Understanding Influence Of P Placement Under Field Conditions

P management in reduced-till has been a concern for farmers.

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Summary: *Despite various advantages of reduced-till systems, it has been found that surface application of phosphorus (P) leads to an accumulation of P in the surface 0 to 5 cm of soil layer and a depletion of available P deeper in the profile. We measured changes in soil pH, resin extractable P, and speciation of P at five-week and six-month intervals after P application to a soil system that was under long-term reduced-till. Resin extractable P was lower for broadcast treatments as compared to deep-band treatments for both the time periods. Resin extractable P was greater for liquid P-treated soils when compared to the granular P-treated soils. Speciation results showed that granular P fertilizers tended to form iron (Fe) phosphate-like products whereas liquid forms were found to remain in adsorbed P-like forms in soil five weeks after application. Over the six-month period, reaction products of broadcast/ granular and broadcast/liquid and deep-banded/ granular fertilizers transformed to Calcium (Ca)-phosphate or mixtures of Ca-, Fe-, aluminum (Al)- and adsorbed phosphate-like forms while deep-banded liquid P continued to remain mainly as adsorbed P-like forms.*

Phosphorus management in reduced-till systems has been a great concern for farmers. It has been found that P application, mostly in granular forms, leads to an accumulation of available P on the surface 0 to 5 cm of soil layer and a depletion of available P deeper in the profile. Deep placement of nutrients below the first 5 to 10 cm of the soil should be superior to other placements when nutrient stratification, coupled with topsoil moisture deficit, reduces nutrient uptake from shallow soil layers. Inconsistent results have been obtained from the research conducted to study the effects of tillage and deep placement of P fertilizers on grain yields of crops grown in Kansas. Knowledge of the dominant solid P species present in the soil following application of P fertilizers, and linking that to potential P availability, would help understand how to manage P in efficiently reduced-till systems.

The objective of this research was to understand the influence of placement (broadcast vs. deep-banded P), fertilizer source (granular vs. liquid P), and time on reaction products of P under field conditions.

Materials/methods

Site. A field-based study was performed at the Agronomy North Farm located in Manhattan, Kansas. This site has a history of more than five years of reduced-till studies.

Sources. Two P fertilizer sources were granular mono-ammonium phosphate (granular MAP) and technical grade MAP (liquid MAP).

Application. Phosphorus was applied at 75 kg/ha and N, as urea, was applied at 200 kg/ha. Urea was broadcast (control) and deep banded (control). Granular

Table 1. Percentages of P species in soils in the fertilized soil sections(0 to 2.5 cm for the broadcast and 7.5 to 10 am for the deep-band treatments) determined by linear combination fitting of the first derivative of XANES spectra.

						Red.
Treatment	Al- Phosphates	Ca-Phosphates	Fe(III) Phosphate	Fe(II) Phosphate	Adsorbed P	c2 ‡
5 weeks						
Urea Broadcast (Control)	-	-	-	57.9	42.1	0.06
Gr. MAP Broadcast	11.3	-	-	69.2	19.5	0.01
Liquid MAP Broadcast	-	17.7	38.9	-	43.4	0.06
Urea Deep band (Control)	40.5	47.0	-	-	12.5	0.01
Gr. MAP Deep band	-	-	-	64.5	33.5	0.12
Liquid MAP Deep band	-	-	-	46.7	53.4	0.01
6 months						
Urea Broadcast (Control)	60.4	-	-	39.6	-	0.41
Gr. MAP Broadcast	46.3	-	-	-	53.6	0.01
Liquid MAP Broadcast	-	100	-	-	-	1.13
Urea Deep band (Control)	-	53.0	-	47.0	-	6.6
Gr. MAP Deep band	-	51.6	-	-	48.4	1.47
Liquid MAP Deep band	-	19.8	-	-	80.3	0.01

MAP was broadcast and deep banded, liquid MAP (TGMAP) was broadcast and deep banded. Broadcast treatments were applied on the surface and gently mixed, whereas deep-band treatments were applied approximately at 10 cm depth in two rows per plot.

Soil sampling was done at five-week and six-month intervals after treatment. Each time 30 cm long solid cores were extracted using an auger and divided into 2.5 cm slices, air dried, and sieved <2mm.

Analysis: All data were analyzed using proc. mixed procedure using SAS software (SAS 9.1, 2007). Pairwise Bonferroni method was used for pairwise comparison of all the treatments at a = 0.05 level of significance. Synchrotron-based bulk x-ray absorption near-edge structure (XANES) spectroscopy analysis (to determine chemical form of reaction products) was performed at sector 9BM-B, Advanced Photon Source, Argonne, IL, USA. The first derivatives of reduced spectra for the samples were analyzed by linear combination fitting (LCF) using IFEFFIT software. Spectra for the various standard compounds were reduced and normalized as for the spectra of the soil samples.

Overview

Mixed results (lower, higher, or no significant difference) were observed for soil pH when comparing differences in soil pH among the urea added control plots and the urea + MAP (as granular or liquid MAP) added plots (data not shown). Acidification effects of MAP on soil pH have been reported by many researchers. However, hydrolysis of urea consumes two moles of protons for each mole of urea hydrolyzed, thereby resulting in an increase in pH. So the combination of these reactions (nitrification of NH4+ and hydrolysis of urea) in turn could result in mixed effects on overall soil pH. At five weeks, in the added zones, soil pH of both urea and MAP (as granular or liquid) was significantly lower (by about 0.2 to 0.5 units) than the original soil pH (5.3). However, soil pH of six-month samples was higher (by about 0.2 or 0.6 units) when compared to the soils sampled from the same plots (i.e., that received same soil treatment) at five weeks. This could most likely be due to neutralization of initial treatment effects on soil pH with time and in-field seasonal variation of soil pH. Broadcast urea control (0 to 2.5 cm) had slightly higher total P concentration (500 to 620 mgP/kg) when compared to that of deep-band control (7.5 to 10 cm) (400 to 450 mgP/kg), which can be attributed to P stratification due to reduced-till practice.

Resin extractable P. We used resin extractable P to estimate potential available P in soils. The P supplying power of soils assessed by anionic exchange resins has been shown to correlate satisfactorily with P uptake and P concentration in the biomass. Therefore, resin extractable P can be considered as a reliable index of available P in soils. At five weeks, in the urea broadcast (control) and urea deep-band (control) plots, percent resin extractable P concentrations were 3.4 and 9.2, respectively (Figure 1). In the deep-band P plots, both the granular and liquid treatments had a significantly higher percent resin extractable P in comparison to the no-P urea broadcast or urea deep-band treatments. At six months, only the deep-band liquid treatment had a significantly higher percent resin extractable P in comparison to both the no-P urea broadcast or no-P urea deep-banded treatments.

Spectra. Bulk XANES spectra suggested that the majority of P (69.2%) in the broadcast granular MAP treatment at five weeks was iron(II) phosphate-like P form (vivianite {Fe(II)3(PO4)2.8(H2O)} (Table 1). The spectra for broadcast liquid MAP-treated soil suggested two major forms of P in this soil:

1. 38.9% as iron(III)-phosphate-like {Strengite (FePO4.2H2O)}
2. 43.4% as adsorbed P forms.

Similarly, for the deep-band granular-MAP-treated soils at five weeks, the majority of P (64.5%) existed as iron(II) phosphate-like form while adsorbed P accounted for the rest. The spectra of the deep-band liquid MAP-treated soils suggested 46.7 percent of iron(II) phosphate-like P and 53.4 percent as adsorbed P (Table 1). Over a six months time period, reaction products of broadcast granular MAP and liquid MAP-treated soils were transformed to Ca phosphate-like, Al phosphate-like, and Fe phosphate-like forms while the majority of P in deep-band liquid MAP-treated soils continued to remain in adsorbed P-like forms. Overall research has suggested the formation of sparingly soluble-mixed Al phosphates and/or Fe phosphates as a possible mechanism restricting solubility of acid soils. Similarly, depending on the activity of Ca2+ in soil solutions, precipitation of P as Ca-phosphates can also be responsible for restricting P solubility in slightly acidic, neutral, or alkaline soils.

Conclusions

It appears that when liquid MAP is deep-placed in no-till soil systems, more P remains in resin extractable P forms for six months after fertilizer application. In contrast, broadcasted P, either in granular or in liquid form, tended to transform into less extractable P forms after five-week or six-month time periods. Formation of Fe-, Al-, and/or Ca-P solid species, with different solubility, may have been the reason for the observed differences in extractability or potential availability of P between broadcast and deep-placed granular and liquid MAP evaluated in this study.

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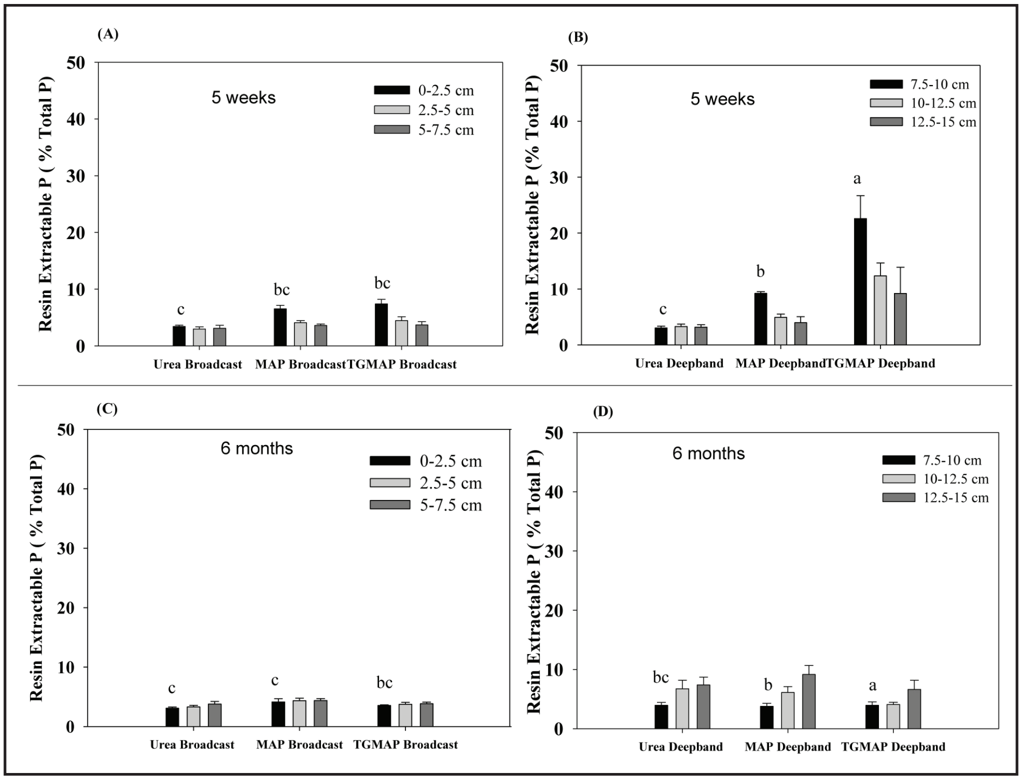

Figure 1. *Resin extractable P (as a % of total P) in soil sections at different distances from the point of fertilizer application. Error bars represent standard errors of (A) five weeks broadcast, (B) Five weeks deep-band, (C) Six months broadcast, and (D) Six months deep-band treatments. Granular = MAP; Liquid =TGMAP.*

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