships between Grain Yields and Plant NDVI

A significant relationship was observed between grain yield and plant NDVI at 2 months following soybean planting (**Fig. 1**). Based on this linear relationship, increasing plant NDVI by 0.1 at 3 month after planting soybeans increased grain yields by 126.1 kg ha^{-1}.

4. DISCUSSION

Previous research was limited and not conclusive. According to De Figueiredo *et al*. (2012), polymer-coated P improved plant height of corn compared to standard P application. However, this study showed no effect of coated P with polymer Avail on soybean height. Plant LAI and NDVI generally improved with P and polymer Avail applications to winter wheat previous crop. Applying P at 45 kg and 90 kg P ha^{-1} with polymer Avail to wheat previous crop increased soybean LAI by 4.5 and 10.2% over uncoated P, respectively at 3 months after planting. Plant NDVI at 3 months after soybean planting improved with P and polymer Avail applied to previous crop at 45 kg and 90 kg P ha^{-1} by 1.8% and 2.5% over control, respectively.

Previous studies showed that corn grain yields were not affected by P fertilization (Kolawole, 2012) and wheat grain yields did not significantly improve with application of Monoammonium Phosphate (MAP) coated with Avail compared to uncoated MAP (Karamanos and Puurveen, 2011). However, De Figueiredo *et al*. (2012) reported higher corn yields with the polymer-coated MAP over conventional MAP. In the study conducted by Kamara *et al*. (2012), application of P fertilizer increased pod number per plant, which contributed to increased soybean yields. Kamara *et al*. (2012) recommended applying 40 kg P ha^{-1} to optimize soybean production. Liu *et al*. (2010) reported that no P application reduced soil P, but applying high P fertilizer rate at 80 kg ha^{-1} increased soybean yields. Zheng *et al*. (2010) reported that soybean yields increased with P application rate of up to 55.67 kg ha^{-1}. In this study, applying 45 kg and 90 kg P ha^{-1} with polymer Avail to winter wheat previous crop increased soybean yields by 8.1 and 4.0% over uncoated P, respectively. Compared to untreated control, grain yields of soybean increased by 12.3 and 20.2% with applying 45 kg and 90 kg P ha^{-1} with polymer Avail to previous wheat crop, respectively. Based on linear relationship, increasing plant NDVI by 0.1 increased soybean yields by 126.1 kg ha^{-1}. It agrees with Raun *et al*. (2001), who reported a strong relationship between plant NDVI and yields of winter wheat.

5. CONCLUSION

This study investigated the effect of two P rates (45 and 90 kg P_2O_5 ha^{-1}) with and without Avail applied to winter wheat previous crop on growth and yield of following soybeans crop grown under dryland conditions. Application of 90 kg P ha^{-1} with polymer Avail to winter wheat previous crop increased soybean LAI at 3 months after planting by 22.8% over untreated control. Application of lower P rates at 45 kg ha^{-1} with Avail to winter wheat improved soybean LAI by 11.8%. Addition of polymer Avail to 45 kg and 90 kg P ha^{-1} to winter wheat previous crop increased soybean LAI by 4.5 and 10.2% compared to P rates without polymer Avail, respectively. Plant NDVI improved by 1.8% and 2.5% over control at 3 months after soybean planting with 45 kg and 90 kg P ha^{-1} in combination with polymer Avail applied to winter wheat previous crop, respectively. Compared to untreated control, soybean yields increased by 12.3 and 20.2% with 45 kg and 90 kg P ha^{-1} and polymer Avail applied to previous wheat crop, respectively. Compared to 45 kg and 90 kg P ha^{-1} without Avail, coating P with Avail increased soybean yields by 8.1 and 4.0%, respectively. A significant positive linear relationship showed that increasing plant NDVI by 0.1 increased crop yield by 126.1 kg ha^{-1}. Application of P and polymer Avail to winter wheat previous crop did not affect soybean LAI and NDVI at 2 months after planting, plant height, grain moisture and seed weight. Generally, grain yield of soybeans increased due to improved plant LAI and NDVI with P and polymer Avail applications to winter wheat previous crop. Future research may evaluate application of P with Avail to wheat previous crop on following soybeans under irrigation system.

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