Soil pH and Planting Timing Effects on Yield

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Introduction and Objectives

In the Mid-Atlantic region, little yield difference has been observed between April- and May-planted soybeans. However, earlier planting may expose soybeans to cooler temperatures and increased disease pressure, potentially reducing yields. Recent research on double-cropped soybeans (DSB) has also highlighted the negative impact of aluminum (Al) and iron (Fe) uptake on early-planted soybeans. Maintaining a higher soil pH can help mitigate these effects by reducing Al and Fe solubility. By increasing soil pH, soybean producers in coastal soils may benefit from an extended pre-solstice growing season, potentially achieving higher yields.

Conversely, raising soil pH may reduce the availability of other micronutrients such as manganese (Mn), zinc (Zn), and copper (Cu). Additionally, higher pH can increase the cation exchange capacity at soil particle edge sites, potentially leading to greater leaching of boron (B) and sulfate (SO4) from the soil surface. To fully assess the impact of liming, it is essential to evaluate its effects on all nutrients within these soils. The objective of this study was to examine the yield and nutrient uptake of full-season soybeans across different liming rates (0–1.0 tons/acre) and two planting timings (early and late).

Methods

The study was conducted at the Carvel Research and Education Center in Georgetown, DE on a field with a terminated rye cover crop. The experimental design was a randomized complete block design (RCBD) with two factors: liming rate (0, 0.25, 0.5, 0.75, and 1.0 tons/acre) and planting timing (late April and late May). Lime was applied in March 12, 2024, and incorporated using vertical tillage (Turbo Till). Based on initial soil test results, a dolomitic lime was selected. The experiment included three replications, totaling 30 plots (10 x 30 feet each). The first planting occurred on April 9th, 2024 and the second planting on May 29th, 2024.

Pre-plant soil samples (8-inch depth) were collected before lime application to establish baseline nutrient levels for each plot. Soybean tissue samples were taken at V3 and R1 growth stages to monitor nutrient uptake throughout the season. Post-harvest soil samples were also collected from the upper 8 inches of each plot. All samples were submitted to the University of Delaware Soil Testing Lab for analysis. Yield data were collected at the end of the growing season using a plot combine.

Statistical analysis was conducted using SAS software. The data were analyzed as a factorial RCBD to assess treatment effects. Tissue nutrient content was correlated with yield and initial soil nutrient levels.

Figure 1: Plots in early summer at the Carvel Research and Education Center.

Results and Discussion

Soybean Yields as Affected by Liming Rate and Planting Timing

Soybean yield results showed no significant differences among liming rates (Figure 1a). Although some variation was observed, with yields ranging from 56.27 to 64.14 bu/ac, there were no significant differences. The highest average yield (64.14 bu/ac) was recorded at the 0.75 tons/acre lime rate, while the lowest yield (56.27 bu/ac) occurred at the 0.5 tons/acre rate. The control treatment (0 tons/acre) produced an average yield of 59.01 bu/ac, similar to the highest liming rate (1.0 tons/acre) at 57.45 bu/ac. These findings suggest that within the tested range, liming did not have a consistent effect on soybean yield. While it may indicate lime had not had time to work yet, soil tests below confirm pH changes by the end of the season.

However, planting timing had a significant impact on yield. Soybeans planted in April yielded an average of 62.67 bu/ac, while those planted in May averaged 54.74 bu/ac, indicating that earlier planting resulted in higher yields. This could be due to warmer weather conditions than normal in April 2024.

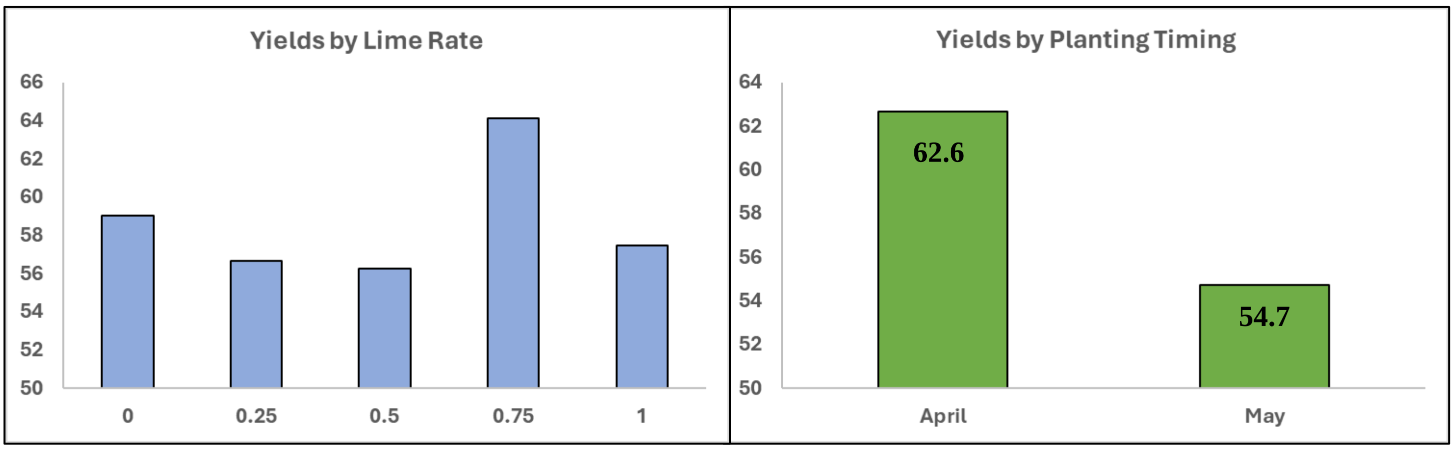

Figure 2: Yields based on a) liming rate (no statistical differences) and b) planting date (p = .0134).

Change in Soil Elemental Concentrations by Mehlich3 Extraction Over the Season

Soil nutrient concentrations responded variably to liming, with some elements showing significant changes while others remained unaffected. Calcium, pH, magnesium, boron, and base saturation exhibited significant responses to increasing lime rates. Calcium concentrations increased significantly with liming (p = 0.0315), with the highest rate (1.0 ton/acre) leading to the greatest increase. Soil pH also rose with lime application (p = 0.0002), with the highest lime rate producing the largest increase, confirming the expected neutralizing effect of lime on soil acidity. Magnesium levels showed a similar trend (p = 0.0001), with higher lime rates leading to greater accumulation.

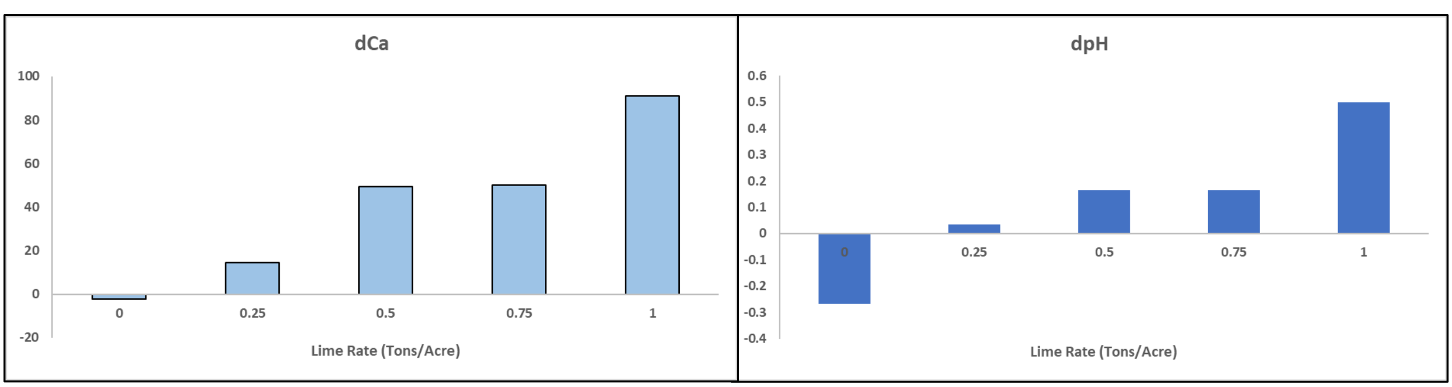

Figure 3: Changes in soil Ca and pH with liming rates between 0 to 1 ton per acre.

In contrast, phosphorus, manganese, zinc, copper, iron, sulfur, and sodium did not exhibit significant changes in response to liming. There are observable trends in the data that may still be agronomically relevant. Aluminum (Al) showed a decreasing trend with increasing lime application, dropping from 24.75

mg/kg at 0 tons/acre to -29.12 mg/kg at 1.0 ton/acre. This aligns with expectations, as liming reduces soil acidity, thereby lowering aluminum solubility. Even though this change was not statistically significant, the consistent decline suggests that liming may still help mitigate Al toxicity, particularly in coastal soils where low pH can lead to higher Al availability. Iron (Fe) followed a similar decreasing trend, moving from 6.79 mg/kg at 0 tons/acre to -0.96 mg/kg at 1.0 ton/acre. Although not statistically significant, this suggests that liming may reduce Fe solubility, which is consistent with reduced availability of Fe at higher pH.

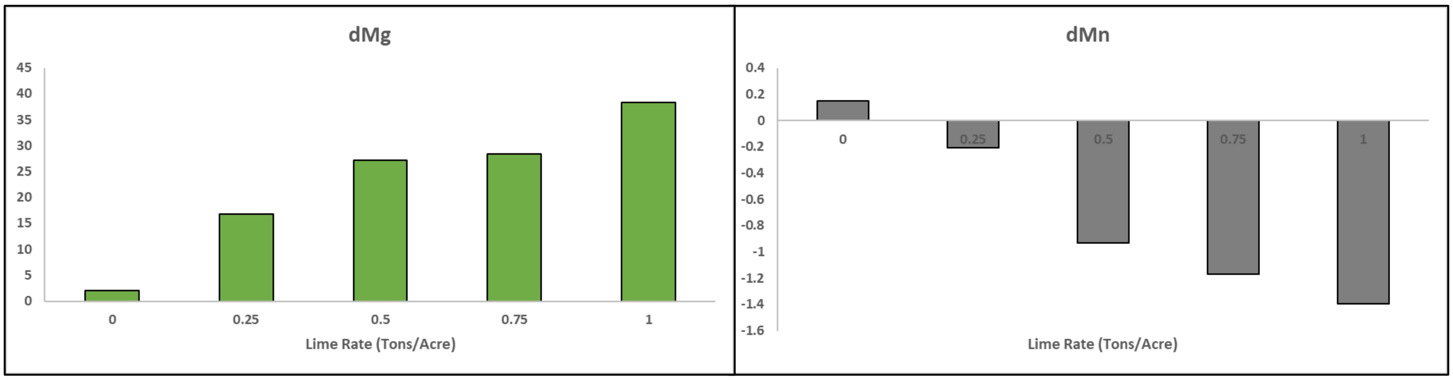

Figure 4: Changes in soil Mg, which was significant, and soil Mn with lime rates. Although Mn was not significantly different it did trend downward.

Micronutrient availability generally trended downward with increasing lime rates, particularly for manganese (Mn), zinc (Zn), and copper (Cu). Manganese declined from 0.15 mg/kg at 0 tons/acre to -1.40 mg/kg at 1.0 ton/acre, while zinc and copper fluctuated but showed slight overall reductions at higher lime rates. This follows established soil chemistry principles, where micronutrient solubility tends to decrease as soil pH increases. Although these changes were not significant, they may still be relevant for growers managing soils with marginal micronutrient levels.

Phosphorus (P) showed a general trend of decreasing availability with liming, with values declining from -6.95 mg/kg at 0 tons/acre to -15.94 mg/kg at 1.0 ton/acre. While not significant, this suggests that higher lime rates may have affected P availability, possibly through increased fixation with calcium.

Boron (B) was one of the few nutrients that showed a clear trend and statistical significance. Although the overall effect was small, boron levels decreased from -0.01 mg/kg at 0 tons/acre to 0.34 mg/kg at 1.0 ton/acre, which may indicate increased leaching or reduced plant availability at higher pH. The changes really only occurred at the 1 ton lime rate though.

While many of the observed trends were not statistically significant, they align with known soil chemistry principles. The reductions in Al and Fe availability with liming reinforce the potential benefits of pH management for mitigating metal toxicity in soybean production. However, the downward trends in Mn, Zn, Cu, and P suggest that growers should monitor micronutrient levels when applying lime, particularly in soils that are already near deficiency thresholds.

Nutrient Concentrations at Early Soybean Stages (V3) Based on Liming Rate

At the V3 growth stage, manganese (Mn), zinc (Zn), and boron (B) concentrations in soybean tissue were significantly affected by liming. For Mn, concentrations were highest in the 0 and 0.25 tons/acre lime treatments (832.7 and 824.8 ppm, respectively) and declined with increasing lime rates, reaching the lowest level at 0.75 tons/acre (719.5 ppm). The 1.0-ton rate showed a slight rebound (763.2 ppm), but overall, Mn availability declined as soil pH increased. This trend aligns with the expected reduction in Mn solubility at higher pH levels.

Table 1: Response of upper trifoliate leaves to lime rates for Mn, Zn, and B (ppm)

Lime (T/A)	Mn	Zn	B
0	0.83	0.85	0.89
0.25	0.82	0.83	0.82
0.5	0.74	0.78	0.83
0.75	0.72	0.77	0.85
1	0.76	0.77	0.79
pvalue	*0.0949*	*0.051*	*0.0205*

Zinc (Zn) concentrations followed a similar pattern, with the highest levels in the 0 and 0.25-ton lime treatments (849.5 and 834.7 ppm, respectively). Zn availability decreased steadily with increasing lime rates, reaching the lowest concentration (767.6 ppm) at the highest lime application. The significant reduction in Zn with liming is consistent with soil chemistry principles, as Zn becomes less soluble at higher pH.

Boron (B) also showed a significant response to liming but followed a slightly different trend. The highest concentration occurred at 0 tons/acre (889.2 ppm), while the lowest value was observed at 1.0 ton/acre (794.7 ppm). Intermediate lime rates showed mixed results, with 0.75 tons/acre maintaining relatively high B levels (846.1 ppm). The statistical groupings indicate that B availability fluctuated more than Mn and Zn but still showed an overall decline at higher lime rates. This could indicate leaching or reduced plant uptake due to decreased solubility.

In summary, the significant reductions in Mn, Zn, and B with increasing lime rates suggest that excessive liming could negatively impact micronutrient availability in soybean. While soil pH adjustments may benefit crop growth by reducing Al and Fe toxicity, careful monitoring of Mn, Zn, and B is necessary, particularly in soils with marginal micronutrient levels.

Changes in Nutrient Leaf Concentration Based on Planting Timing

Changes in nutrient concentrations between the V3 and R2 stages varied by planting timing. N, P, and K declined more in the April planting than in May, with N decreasing by 0.40 percentage points in April but increasing slightly (+0.12) in May. P declined by 0.048 percentage points in April but increased by 0.053 in May. K decreased in both plantings but dropped more sharply in April (-0.591) than in May (-0.165). S followed this trend, declining slightly in April (-0.005) but increasing (+0.02) in May. Mg declined in April (-0.018) but remained nearly unchanged in May (+0.0012).

Table 2: Change in nutrient concentrations between V3 to R2 in soybean leaves based on planting timing.

Timing	dN	dP	dK	dCa	dMg	dS
April	-0.40 b	-0.05 b	-0.59 b	-	-0.02 b	-0.01 b
May	0.12 a	0.05 a	-0.17 a	-	0.00 a	0.02 a
p-value	0.0002	<0.0001	<0.0001	NS	<0.0001	<0.0001

Micronutrient concentrations also shifted differently between planting timings. Mn increased from V3 to R2 in both plantings but rose more in May (+8.62 ppm) than in April (+3.19). B also increased more in May (+7.6 ppm) than in April (+2.16). In contrast, Fe decreased significantly in both planting timings but declined more in May (-65.69 ppm) than in April (-38.46). The most notable difference was in Al, which dropped sharply in both timings but was reduced nearly five times more in May (-400.4 ppm) than in April (-76.41).

Table 3: Change in micronutrient concentrations between V3 to R2 in soybean leaves based on planting timing. Data also includes Na and Al.

Timing	dMn	dZn	dCu	dFe	dB	dNa	dAl
April	3.19 b	-	-	-38.46 a	2.16 b	-	-76.41 a
May	8.62 a	-	-	-65.69 b	7.60 a	-	-400.40 b
p-value	0.0329	NS	NS	0.061	0.0068	NS	<0.0001

Although these nutrient shifts suggest differences in uptake patterns between planting timings, it is unclear whether they contributed to yield differences. Yields were significantly higher in the April planting, suggesting that despite the greater declines in macronutrient concentrations, early planting still resulted in better overall crop performance. The greater reductions in Al and Fe in May-planted soybeans may indicate differences in root uptake or soil chemistry, but further analysis is needed to determine their impact on plant health and yield.

Conclusions

Soybean yield was not significantly affected by liming rate but was higher with earlier planting. Despite pH increases with liming, there were minimal impacts on nutrient availability in the soil, except for expected increases in Ca and base saturation and decreases in Al. In plant tissue, liming reduced Mn and Zn concentrations at V3, but B showed a less consistent response. Differences in nutrient uptake were more pronounced between planting timings, with early-planted soybeans showing greater declines in N, P, K, and S from V3 to R2, while May-planted soybeans had a sharper reduction in Al and greater increases in Mn and B. While these shifts may reflect differences in soil nutrient availability or plant uptake efficiency, they did not appear to negatively affect early-planted soybeans, which still achieved the highest yields. These results suggest that early planting remains beneficial despite some shifts in nutrient availability, while liming effects on nutrient uptake were relatively minor at the rates performed.