BENEFITS OF LIME PLACEMENT ON GRAIN YIELD RESPONSE AND REMEDIATION OF ACID SUBSOILS

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Objective and Relevance

An extensive root system is essential for crop plants to tolerate short- and long-term periods of drought that often occur during the growing season in Missouri. Acid subsoils reduce root growth and grain yield. Stratification of pH values is common in claypan soils in Missouri. In soil survey publications, surface soil samples of claypan soils may have optimum pH values; however, the subsoil from 8 to 20 in. may decrease to pH values as low as 3.6, 4.5, and 4.5 for soils such as Putnam, Mexico, and Armstrong, respectively (Ferguson, 1995). In three-paired watershed research, seventy five soil samples from the Ap, AB, and Bt1 horizons had average pH values of 6.6 ($\pm$1.7), 6.3 ($\pm$0.6), and 4.9 ($\pm$1.2), respectively (Udawatta, unpublished). Drainage research plots had subsoil (8-18 in.) pH values from 4.7 to 5.2 (Nelson, unpublished) while other research indicated average subsoil pH values from 29 claypan soils at the 0-6 in., 6-12 in., 12-24 in., and 24-36 in. depths were 6.2, 6.0, 5.0, and 5.1 (Scharf, unpublished). Over 60% of the 29 fields had pH values less than 5 at the 12-24 in. depth. The lowest pH value at any site was 4.4. Acidic subsoils (at or below the 12 in. depth) may be a greater barrier to root growth than physical restrictions in many soils in Missouri.

Research on cotton (Adcock et al., 1999) and alfalfa (Rechcigl et al., 1991) has demonstrated the benefit of deep lime placement. Methods that incorporated lime increased corn grain yields greater than conventional liming techniques using surface applications (Farina and Channon, 1988). In this research, corn grain yields increased 20 bu/a in a dry year while in a wet year grain yield increased 6 bu/a (Farina and Channon, 1988). Low soil pH, 5 to 5.5, is an agronomic and environmental concern. Macronutrient and microbial activity is restricted and phytotoxic levels of exchangeable Al and Mn are common at low soil pH values. In addition, nitrification may be limited in an acidic environment. Nitrogen applications from ammonium-based N fertilizers acidify soils and require agriculture lime applications to neutralize the impact on soil pH. N sources may require 1.8 to 5.4 lb $CaCO_3$ to neutralize acidity depending on the N source. Anhydrous ammonia applications are commonly used throughout the region and may contribute to a decrease in subsoil pH while the surface soil pH is acceptable. A deep lime application may also reduce the impact of low soil pH on root growth and development.

Acid-subsoil amelioration has been studied with long-term impacts on soil pH levels (Toma et al., 1999; Farina et al., 2000b). Grain and forage yields increased 29 to 50% even 16 yr. after application (Toma et al., 1999) with increased returns (Farina et al., 2000a). Deep placement of dry lime at 1500 lbs/acre over two years increased soybean grain yields over 4 bu/a and increased profitability $94/acre compared to deep tillage only (Tupper et al. 1987). Farmers have utilized no-till and conventional tillage systems to attain specific production goals. Incorporation of lime may be necessary to realize an immediate (Toma et al. 1999) increase in grain yield. Deep placement of lime utilizing conservation-type knives could accomplish an

immediate increase in grain yield, provide zone-tillage, increase subsoil pH, and maintain surface residue. Concerns regarding the practicality and economics of deep incorporation have been expressed; however, numerous producers continue to subsoil claypan soils. Previous MU research has evaluated pH management in the top 6 to 8 inches of soil; however, no research has evaluated deep lime applications or the impact on subsoil properties. This research initiates a long-term evaluation of the impact of addressing subsoil pH correction in no-till and reduced tillage cropping systems. *The objective of this research is to evaluate yield response of corn and soybean to lime placement and the impact on subsoil pH.* We will maintain the field that was established in 2012 and 2013. Corn plots will rotate into soybean while soybean will rotate into corn. A third location was established for 2014 and treatments were applied in the fall of 2013 which is more typical of a deep tillage treatment.

Materials and Methods

A field trial was established at the University of Missouri Greenley Research Center on a Putnam silt loam that has been in continuous no-till production for over 13 years with an acid subsoil in May 2012 and the fall of 2012 (Table 1). A third research site was established in November 2013. A factorial arrangement of treatments included placement (no-till surface and conservation subsoiler deep placement), crop (corn and soybean), and lime rates (0, 1.5, and 3 tons/acre with 600 lbs effective neutralizing material/ton) to evaluate the response of corn or soybeans within a given year. Pelleted lime (Kelly's Limestone, Newark, MO) was derived from mined calcium carbonate and magnesium carbonate. A 2% lignosulfonate was utilized as the binding agent for pelletizing. The conservation subsoiler (Case IH 2500 ecolo-til) (Figure 1, left) had custom built shank (Figure 1, right) to deliver and distribute lime to 4 different levels in the soil profile, while delivery and metering was accomplished using a commercial Montag (Figure 1, left) dry fertilizer air delivery system. The selected rates of lime were based on an average subsoil recommendation (high rate), top 6 inches of soil recommendation (low rate), and a non-treated control. A site with a low surface pH was utilized in the experiment (Table 1).

Figure 1. Deep placement applicator with Montag dry fertilizer air delivery system (left) and custom built applicator shank (right).

Precipitation is reported in Table 2 while field management and crop protection chemical applications for corn and soybean are reported in Tables 3 and 4, respectively. This research evaluated soil pH at four depths (0-5, 6-10, 11-15, and 16-20 inches) similar to other research (Farina et al. 2000a, 2000b; Tupper et al., 1987), grain yield, and crop growth characteristics. Soil samples were collected in the fall of 2012 and 2013. Soil sampling depth corresponded to the different distribution drop tubes on the applicator shank.

Figure 2. Soil during application (left), after application (center), and an overhead overview after application (right).

The center two rows of corn were harvested for yield and converted to 15%, while the center 5 ft of the soybean plot was harvested and adjusted to 13% moisture prior to analysis. Grain samples were collected and were analyzed for protein and oil (soybean), and starch, protein, oil (corn) using near-infrared spectroscopy (Foss Infratec 1241 Grain Analyzer, Eden Prairie, MN) (data not presented). All data were subjected to ANOVA and means separated using Fisher's protected LSD at $P = 0.1$.

Results

The custom built shank effectively distributed lime throughout the soil profile (Figure 2). The modified shank caused more soil disturbance than normal and tillage following application was utilized to smooth the soil surface (Tables 3 and 4) prior to planting. No tillage was used in the surface application only treatments. The site for 2013 was established and treatments were applied on Nov. 27, 2012. An extensive drought occurred in 2012. Precipitation during the 2012 growing was 7.3 inches below normal (Table 2).

Corn plants were 2 to 5 inches taller (July 5) in the deep placed treatments compared to no-till, which persisted until tasseling (August 2) in 2012 (Table 5). Plants were slightly taller for the surface applied lime at 2 ton/acre in 2013, but were shorter in the deep placed lime treatments established in 2013. The site established in 2012 had plant populations that were generally greater in the no-till surface applied treatments compared to the deep ripped/placement

treatments in 2012, and no differences were observed in 2013. Deep placement had greater plant populations than surface applied lime at the site established in 2013. There was no treatment effect on soybean height in 2012 or 2013, and there was no treatment effect on plant population in 2012 (Table 6). However, soybean plant population was 30,000 to 31,000 plants/acre greater with surface applied lime at 1.5 ton/acre compared to deep placement at both locations in 2013.

Soil test pH_s in the top 5 inches of soil for the surface applied lime increased in corn and soybean as lime rate increased; however, there was no effect of deep placement on pH_s in the top 5 inches of soil (Table 7). At 6 to 10 inches deep, soil pH_s increased 0.5 points for deep placed lime at 1.5 tons/acre in soybean. No differences were observed 11 to 20 inches deep in the soil profile 6 months after application.

In an extremely dry year (2012), deep placement treatments increased corn yields 4 to 8 bu/acre (Figure 3a). However, no differences in yield among lime treatments were detected. In 2013, grain yield was 14 bu/acre greater for the no-till, non-treated control compared to deep tillage non-treated control, and 9 bu/acre greater for the surface applied lime at 1.5 ton/acre compared to deep placement at 1.5 ton/acre (Figure 3a). Grain yields were not affected by deep placement compared to surface applied lime at the site established in 2013 (Figure 3b).

Deep placement treatments in 2012 reduced soybean yield in the non-treated control and lime at 1.5 ton/acre (Figure 4a), while there was no effect of placement on soybean yield at the 3 ton/acre rate. Grain yields were 2 to 3 bu/ac greater for the no-till, non-treated control and surface applied lime compared to the equivalent deep placement treatments in 2013 (Figure 4a). Limited differences were observed among treatments at the site established in 2013 (Figure 4b).

In dry years (2012 and 2013), slight differences in corn grain yields were observed when comparing no-till surface lime applications compared to deep placement. Deep tillage did not increase soybean yields at the site established in 2012 over the first two dry years of this research.

References

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Table 1. Initial soil characteristics at different depths for the sites established in 2012 and 2013.

Soil characteristics	0-5 inches	6-10 inches	11-15 inches	16-20 inches
Established in 2012				
pH	5.6 ± 0.2	5.6 ± 0.4	4.6 ± 0.2	4.6 ± 0.2
Neutralizable acidity (meq/100 g)	3.5 ± 2	2.9 ± 1	8.5 ± 1.6	6.8 ± 1.0
Organic matter (%)	2.7 ± 0.3	2.3 ± 0.1	2.3 ± 0.3	2.2 ± 0.2
Bray 1P (lb/acre)	15.5 ± 8.7	4.5 ± 1.3	3.5 ± 1.9	13.0 ± 4.0
Ca (lb/acre)	3950 ± 310	4640 ± 590	4690 ± 630	4450 ± 600
Mg (lb/acre)	441 ± 87	615 ± 169	875 ±123	889 ± 136
K (lb/acre)	159 ± 11	155 ± 25	202 ± 30	206 ± 14
CEC (meq/100 g)	15.4 ± 2.3	17.3 ± 3.2	24.2 ± 3.2	22.0 ± 2.3
Established in 2013				
pH	5.0 ± 0.1	5.0 ± 0.5	4.9 ± 0.7	4.9 ± 0.8
Neutralizable acidity (meq/100 g)	5.1 ± 0.5	4.9 ± 1.9	6.9 ± 4.0	6.8 ± 3.8
Organic matter (%)	3.0 ± 0.6	1.9 ± 0.4	1.8 ± 0.3	1.4 ± 0.4
Bray 1P (lb/acre)	113.5 ± 41.2	17.0 ± 9.6	10.3 ± 3.6	27.5 ± 17.3
Ca (lb/acre)	2535 ± 273	2911 ± 616	3692 ± 1634	3697 ± 1497
Mg (lb/acre)	274 ± 81	370 ± 171	659 ± 403	757 ± 375
K (lb/acre)	530 ± 214	142 ± 42	160 ± 69	208 ± 76
CEC (meq/100 g)	13.3 ± 1.4	13.9 ± 3.3	19.1 ± 6.4	19.4 ± 4.8

Table 2. Monthly precipitation average (10-year) and during the 2012 and 2013 growing seasons at Novelty.

Month	10-year average[†]	2012	2013
		---------- Inches ----------	
Apr.	3.9	---	---
May	4.4	---[‡]	10.3
June	4.9	2.2	3.6
July	3.7	0.7	1.9
Aug.	4.8	3.0	0
Sep.	3.4	3.6	3.1
Total	25.1	9.5	18.9

[†]Averaged from 2000 to 2009.

[‡]Planted May 30, 2012

Table 3. Field and management information for the corn sites established at Novelty in 2012 and 2013.

	Established in 2012		Established in 2013
Management information	2012	2013	2013
Plot size (ft)	15 by 80	15 by 80	15 by 75
Hybrid or cultivar	DKC 63-25 VT3	DKC 63-25 VT3	DKC 63-87
Planting date	30 May	14 May	14 May
Row spacing (inches)	30	30	30
Seeding rate (seeds/acre)	30,000	30,000	30,000
Harvest date	12 Oct.	19 Sep.	19 Sep.
Maintenance fertilizer	None	None	None
Nitrogen	60 lbs N/acre (Urea) and 130 lbs N/acre (PCU)	200 lbs N/acre (AA)	120 lbs N/acre (PCU)
Lime	29 May	None	27 Nov
Tillage	Tilloll 2x 30 May Cultipacked 30 May in deep tilled treatments	None	Tilloll 2x 1 May
Weed management			
Burndown	5 June, Verdict (5 oz/acre) + Roundup PowerMAX (32 oz/acre) + NIS (0.25% v/v) + UAN (1 qt/acre)	22 May, Lexar (2.5 qt/acre) + Roundup PowerMAX (32 oz/acre) + COC (1 qt/acre)	22 May, Lexar (2.5 qt/acre) + Roundup PowerMAX (32 oz/acre) + COC (1 qt/acre)
Postemergence	22 June, Roundup PowerMAX (32 oz/acre) + DAS (17 lbs/100 gal) + COC (1 qt/acre) + Callisto (3 oz/acre) + Atrazine (1 qt/acre)	27 June, Roundup PowerMAX (32 oz/acre) + DAS (17 lbs/100 gal) + COC (1 qt/acre) + Callisto (3 oz/acre) + NIS (0.25% v/v)	27 June, Roundup PowerMAX (32 oz/acre) + DAS (17 lbs/100 gal) + COC (1 qt/acre) + Callisto (3 oz/acre) + NIS (0.25% v/v)
Insect management	NA	NA	NA
Disease management	NA	NA	NA

Table 4. Field and management information for the soybean sites established at Novelty in 2012 and 2013.

	Established in 2012		Established in 2013
Management information	2012	2013	2013
Plot size (ft)	15 by 80	15 by 80	15 by 75
Hybrid or cultivar	AG3730 RR2	AG3730 RR2	AG3731 RR2
Planting date	30 May	8 May	16 May
Row spacing (inches)	7.5	7.5	7.5
Seeding rate (seeds/acre)	200,000	200,000	200,000
Harvest date	4 Oct.	9 Sep.	9 Sep.
Maintenance fertilizer	None	None	None
Urea and PCU			
Lime	29 May	None	27 Nov
Tillage	Tilloll 2x 30 May Cultipacked 30 May in deep tilled treatments	None	Tilloll 2x 1 May
Weed management			
Burndown	5 June, Verdict (5 oz/acre) + Roundup PowerMAX (32 oz/acre) + NIS (0.25% v/v) + UAN (1 qt/acre)	22 May, Prefer (2.25 qt/acre) + Roundup PowerMAX (32 oz/acre) + COC (1 qt/acre) + UAN (1 qt/acre)	22 May, Prefer (2.25 qt/acre) + Roundup PowerMAX (32 oz/acre) + COC (1 qt/acre) + UAN (1 qt/acre)
Postemergence	22 June, Reflex (1.25 pt/acre) + Roundup PowerMAX (22 oz/acre) + DAS (17 lbs/100 gal) + NIS (0.25% v/v)	NA	NA
Insect management	NA	NA	NA
Disease management	NA	NA	NA

†Abbreviations: COC, crop oil concentrate; DAS, diammonium sulfate; NA, None applied; NIS, non-ionic surfactant; UAN, 32% urea ammonium nitrate.

Table 5. Corn plant population and heights as affected by no-till surface or deep placed lime (non-treated = 0 ton/acre, low = 1.5 ton/acre, and high 3.0 ton/acre) for sites established in 2012 and 2013.

	2012			2013	
	Height			Height	
Lime placement	July 5	August 2	Population	October 4	Population
	---- Inches ----		No./acre	Inches	No./acre
Established in 2012					
Surface non-treated	36	65	30,100	80	26,700
Surface 1.5 ton/acre	37	64	30,000	81	27,100
Surface 3 ton/acre	34	63	29,200	82	27,400
Deep placement non-treated	39	67	26,000	80	26,900
Deep placement 1.5 ton/acre	38	68	28,000	80	27,700
Deep placement 3 ton/acre	39	67	27,900	79	28,400
LSD (P = 0.1)	2	2	2,200	2	NS
Established in 2013					
Surface non-treated				103	27,000
Surface 1.5 ton/acre				100	24,000
Surface 3 ton/acre				101	26,000
Deep placement non-treated				102	28,800
Deep placement 1.5 ton/acre				99	28,200
Deep placement 3 ton/acre				97	28,800
LSD (P = 0.1)				4	1,700

Table 6. Soybean plant population and heights as affected by no-till surface or deep placed lime (non-treated = 0 ton/acre, low = 1.5 ton/acre, and high 3.0 ton/acre) for sites established in 2012 and 2013.

	2012		2013	
Lime placement	Height	Population	Height	Population
	Inches	No./acre	Inches	No./acre
Established in 2012				
Surface non-treated	22	187,000	28	153,000
Surface 1.5 ton/acre	22	205,000	28	157,000
Surface 3 ton/acre	22	161,000	26	166,000
Deep placement non-treated	22	196,000	27	145,000
Deep placement 1.5 ton/acre	21	183,000	26	127,000
Deep placement 3 ton/acre	22	203,000	26	148,000
LSD (*P* = 0.1)	NS	NS	NS	21,000
Established in 2013				
Surface non-treated			31	170,000
Surface 1.5 ton/acre			31	170,000
Surface 3 ton/acre			31	148,000
Deep placement non-treated			28	152,000
Deep placement 1.5 ton/acre			31	139,000
Deep placement 3 ton/acre			31	148,000
LSD (*P* = 0.1)			NS	25,000

Table 7. Soil test pH_s values at 0 to 5, 6 to 10, 11 to15, and 16 to 20 inch depths after corn and soybean harvest for the experimental site established in 2012. Interactions between factors were presented when appropriate.

	pH_s					
	0-5 in.		6-10 in.			
Lime placement	Corn	Soybean	Corn	Soybean	11-15 in.	16-20 in.
Established in 2012						
Surface non-treated	5.4	5.8	4.9	4.7	4.8	4.5
Surface 1.5 ton/acre	5.9	6.6	4.7	4.7	4.7	4.5
Surface 3 ton/acre	6.2	6.4	4.8	4.7	4.7	4.5
Deep placement non-treated	5.7	5.7	4.8	4.7	4.7	4.5
Deep placement 1.5 ton/acre	5.7	5.8	5.0	5.2	5.1	4.5
Deep placement 3 ton/acre	5.4	5.8	4.8	4.7	4.6	4.4
LSD (*P* = 0.1)	----- 0.3 -----		----- 0.4 -----		NS	NS

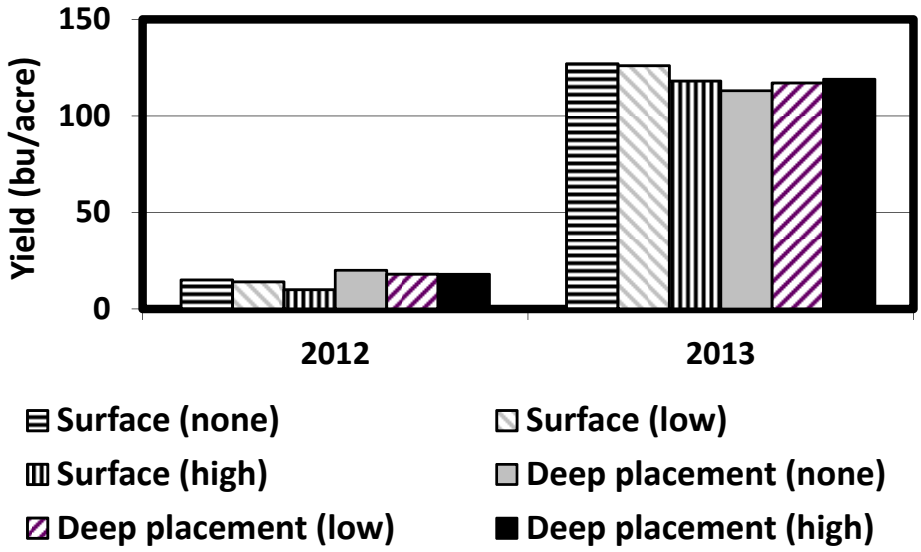


Figure 3a. Corn grain yield response to no-till surface or deep placed lime (none = 0 ton/acre, low = 1.5 ton/acre, and high 3.0 ton/acre) established in 2012. LSD (*P* = 0.1) was 4 and 9 bu/acre in 2012 and 2013, respectively.

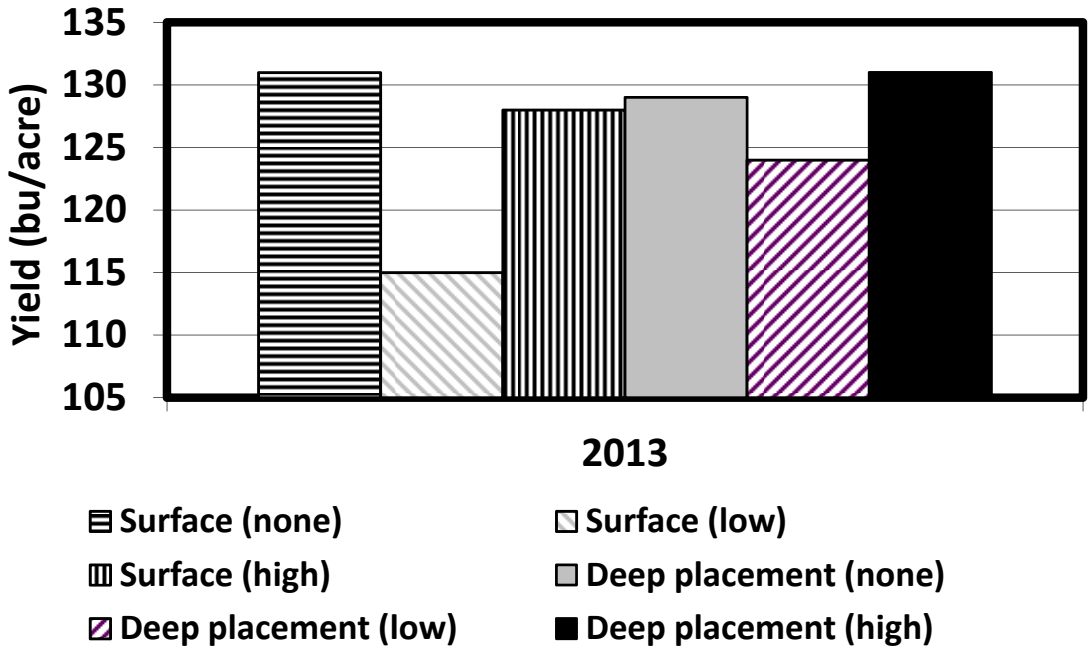


Figure 3b. Corn grain yield response to no-till surface or deep placed lime (none = 0 ton/acre, low = 1.5 ton/acre, and high 3.0 ton/acre) established in 2013. LSD (*P* = 0.1) was 12 bu/acre in 2013.

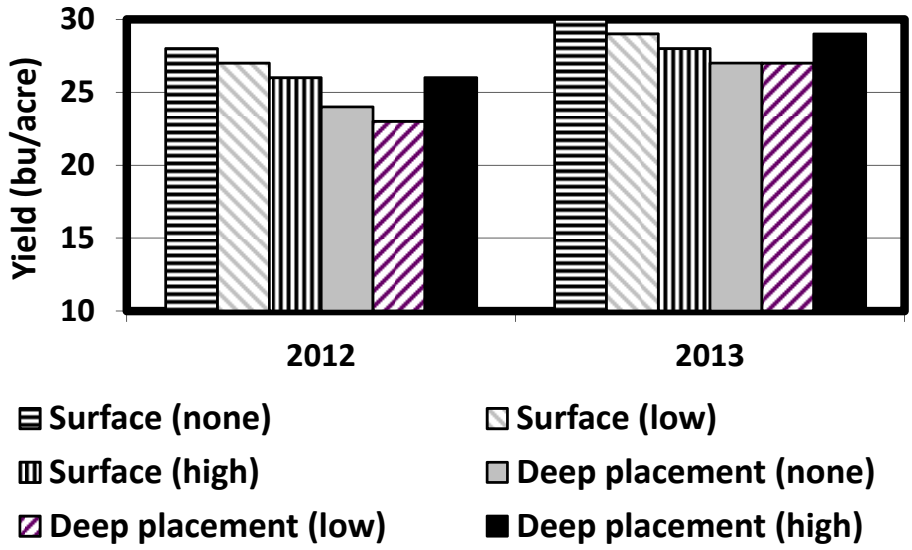
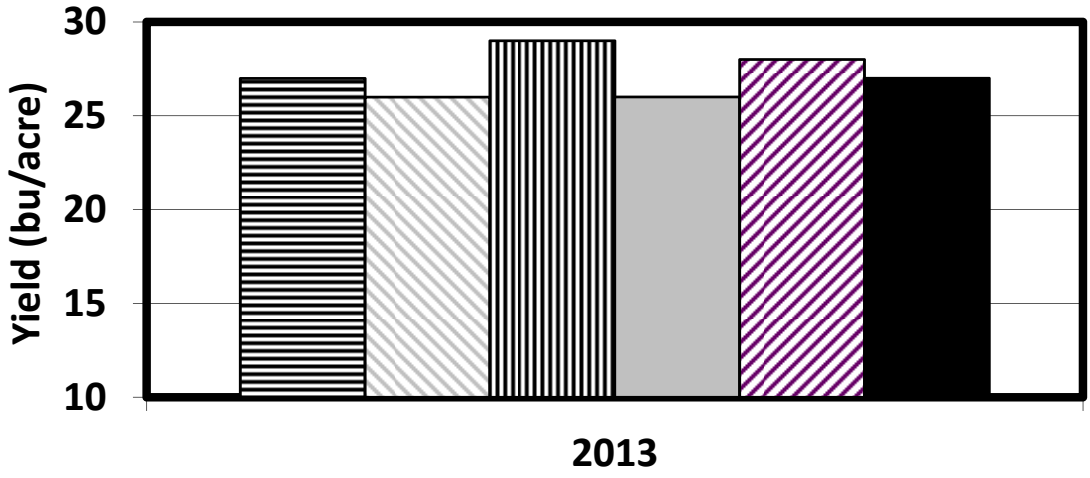


Figure 4a. Soybean grain yield response to no-till surface or deep placed lime (none = 0 ton/acre, low = 1.5 ton/acre, and high 3.0 ton/acre) established in 2012. LSD (*P* = 0.1) was 2 and 2 bu/acre in 2012 and 2013, respectively.



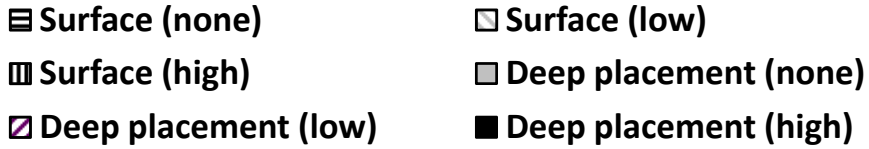


Figure 4b. Soybean grain yield response to no-till surface or deep placed lime (none = 0 ton/acre, low = 1.5 ton/acre, and high 3.0 ton/acre) established in 2012. LSD (*P* = 0.1) was 3 bu/acre in 2013.