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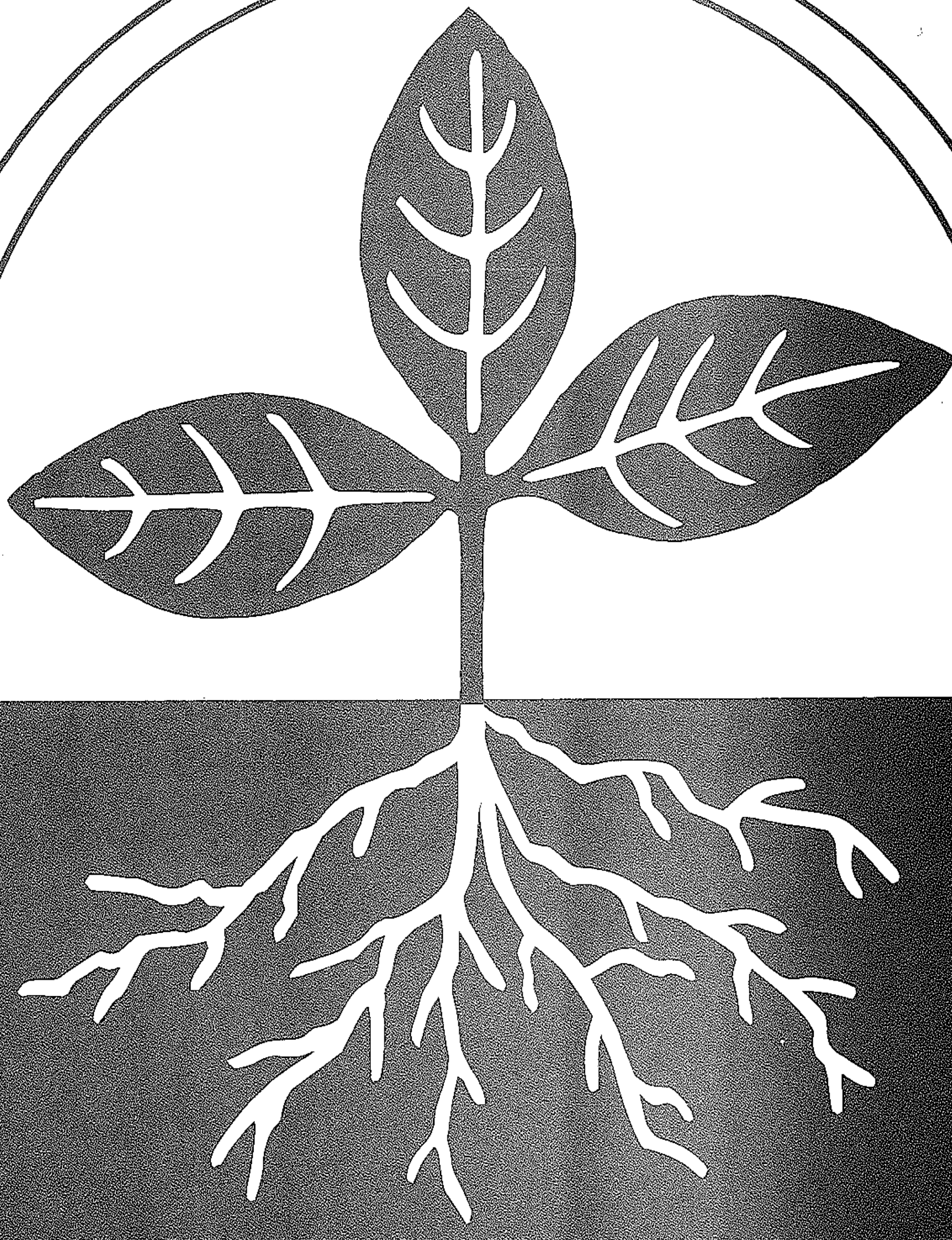

Soybean Yield and Economic Response to Broadcast Incorporated and Deep Band Placement of Lime on Low pH Soils

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Abstract

Failure of plants to develop deep, vigorous root systems is often related to subsoil acidity (4). Attempts to correct subsoil acidity by the broadcasting and deep incorporation of lime are expensive and have high energy requirements. In an effort to develop a more economical and efficient means of correcting subsoil acidity, deep band placement applications of suspension and dry lime were made below the drill behind a parabolic shank. These treatments were compared with and without surface broadcast and disk incorporated lime on Dundee (Aeric Ochraqualf) and Forestdale silt loam (Typic Ochraqualf) soils.

The response from 2 years of lime applications and one year of residual effect showed that deep band placement of dry lime on a moderately acid subsoil was effective in increasing soybean yields, and that the cumulative returns over 3 years were $32.54 per acre more than the increased cost of the deep liming treatment. Ripper-hipping soils with hardpans containing acidic zones in the subsoil resulted in decreased soybean yields of 2.6 bu/A without surface lime and 2.7 bu/A with surface lime, without deep band placement of lime. Results reported in this publication are based on data from only 3 years of observation at one location. Other research has been conducted on both soybeans and cotton and more research is needed to determine responses under other conditions.

Introduction

Many soils of the southeastern United States have subsoils which are acidic and low in fertility. The problem of highly acidic subsoil restricting plant root growth has long been recognized. Pettiet's (6) study showed that cotton yields in extensive areas of the Mississippi Delta could possibly be improved by correcting the soil acidity and compaction problems found on several soil types. He concluded that applying sufficient ground limestone on fields testing below pH 5.5 in the surface, and annual deep tillage practices, should reduce the number of problem areas within a field.

Pearson et al. (5) found that lime moved slowly in the soil profile and was influential mainly in the immediate vicinity of application. Thus, surface applications of lime, without some degree of mixing in the soil, were not effective in correcting subsoil acidity. Doss et al. (1) reported in Alabama that incorporating lime 12 inches deep with a moldboard plow was sufficient to obtain a satisfactory root system for improved yields of cotton and corn. However, broadcast surface applications of lime with deep incorporation by moldboard plowing require high rates of lime and have high energy requirements.

Primary tillage tools, such as subsoilers and chisels, are used to shatter compacted soil layers, improving water infiltration and root penetration. Yield increases occur on many soils in the Mississippi Delta when hardpan layers are fractured. However, on some soils the yield response is limited or may be negative when hardpans are fractured (3). Many of these soils contain a low pH (4.8-5.5) in the subsoil, which produces chemical barriers to root penetration and proliferation. Deep tillage to fracture the hardpans on some of these problem soils could result in yield reductions from root exposure to Al and Mn toxicities which may result from subsoil acidity. Thus, to produce yield responses from deep tillage in subsoils with high acidity, the acidity must be adjusted to a suitable level for root growth to proceed.

Planting cottonseed directly over a thin vertical limed column of soil resulted in a greater penetration of roots than planting over an unlimed column (5). Pearson et al. also found tap root elongation over the thin vertical limed column did not differ from that in the 100% limed treatment. They suggest that yield improvement could be made if lime injected behind a subsoiler shank would leave the subsoiled slot limed from top to bottom. Improved root penetration could result if plants were seeded over the limed slot year after year.

Equipment Developed

In an effort to develop a more economic means of placing lime into the subsoil, band placement of lime behind a Stoneville parabolic super chisel shank (7) was explored. The equipment developed at Stoneville for the incorporation of banded lime into the subsoil

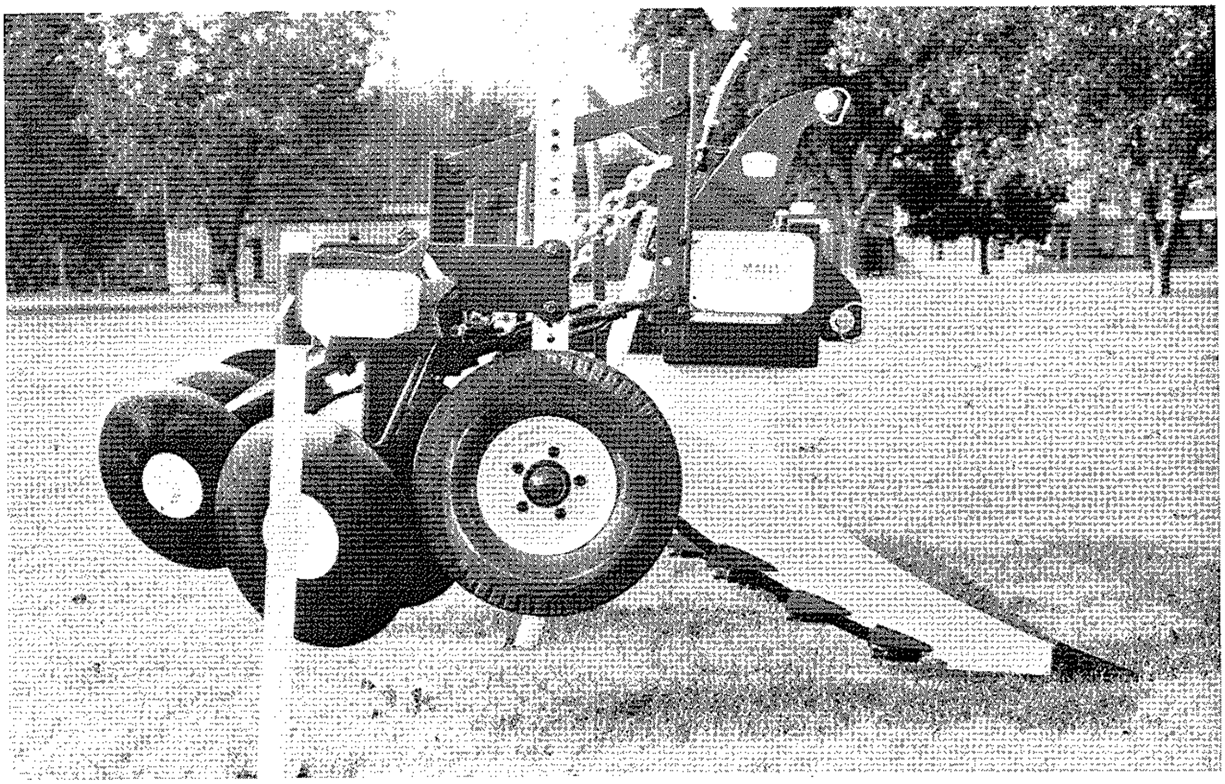

Figure 1. Deep banding suspension lime applicator.

Figure 2. Applying suspension lime in acid subsoil.

consolidated several tillage practices. Subsoil tillage, lime application, and hipping were accomplished in one trip across the field, which reduced land preparation and application costs.

In 1979, a two-row suspension lime applicator was designed and built (Figure 1). It injected a lime suspension slurry (50% lime by weight, 49% water, and 1% clay) in a 4-inch wide concentrated band into each drill row. The applicator had a 1-inch-square tubing with flood jet nozzles at 8, 11, and 14 inches deep, attached to the rear of a parabolic super chisel shank. These nozzles sprayed the lime slurry in the drill row, behind the shank, and just ahead of the hipper (Figure 2). The combined operation assured row placement over the limed area by forming the bed directly over the subsoil trench.

Preliminary studies with this equipment on soybeans (2) showed yield increases of 5.7 bu/A on soils with a subsoil pH of 4.8 when approximately 1,500 lb/A of suspension lime were banded in the drill area to a depth of 15 inches. However, the cost of suspension lime is approximately three times that of dry agricultural lime. For this reason, the 1981 studies were directed to look at the possibility of deep band placement of dry agricultural lime in the drill on soils containing acid subsoils and compacted zones.

In 1981, a four-row, deep banding, dry lime applicator was built utilizing a parabolic shank in a ripper-hipper arrangement with a fertilizer attachment mounted on top (Figure 3). The fertilizer assembly was modified to deliver lime to each row through a pair of tubes joined at the top of each parabolic shank. This equipment was provided by W & A Manufacturing Co., Pine Bluff, Arkansas.

Procedure

A 3-year dry land study was initiated in 1983 to evaluate the response of soybeans to broadcast surface-applied lime in various combinations with deep band placement of suspension and dry lime. An experimental area was selected on a Dundee (Aeric Ochraqualf) and Forestdale (Typic Ochraqualf) silt loam soil with a moderately acid subsoil near Steiner, Mississippi. This experiment was factorially arranged in a randomized complete block design with four replications. The data were analyzed separately for each year. Plots were 12 rows wide and approximately 0.3 acres in size. The identity of each plot was retained throughout the 3-year study.

During the study, lime and deep tillage treatments were used the first 2 years (1983 and 1984), while the final year (1985) consisted of measuring only the

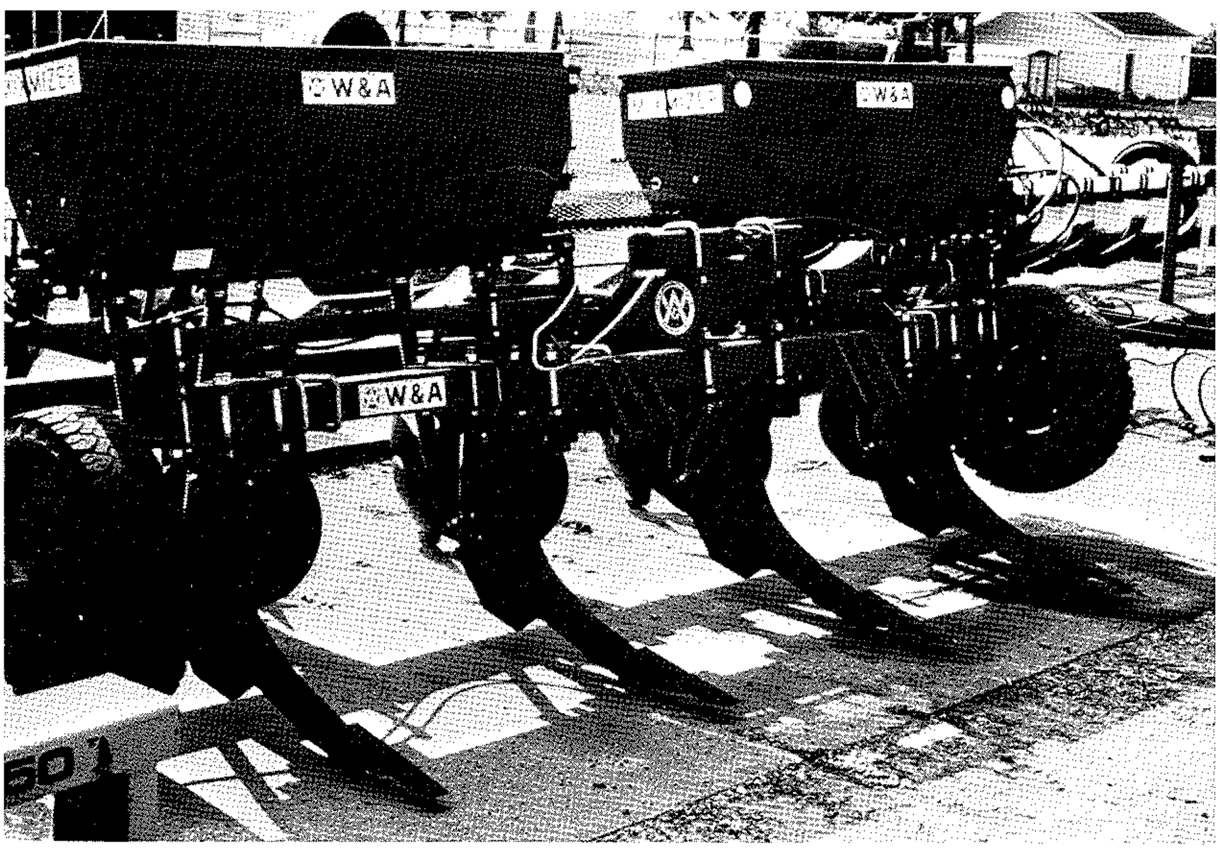

Figure 3. Deep banding lime applicator.

Figure 4. Applying dry lime in acid subsoil.

residual response to the two previous years' treatments without additional lime or deep tillage. The 2-year annually applied deep-placement treatments were: (a) check–no ripper-hipping; (b) ripper-hipping 15 inches deep in the drill; (c) 1,500 lb/A suspension lime banded 6 to 15 inches deep in the drill with ripper-hipping; and (d) 1,500 lb/A dry agricultural lime in a band 6 to 15 inches deep in the drill with ripper-hipping (Figures 4 and 5). Each of the deep-placement treatments had two additional treatments: (a) check-no surface lime, and (b) 4,000 lb/A dry lime broadcast on the surface and disked in approximately 6 inches deep each spring.

The deep banded lime concentration of 1,500 lb/A was equivalent to approximately 10,000 lb/A broadcast and incorporated 6 inches deep. The soybean seed was not treated with molybdenum in this study. All other cultural practices were identical for the treatments.

Results and Discussion

A combination of surface broadcast and disk incorporated with deep banded placement of dry lime in the drill was the most effective treatment (Table 1, No. 8) in 1983. This combination treatment produced

Figure 5. Two-inch band of dry lime (arrow) 6 to 15 inches deep in the drill.

a higher yield than the unlimed treatments with or without ripper-hipping (No. 1 and 2). Soybean bushel weight and seed size were lowest for the unlimed treatment without deep tillage (No. 1) as shown in Table 2.

In 1984, excessive rains delayed harvest of the test until December 10. This delay certainly reduced yields and possibly caused smaller differences among treatments. The deep banded dry lime treatment (No. 6) was the most effective treatment and produced a significantly higher yield than the deep tillage treatment without deep lime (No. 2) and the deep banded suspension lime treatment (No. 5).

Weather conditions in 1984 were such that the field was rutted by the combine and it was necessary to land plane the test area during the 1985 seedbed preparation. This may have reduced the residual effect from the surface applied lime treatments by distributing a small part of this limed soil across all treatments, possibly increasing the yield of non-surface limed treatments and reducing the yield of surface lime treatments. The test was not hipped over old soybean stubble in 1985, as was desired, because the stubble had been destroyed in seedbed preparation. Thus, planting directly over the old row may have been less precise than previous plantings.

Table 1. Soybean yields, operation costs, and returns above specified costs affected by applications of surface and/or deep banded lime and/or ripper-hipping of Dundee and Forestdale silt loam soils, Steiner, MS, 1983-85.

Trt No.	Dry lime[1] surface incorporated	Rip and hip	Deep lime[2]		Soybean yields				Sum 1983-85	
			Suspension	Dry	1983	1984	1985	3-yr avg	Specified[3] expenses	Returns above specified expenses
					(bu/A)				($/A)	
1	No	No	No	No	34.7 b[4]	30.4 ab	42.1 ab	35.7 bc	0.00	726.14
2	No	Yes	No	No	33.3 b	26.9 b	39.1 b	33.1 c	9.19	664.07
3	Yes	No	No	No	39.8 ab	29.9 ab	45.9 a	38.6 ab	93.55	691.57
4	Yes	Yes	No	No	36.1 ab	29.3 ab	42.4 ab	35.9 bc	102.79	627.42
5	No	Yes	Yes	No	37.4 ab	28.0 b	41.3 ab	35.5 bc	84.75	637.32
6	No	Yes	No	Yes	39.6 ab	32.8 a	45.0 a	39.1 a	36.62	758.68
7	Yes	Yes	Yes	No	37.3 ab	29.1 ab	43.6 ab	36.7 ab	178.36	568.12
8	Yes	Yes	No	Yes	41.8 a	30.3 ab	43.1 ab	38.4 ab	130.22	650.84

1 Surface broadcast lime, disk incorporated, was applied at the rate of 4,000 lb/A in 1983 and again in 1984.
2 Deep banded suspension or dry lime was applied at the rate of 1,500 lb/A in 1983 and again in 1984.
3 Specified costs for each treatment include only the costs of the lime and its application and/or equipment necessary for that treatment.
4 Values for soybean yields in a column followed by the same letter are not significantly different at the 10% level according to Duncan's Multiple Range Test.

Table 2. Soybean bushel weights and seed size as affected by applications of surface and/or deep banded lime and/or ripper-hipping of Dundee and Forestdale silt loam soil, Steiner, MS, 1983-85.

Trt No.	Dry lime surface incorporated	Rip and hip	Deep lime		Bushel weight				Seed weight			
			Suspension	Dry	1983	1984	1985	3-yr avg	1983	1984	1985	3-yr avg
					(lb/bu)				(gm/100 seed)			
1	No	No	No	No	55.6 b[1]	53.3	54.7	54.5	13.53 b	15.98	16.31	15.27 b
2	No	Yes	No	No	56.1 ab	52.5	54.1	54.2	13.90 ab	15.94	16.37	15.40 ab
3	Yes	No	No	No	56.1 ab	53.0	54.5	54.5	13.75 ab	15.90	16.45	15.37 ab
4	Yes	Yes	No	No	56.4 a	52.2	54.4	54.3	14.15 a	16.13	16.18	15.49 ab
5	No	Yes	Yes	No	56.3 a	52.7	54.4	54.5	13.83 ab	16.14	16.33	15.43 ab
6	No	Yes	No	Yes	56.2 ab	53.5	54.5	54.7	13.98 ab	16.00	16.81	15.59 a
7	Yes	Yes	Yes	No	56.6 a	52.5	54.7	54.6	13.95 ab	16.22	16.19	15.45 ab
8	Yes	Yes	No	Yes	56.3 a	53.0	54.8	54.7	13.90 ab	16.13	16.41	15.48 ab

1 Values in a column followed by the same letter or no letter are not significantly different at the 5% level according to Duncan's Multiple Range Test.

The residual effect of the 1983 and 1984 treatments was measured in the final year of this study (1985) as shown in Table 1. The surface applied treatment (No. 3) and the deep dry lime treatment (No. 6) had higher residual yields than the unlimed ripper-hipping treatment (No. 2). No other significant effects were measured in 1985. However, the treatment trends established in 1983 and 1984 were still evident in 1985 soybean yields.

Deep tillage of soils with a moderately low pH subsoil without the addition of deep lime resulted in slight decreases in yields in all 3 years. On the average, yields were decreased 2.6 bu/A without surface lime and 2.7 bu/A with surface lime by ripper-hipping. This trend has also been noted in other studies on low pH subsoils (2).

The response from 2 years of lime treatments and 1-year residual effect are shown in Table 1 as the 3-year average soybean yields. The deep banded dry lime treatment (No. 6) produced higher yields than the surface broadcast lime, disk incorporated, and ripper-hipping treatment (No. 4), check (No. 1), deep banded suspension lime treatment (No. 5), and the unlimed treatment with ripper-hipping (No. 2). Yields harvested from the surface lime treatment (No. 3) and from the combination surface and deep limed treatments (No. 7 and 8) were also higher than from the unlimed ripper-hipping treatment (No. 2) and were not significantly lower than the deep banded dry lime treatment (No. 6). The 3-year average seed weight was also increased by the application of deep dry lime compared to the unlimed check (No. 1) but did not significantly differ from all other treatments (Table 2).

Soil data were taken in each plot in the fall of 1983

Table 3. Soil pH, exchangeable H^+ and Ca^{2+} as influenced by applications of surface and/or deep band lime, and/or ripper-hipping Dundee and Forestdale silt loam soils, Steiner, MS, 1983.

Trt No.	Dry lime surface incorporated	Rip and hip	Deep lime: Suspension	Deep lime: Dry	Soil acidity A	Soil acidity B	Soil acidity C	Exchangeable H^+ A	Exchangeable H^+ B	Exchangeable H^+ C	Exchangeable Ca^{2+} A	Exchangeable Ca^{2+} B	Exchangeable Ca^{2+} C
					(pH)			(meq/100 g)					
1	No	No	No	No	6.38 ab[2]	5.95	5.60	1.50 abc	2.18	3.40	8.32	9.32	8.78 b
2	No	Yes	No	No	5.98 b	5.82	5.70	1.95 abc	2.68	3.80	6.68	6.26	7.94 b
3	Yes	No	No	No	6.82 a	5.48	5.68	1.10 bc	3.08	4.95	10.08	7.14	9.07 b
4	Yes	Yes	No	No	6.92 a	6.18	5.55	0.78 c	2.12	3.82	9.66	9.53	9.11 b
5	No	Yes	Yes	No	5.88 b	5.70	6.50	2.32 ab	2.98	2.55	4.79	6.55	18.19 a
6	No	Yes	No	Yes	5.98 a	6.42	5.25	2.55 a	2.28	4.48	4.91	8.94	8.06 b
7	Yes	Yes	Yes	No	6.53 ab	5.88	6.30	1.18 abc	2.50	2.88	7.31	8.99	13.98 ab
8	Yes	Yes	No	Yes	6.58 ab	5.65	5.48	1.08 bc	2.98	4.45	6.80	6.00	8.44 b

Soil sampling depth[1]

[1] Soil sample depth: A = 0 to 5 inches, B = 5 to 10 inches, and C = 10 to 15 inches.

[2] Means followed by the same letter or no letter are not significantly different at the 5% level by the Waller-Duncan K-Ratio T-Test.

Table 4. Soil pH, exchangeable H^+ and Ca^{2+} as influenced by applications of surface and/or deep band lime, and/or ripper-hipping Dundee and Forestdale silt loam soils, Steiner, MS, 1985.

Trt No.	Dry lime surface incorporated	Rip and hip	Deep lime: Suspension	Deep lime: Dry	Soil acidity A	Soil acidity B	Soil acidity C	Exchangeable H^+ A	Exchangeable H^+ B	Exchangeable H^+ C	Exchangeable Ca^{2+} A	Exchangeable Ca^{2+} B	Exchangeable Ca^{2+} C
					(pH)			(meq/100 g)					
1	No	No	No	No	6.50[2]	5.63	5.75	1.28	3.28	4.50	5.48	5.61	6.52
2	No	Yes	No	No	6.80	6.45	6.35	1.13	2.20	2.53	6.05	6.31	8.34
3	Yes	No	No	No	7.38	6.13	5.83	0.55	2.25	5.10	7.38	6.23	6.66
4	Yes	Yes	No	No	7.03	6.28	6.03	1.23	2.33	3.70	7.40	7.52	6.97
5	No	Yes	Yes	No	6.83	6.13	6.23	0.90	2.93	3.80	6.76	6.64	9.54
6	No	Yes	No	Yes	6.60	5.83	5.38	1.33	3.13	5.05	5.55	5.24	8.63
7	Yes	Yes	Yes	No	7.03	6.38	6.38	1.38	2.48	3.18	8.50	7.31	9.87
8	Yes	Yes	No	Yes	7.45	6.23	5.50	0.00	2.60	4.98	7.49	6.33	6.16

Soil sampling depth[1]

[1] Soil sample depth: A = 0 to 5 inches, B = 5 to 10 inches, and C = 10 to 15 inches.

[2] Means were not significantly different at the 5% level by the Waller-Duncan K-Ratio T-Test.

and 1985 and are presented in Tables 3 and 4. Soil pH tended to be increased in the top 5 inches by surface liming or by surface lime with ripper-hipping. It was more difficult to keep rows straight in the deep dry lime treatments than in the deep suspension lime treatments.

The same tractor was used for both treatments and the four-row dry lime applicator required more horsepower than the two-row suspension lime applicator. Steering the 110 HP tractor straight was much more difficult with the fully loaded four-row applicator. Thus, taking soil samples from the amended soil in the drill is more reliable for the deep banded suspension lime than for the deep banded dry lime treatments. This is shown by the higher soil pH values in the 10- to 15-inch sampling depth for suspension lime. However, soybean roots were able to utilize the deep banded dry lime treatment even if it was not directly under the drill as sampled. This is indicated by the yield responses of the deep banded dry lime treatments.

When lime is applied to the soil, exchangeable H^+ decreases, and exchangeable Ca^{2+} increases. This was evident in this study for surface applications of lime and for deep banded applications of suspension lime, but not for deep banded dry lime. Thus, it suggests that the band of dry lime was not being consistently sampled in the drill row. However, the yields show the subsoil was being modified within the rooting zone by treatment even though this sampling technique did not show it.

The total additional costs of lime and its application, incorporation costs, and ripper-hipping costs are shown in Table 1 for 1983 and 1984 as specified costs. The lowest cost liming treatment studied in this experiment was the deep placement of banded dry lime with a total cost of $36.62 per acre over the 2-year period. Neither liming nor deep tillage costs were incurred in the third year of the study since the residual effects were measured in 1985. The total receipts, less treatment costs, for the 3-year study are shown in Table 1 as returns above specified expenses. These returns are based on the 5-year average price ($6.78/bu) that soybean producers received as reported by the Mississippi Livestock and Crop Reporting Service. The only treatment that increased returns above treatment costs was the deep band placement of dry lime (No. 6) by $32.54 per acre for the 3-year period. No other treatment recovered treatment costs due to increasing yields over the check treatment (No. 1) during the 3 years. This could possibly change if additional years had been included in this study to measure prolonged residual effects of liming.

Acknowledgment

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