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SOILS AND PLANT NUTRITION

Evaluation of Calcium Nitrate as an In-furrow Applied Starter For Cotton

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INTERPRETIVE SUMMARY

This research was conducted to evaluate rates of calcium nitrate [$Ca(NO_3)_2$] applied in-furrow as a starter fertilizer for cotton production at two locations. At one location the $Ca(NO_3)_2$ treatments were compared with a 1.5 gal acre^{-1} of in-furrow applied ammonium polyphosphate (11-37-0) for cotton production. Previous research showed in-furrow applications of 11-37-0 should be limited to 1.5 gal acre^{-1} on the medium textured loess-derived soils since higher rates reduced seed germination. In-furrow starter applications have certain advantages including lower equipment costs and reduced soil erosion potential for cotton producers on loess-derived soils. However, there is a need for a starter fertilizer that can be in-furrow applied over a wide application range without reducing seed germination in order to avoid possible problems associated with calibration.

Research was conducted on a Loring silt loam (fine-silty, mixed, thermic, Typic Fragiudalf) and a Collins silt loam (coarse-silty, mixed, acid, thermic Aquic Udifluvent). Native vegetation was the winter cover on the Loring soil while winter wheat was the cover on the Collins soil. Treatments were evaluated for four years (1994–1997) on the Loring soil and three years (1994–1996) on the Collins soil. No-tillage production was used on both soils except in 1994 when conventional-till was used on the Collins soil.

In-furrow starter treatments of 0, 2, 4, 8, and 12 lb N acre^{-1} as $Ca(NO_3)_2$ were applied to cotton produced on both soils. Additional treatments evaluated on the Loring soil included in-furrow applying 11-37-0 at 1.5 gal acre^{-1}, surface-banding 11-37-0 at 7.5 gal acre^{-1}, and co-applying 11-37-0 at 7.5 gal acre^{-1} plus $Ca(NO_3)_2$ at 10 lb N acre^{-1} as separate surface-bands. The treatment effects on yields produced on both soils were similar. For the Loring soil, in-furrow applications of 2 to 8 lb N acre^{-1} as $Ca(NO_3)_2$ produced first-harvest yields of 825 to 838 lb lint acre^{-1}. These yields represent a 14 to 16% increase over the check yield (724 lb lint acre^{-1}). Surface-banding 7.5 gal of 11-37-0 acre^{-1} produced a 928 lb lint acre^{-1} first-harvest yield, which is a 28% increase compared with the check. Total yields produced by the in-furrow $Ca(NO_3)_2$ starters ranged from 1116 to 1141 lb lint acre^{-1} and were 14 to 16% greater than the check (982 lb lint acre^{-1}). Yield differences among the starter treatments were observed. For instance, in-furrow application of 8 lb N acre^{-1} as $Ca(NO_3)_2$, 1.5 gal of 11-37-0 acre^{-1}, and surface-banding 7.5 gal 11-37-0 acre^{-1} resulted in higher total lint yields than in-furrow application of 12 lb N acre^{-1} as $Ca(NO_3)_2$. On the Collins soil, in-furrow $Ca(NO_3)_2$ applications of 2 to 8 lb N acre^{-1} increased yields from 6 to 8% greater than the check yield. Using $Ca(NO_3)_2$ as an in-furrow starter increased cotton yields over a wide range of application.

ABSTRACT

Increased acreage of no-tillage cotton (*Gossypium hirsutum L.*) has heightened interest in starter fertilizers. Crop residues and winter covers used to retard eroision also restrict water evaporation and reduce soil temperatures, which can reduce seed germination and plant vigor. Applying a small amount of fertilizer close to the seed may improve plant vigor and yields. Our research evaluated $Ca(NO_3)_2$ applied in-furrow for no-till cotton between 1994 and 1997 on a Loring silt loam (fine-silty, mixed, thermic, Typic Fragiudalf) and between 1994 and 1996 on a Collins silt loam (coarse-silty, mixed, acid, thermic Aquic Udifluvent). Winter covers included native vegetation on the Loring soil and winter wheat (*Triticum asetivum L.*) cover on the Collins soil. No-tillage production was used on all but the Collins

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soil in 1994. Total fertilizers applied, broadcast with or without starter, were 90, 20, and 56 kg ha^{-1} of N, P and K, respectively. The $Ca(NO_3)_2$ starter treatments of 17, 34, 68, and 102 L ha^{-1} were applied in-furrow to both soils. Additional starters applied to the Loring soil included ammonium polyphosphate (11-37-0) applied either in-furrow at 14 L ha^{-1} or surface-banded at 70 L ha^{-1}. In-furrow $Ca(NO_3)_2$ applications increased cotton yields 14 to 16% on the Loring soil and 6 to 8% on the Collins soil. The 11-37-0 applications increased the Loring soil yields 16 and 21% from in-furrow and surface-banding, respectively. A wide in-furrow application range (17 to 68 L ha^{-1}) of $Ca(NO_3)_2$ increased cotton yields.

Applying a fertilizer close to the planted seed for enhanced plant vigor and improved yield has gained renewed interest with increased acreage of no-tillage cotton (*Gossypium hirsutum* L.) production. The soil environment of no-tillage systems is affected by surface crop residues and winter covers used for erosion control. These residues reduce moisture evaporation and lower soil temperatures, which may reduce and/or delay germination and early plant growth. Applying fertilizer as a starter has been reported to increase yields of no-till corn (*Zea Mays* L.) and cotton (Howard and Mullen, 1991; Howard and Tyler, 1987; Howard and Hoskinson, 1990; Hutchinson and Howard, 1997).

Starter fertilizers have been applied by several methods, each of which has increased no-till yields (Hutchinson and Howard, 1997). Each application method has certain advantages and disadvantages. A popular method is to band fertilizers five cm to the side and five cm below the planted seed (side-banding). Additional equipment including row applicators and an additional tool bar to attach the applicators is required for the placement process. In addition, extra tractor power and weights may be needed in the planting process. A second method is to surface-band fertilizers over the row behind the planter. Fertilizer rates generally need to be higher if applied as a surface-band (Hutchinson and Howard, 1997). These higher rates may require additional fertilizer hopper or tank capacity which will allow refilling to coincide with seed hopper refilling. A third application method involves applying fertilizers in direct contact with the seed at planting which may reduce germination with high application rates or light textured soils. Equipment costs should be low with this method since in-furrow applications can be achieved through a nozzle attached to the planter unit bracket used for fungicide and/or insecticide applications. Sometimes, liquid fertilizers can be mixed with fungicides or insecticides and co-applied through an existing system. In-furrow applications may reduce potential erosion that could occur with the soil disturbance associated with side-band placement.

Crop response to starter fertilization has been found to vary with year, tillage system, soil type, application method, application rate, and nutrient combination of the starter. Research in Alabama showed side-banding starters were more effective for no-till cotton production than for conventional-till production (Touchton et al., 1986). Howard and Hoskinson (1990) reported that increased lint yields from starters were more likely to occur in years of cool wet springs. They also reported that yields were not increased every year and that side-banding 17 kg N and 7 kg P ha^{-1} produced higher no-till cotton yields than starters containing higher P rates. Hutchinson and Howard (1997) evaluated three methods for applying 11-37-0 to conventional- and no-till produced cotton on two loess-derived soils. They reported that in-furrow application of either 28 or 42 L of 11-37-0 ha^{-1} reduced seed germination in both tillage systems on both soils. They concluded that yield response from surface- and side-banded 11-37-0 was greater than from in-furrow applications.

In-furrow applied fertilizers for cotton production need to contain low levels of ammonium. Adams (1966) concluded that reduced germination associated with high ammonium-phosphate applications resulted from a temporary calcium deficiency in the ambient soil solution. For cotton production, non-ammonium fertilizers may be more desirable as an in-furrow applied material than 11-37-0. Calcium nitrate, a non-ammonium N material, should prevent possible germination reductions associated with in-furrow application of high ammonium-phosphate rates.

On the other hand, if P is required as a component of the starter, a fertilizer other than $Ca(NO_3)_2$ would be required since liquid $Ca(NO_3)_2$ and 11-37-0 are not compatible when mixed. Howard and Hoskinson (1990) reported side-banding N as a starter was as effective for increased yields as side-banding N plus P for no-till cotton production on a loess-derived soil having a medium to high extractable P level.

The objective of this research was to evaluate $Ca(NO_3)_2$ as an in-furrow applied starter for cotton production, to evaluate $Ca(NO_3)_2$ application rates, and, at one location, to compare $Ca(NO_3)_2$ with ammonium polyphosphate applied either in-furrow or as a surface band.

MATERIALS AND METHODS

Research was conducted from 1994 through 1997 on a Loring silt loam (fine-silty, mixed, active, thermic Oxyaquic Fragiudalfs) at the Milan Experiment Station, Milan, TN, and from 1994 through 1996 on a Collins silt loam (coarse-silty, mixed, acid, thermic Aquic Udifluvents) at the West Tennessee Experiment Station, Jackson. Mehlich-I extractable P and K were 70 and 230 kg ha^{-1} on the Loring soil and 65 and 222 kg ha^{-1} for the Collins soil. Native winter vegetation was the cover on the Loring soil, while a winter wheat cover was established each fall on the Collins soil. No-tillage production was used each year on both soils except in 1994 when the Collins soil was conventionally tilled.

The experiment design was a randomized complete block with treatments replicated five to six times. The total number of treatments varied each year at both locations. Core treatments evaluated on each soil are listed in Table 1. Uniform rates of N, P, and K were applied to each treatment and equaled 90, 20, and 56 kg ha^{-1}, respectively. These rates were applied as a combination of starter and/or broadcast applications. Ammonium nitrate, concentrated superphosphate, and KCl were the broadcast fertilizer materials. Individual plots were 9.1 m long and four rows wide. Row widths were 1.02 m on the Loring soil and 0.97 m on the Collins soil.

The apparatus for applying the in-furrow starters was attached to the insecticide–fungicide bracket on the back of the planter units. Starters were applied through an orifice as a solid stream directly into the seed furrow. The nutrient concentration of the starter solutions varied since each was diluted with water to allow treatment application at a constant planter speed and CO_2 pressure.

Table 1. Nitrogen-phosphorus rates and combinations of starter materials, application methods, and broadcast fertilizer rates for cotton produced on two loess-derived soils.

Starter			Application		Broadcast		
N	P	Material	Rate	Method	N	P	K
-kg ha^{-1}-			L ha^{-1}		---kg ha^{-1}---		
Treatments applied to both soils							
0	0	Check			90	20	56
2	0	$Ca(NO_3)_2$	17	in-furrow	88	20	56
4	0	$Ca(NO_3)_2$	34	in-furrow	86	20	56
9	0	$Ca(NO_3)_2$	68	in-furrow	81	20	56
13	0	$Ca(NO_3)_2$	102	in-furrow	77	20	56
Additional treatments applied to the Loring silt loam							
2	3	11-37-0‡	14	in-furrow	88	17	56
11	17	11-37-0	70	surface-band	79	3	56
22	17	Comb†	154	surface-band	68	3	56

† 70 L 11-37-0 and 84 L $Ca(NO_3)_2$ applied through two separate systems.

‡ Ammonium Polyphosphate

Applicator lines were cleared between plots by filling with CO_2 and refilling with the next treatment. The 11-37-0 treatments were applied after the $Ca(NO_3)_2$ applications. The surface-band of 11-37-0 was applied as a 10-cm wide band onto the planted row. Surface-banding was accomplished through a flat fan nozzle attached behind the packer wheels.

The cultivar `D&PL 50´ was planted on the Loring soil between 15 and 30 April each year except for 1997. In 1997, `D&PL 5409´ was planted 27 April, but because of the thin stands due to the cool spring, plots were replanted by 13 May. The cultivar D&PL 50 was planted between 5 and 15 May on the Collins soil. Recommended production practices (Shelby, 1996) were used in growing the crop at each location.

A recommended defoliant was applied when 60% of the bolls were open. Lint yields were determined by mechanically picking the center plot rows. Cotton was picked approximately 2 wk after leaf drop with a second picking approximately 3 wk later. This interval varied due to weather and several other factors. In most years, the date of the second picking was delayed to allow sufficient time for the top bolls to open. Percent lint was determined by combining subsamples of seed cotton from individual treatments across replications (less than 4.5 kg) and ginning on a 20-saw gin with dual lint cleaners. Lint yields were calculated by multiplying the lint percentage by seed cotton weights. Total annual lint yields were calculated by adding the first- and second-harvest yields.

Statistical analyses of treatment effect on yields were conducted utilizing SAS Mixed Model procedures (SAS Ins., 1997). The Mixed Model procedure provides Type III F values but does not provide mean square values for each element within the analysis or the error terms. Mean separation was evaluated through a series of protected pair-wise contrasts among all treatments (Saxton, 1998). Means having Type III F error probabilities greater than 0.05 were categorized as non-significant.

RESULTS AND DISCUSSION

Since experiment duration and treatments evaluated at each location differed, yield data will be discussed by soil type. The statistical analysis shows the starter effects were consistent across years on both soils since the year-by-treatment interactions were nonsignificant (Table 2). Therefore, yields will be discussed as four-year averages for the Loring soil and three-year averages for the Collins soil.

Loring silt loam

First- and second-harvest and total lint yields were improved by starter applications when compared with the check (Table 3). Different starters maximized first- and second-harvested yields and total lint yields. Surface-banding 70 L of 11-37-0 ha^{-1} resulted in a 1039 kg lint ha^{-1} first-harvest yield that was higher than other starter yields and 21% higher than the check. In-furrow applications of 17, 34, and 68 L $Ca(NO_3)_2$ ha^{-1} and 14 L ha^{-1} of 11-37-0 produced first-harvest yields ranging from 924 to 939 kg lint ha^{-1}, an increase of 14 to 16% based on the 811-kg check yield. Surface-banded $Ca(NO_3)_2$ was evaluated as a combination band with 11-37-0. First- harvest yields were not improved by applying this combination band when compared with surface-banding 11-37-0. In-furrow application of 102 L of $Ca(NO_3)_2$ ha^{-1} did not increase first-harvest lint yields.

In-furrow application of either 34 or 68 L of $Ca(NO_3)_2$ ha^{-1} or 14 L of 11-37-0 ha^{-1} resulted in second-harvest yields of 344, 340, and 343 kg ha^{-1}, respectively. These yields were 19% higher than the check. Except for these three starters, second-harvest yields were unaffected by starter applications.

Total yields produced by the starters were greater than the check yield. Yields from starter applications ranged from 102 to 230 kg lint ha^{-1} higher than the check, a 9 to 21% increase. In-furrow application of 17, 34, and 68 L of $Ca(NO_3)_2$ ha^{-1} and 14 L of 11-37-0 gave comparable total lint yields. Increased yields from these four treatments were 14 to 16% higher than the check. In-furrow application of 102 L $Ca(NO_3)_2$ ha^{-1} resulted in a 9% higher yield than the check. This increase was the lowest of the in-furrow treatments, but there is no obvious explanation. The 1997 plant populations were unaffected by in-furrow applied starters (data not presented) and visual differences were not detected.

Surface-banding 70 L of 11-37-0 ha^{-1} produced the highest yield of the starter treatments. This yield was 21% higher than the check. This higher yield effect from surface-banding 70 L of 11-37-0 was reported by Hutchinson and Howard (1997). The higher yield suggests the need for P as a starter component. However, in-furrow application of 14 L of 11-37-0 produced yields comparable with those produced by in-furrow application of 34 and 68 L $Ca(NO_3)_2$ ha^{-1}, suggesting the higher yields were

Table 2. Type III F-values from statistical analyses of starter rates, materials, and placement methods on no-tillage cotton yields produced on two loess-derived soils.

	Loring silt loam				Collins silt loam			
	Harvest periods				Harvest periods			
	df	1st	2nd	Total	df	1st	2nd	Total
Year (Y)	3	10.1**	47.4**	30.7**	2	167.8**	36.3**	94.5**
Error a	12				7			
Treatments (T)	7	3.7**	2.5*	7.3**	4	2.3	0.4	3.6*
Y x T	21	1.1	1	1.4	8	2.1	0.6	2
Error b	109				47			

***, ** Significant at the 0.05 and 0.01 probability levels, respectively.**

Table 3. Effects of starter application methods, rates, and materials on cotton produced on two loess-derived soils† .

Starter		Application Method‡	Loring Silt Loam yield by harvest period			Collins Silt Loam yield by harvest period		
Rate	Material		1st	2nd	Total	1st	2nd	Total
L ha^{-1}			lint yield (kg ha^{-1})					
0	Check		811 c§	289 c	1100 d	978 a	266 a	1250 c
17	$Ca(NO_3)_2$	IF	935 b	315 abc	1250 bc	1049 a	294 a	1351 a
34	$Ca(NO_3)_2$	IF	924 b	344 a	1267 abc	1058 a	270 a	1336 a
68	$Ca(NO_3)_2$	IF	939 b	340 ab	1278 ab	1057 a	269 a	1333 ab
102	$Ca(NO_3)_2$	IF	900 bc	302 bc	1202 c	1006 a	255 a	1269 bc
14	11-37-0	IF	933 b	343 ab	1275 ab			
70	11-37-0	SB	1039 a	292 c	1330 a			
154	Comb¶	SB	935 b	302 bc	1238 bc			

† Four year data for Loring silt loam and three year data for Collins silt loam.

‡ Application method: IF - in-furrow; SB - surface-band.

§ Within each yield column, means followed by a common letter are not significantly different at α = 0.05.

¶ 70 L 11-37-0 ammonium polyphosphate and 84 L $Ca(NO_3)_2$ applied through two separate systems.

due to the N component of the starters. This observation is consistent with the findings of Howard and Hoskinson (1990) that side-banded N or N plus P starters produced comparable no-tillage cotton yields on soils with medium to high extractable P levels. Extractable P of the Loring soil was categorized as high, reducing the possibility of a yield response to P fertilization. Differences in yields from starter applications resulted from placement, application rate, and application material since fertilizer nutrient rates were equal.

The percentage of first-harvest to total lint yields has been used as an indicator of earliness for cotton. Therefore, any treatment that increases earliness would be of value to the producer. Earliness evaluations were restricted for treatments that increased both first-harvest and second-harvest yields. The percentage of first-harvest to total yield on the Loring soil ranged from 73 up to 78%. Although yields were increased by starter applications, only one starter treatment, surface-banding 11-37-0, significantly increased earliness.

The $Ca(NO_3)_2$ was a safe material which allowed a 17 to 68 L ha^{-1} application range. This is important for an in-furrow starter because of the possibility of improper application calibration.

Collins silt loam

In-furrow applications of $Ca(NO_3)_2$ did not affect either first- or second-harvest yields although total lint yields were affected by the starters (Table 2). Total lint yields were improved by in-furrow applications of 17, 34, and 68 L of $Ca(NO_3)_2$ ha^{-1} compared with the check (Table 3). These yields were 8% greater than the check yields and were about half the increase observed for the Loring soil. The lower yield response to starters may be associated with several factors including planting date. Howard and Hoskinson (1990) indicated that response to starters was greater with cool moist planting conditions which generally occur very early in the planting season. The Collins soil planting date was seven to 14 days later than the Loring soil planting date.

CONCLUSIONS

In-furrow $Ca(NO_3)_2$ applications increased cotton yields on two loess-derived soils. Applying 17, 34, or 68 L of $Ca(NO_3)_2$ ha^{-1} increased total yields on the two soils. In-furrow application of 102 L of $Ca(NO_3)_2$ produced the lowest starter treatment increase on the Loring soil and did not increase yields on the Collins soil. A wide application range (17 to 68 L ha^{-1}) of $Ca(NO_3)_2$ can be applied in-furrow without reducing yields. On the Loring soil, in-furrow applications of 17, 34, or 68 L of $Ca(NO_3)_2$ produced yields comparable with in-furrow application of 14 L of 11-37-0. Surface-banding 11-37-0 at 70 L ha^{-1} resulted in the highest yield increase of the starter treatments. Producers wanting to use the in-furrow method of starter application should consider applying $Ca(NO_3)_2$ along with conventionally applied materials.

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