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SOURCES *of* NITROGEN *for* COTTON *and* CORN *in Alabama*

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NITROGEN MUST BE applied to Alabama soils for economic production of all non-leguminous crops. Although these soils release some available nitrogen each season from their organic nitrogen reserve, the amount released is too small for satisfactory crop production. Additional nitrogen, therefore, must be obtained from other sources. It may be added to the soil by leguminous plants, plant residues, animal residues, or by commercial fertilizers. Only nitrogen from commercial fertilizers is considered in this report.

Plants can utilize several forms of nitrogen, but the ammonia and nitrate forms are of primary importance. The ammonia form may be attached to soil particles, and while thus attached it is not subject to appreciable leaching. Nitrate is not held to soil particles and is subject to leaching unless held by incorporation into organic matter by soil organisms. Ammonia is rapidly converted to the more easily leached nitrate under most Alabama growing conditions.

Most plants absorb both nitrate and ammonia during all stages of growth, but the relative proportion of each may vary during the life of the plant *(1)*. Ammonia is rapidly converted to nitrate when the soil is warm, moist, well aerated, and the pH is not too low. This conversion, called **nitrification,** is a biological process of soil organisms. Most soils contain an ample supply of the necessary organisms. Under favorable conditions, nitrification begins soon after application of ammonia and it is largely complete within a few days to a few weeks. The rate of nitrification is decreased in winter due to lower soil temperatures, but in no part of Alabama do soil temperatures remain low enough to prevent nitrification for long periods.

The elements accompanying nitrogen in some fertilizers may have an effect on crop production. Calcium nitrate [$Ca(NO_3)_2$], ammonium nitrate plus limestone [$NH_4NO_3 + CaCO_3$], and calcium cyanamid [$Ca(CN)_2$] will produce a yield response in addition to that from nitrogen when calcium is deficient. Crops on sulfur-deficient soils may respond to ammonium sulfate [$(NH_4)_2SO_4$] because of the sulfur which it contains. The sodium in sodium nitrate [$NaNO_3$], though not an essential element, has been found beneficial for some crops. The ammonium phosphates supply two major elements, nitrogen and phosphorus, in the same material. Both nitrogen and potassium are supplied by potassium nitrate [KNO_3]. On the other hand, anhydrous ammonia [NH_3], ammonium nitrate [NH_4NO_3], and urea [$CO(NH_2)_2$] are of value solely for the nitrogen they contain. The natural organics may contain many elements of value to crops.

Nitrogen fertilizers may make the soil more acid, less acid, or have no effect on acidity. The development of acidity from ammonia fertilizers is largely a result of nitrification whereby ammonia is changed to nitrate with a release of acid into the soil.

This cotton is growing on Hartsells fine sandy loam where acidifying nitrogen fertilizers were used without lime from 1929 until 1956. Crabgrass severely infests these acid plots when cultivation is stopped.

Some nitrogen fertilizers leave an excess of a base (such as calcium or sodium) in the soil, which reduces soil acidity.

DESCRIPTION OF FERTILIZER MATERIALS THAT CONTAIN NITROGEN

There are thousands of compounds that contain nitrogen, but only a few can be produced economically for use as fertilizer. The materials listed and discussed here include those used in experiments reported in this publication, as well as some others that have received considerable distribution in commercial trade.

Ammonium nitrate [NH_4NO_3] is produced by combining ammonia with nitric acid. The resulting product is white in color. It contains 32.5 to 33.5 per cent nitrogen, with equal parts of ammonia and nitrate nitrogen. The fertilizer grade is in the form of crystals or pellets that have been coated with a conditioner to reduce caking. It is acid-forming and requires 60 pounds of limestone to neutralize 100 pounds of material.

Ammonium nitrate and limestone are sometimes mixed to form a nonacid-forming product containing 16 to 20.5 per cent nitrogen. This product has been marketed under various names. It contains only enough limestone to neutralize the acidity produced by the ammonium nitrate.

Ammonium phosphates are manufactured by combining ammonia and phosphoric acid. There are two principal forms of this fertilizer, monoammonium phosphate [$NH_4H_2PO_4$] and diammonium phosphate [$(NH_4)_2HPO_4$]. Monoammonium phosphate contains 11 per cent nitrogen and 48 per cent P_2O_5, and diammonium phosphate contains 21 per cent nitrogen and 54 per cent P_2O_5. Both are acid-forming.

Ammonium sulfate [$(NH_4)_2SO_4$] is produced by the reaction of ammonia with sulfuric acid. Large quantities have been produced using by-product ammonia from coke ovens. More recently an increasing amount has been made by reacting synthetic ammonia with sulfuric acid. The nitrogen content is 20.5 per cent and the color may vary from white to yellow to gray. Ammonium sulfate is acid-forming and requires about 110 pounds of limestone to neutralize 100 pounds of material.

Anhydrous ammonia [NH_3] is stored as a liquid under pressure. It has a gauge pressure of 75 p.s.i. at 50° F. and 197 p.s.i.

at 100° F. The nitrogen content is 82 per cent. When released at atmospheric pressure, it forms a colorless gas that is extremely irritating to the nose, eyes, skin, and lungs. It should be released in the soil deep enough so that soil above the release point will seal in the gas. The reaction of ammonia with soil constituents is rapid; the initial product is ammonium hydroxide with a resulting alkaline reaction. This alkaline reaction is only temporary, and as a result of bacterial action, the alkaline reaction disappears and the end result is an increase in soil acidity. One hundred pounds of anhydrous ammonia requires about 148 pounds of calcium carbonate for neutralization.

Nitrogen solutions of several different kinds are produced for fertilizer. These are water solutions of various combinations of ammonia, urea, and ammonium nitrate. The nitrogen content ranges from 21 to 53 per cent. They may have no pressure or a relatively high pressure depending upon the content of free ammonia. Pressure solutions are applied below the soil surface to seal in the gas, whereas non-pressure solutions may be applied on top of the soil.

Calcium cyanamid [$CaCN_2$] is manufactured from coke, limestone, and atmospheric nitrogen. It was one of the earlier products of the synthetic fixation of atmospheric nitrogen. It is produced in powdered, granulated, and pelleted forms, and contains 20 to 22 per cent nitrogen. It produces an alkaline reaction in the soil equivalent to 63 pounds of limestone per 100 pounds of cyanamid. The commercial product is black because of the presence of free carbon. Calcium cyanamid is toxic on direct contact with seeds and seedlings. For row crops it should be applied at least one week prior to planting.

Calcium nitrate [$Ca(NO_3)_2$] is made by reacting limestone with nitric acid. The resulting product is a white material that readily absorbs moisture from the atmosphere. The tendency to become wet and soggy has been reduced by mixing with limestone or by coating the particles. The fertilizer must be used shortly after the moisture-resistant bags are opened. The fertilizer grade contains enough ammonium nitrate to bring the nitrogen percentage up to 15.5 It has a slight neutralizing effect on acid soils. It has been produced as fertilizer in Europe, but has not been manufactured on a large scale in this country.

Cottonseed meal is a by-product of the cottonseed oil industry. It is yellowish brown in color and contains 6 to 9 per cent nitrogen. Because of demand for the product as feed, it is now seldom used as a fertilizer.

Potassium nitrate [KNO_3] is found in a few natural deposits or is manufactured by reacting nitric acid with caustic potash or potassium carbonate. It has less tendency to absorb moisture than most other forms of nitrate. It contains about 13 per cent nitrogen and 43 per cent potash and has a slight neutralizing effect on acid soils.

Sodium nitrate [$NaNO_3$] has two important sources. One is the refined product from deposits in the desert plateaus of Chile. The other is made by reacting nitric acid with sodium carbonate. Both products contains about 16 per cent nitrogen. Sodium nitrate is white in color and is marketed in pellet form. It has a slight neutralizing effect on acid soils.

Urea [$CO(NH_2)_2$] is a synthetic product produced by reacting ammonia and carbon dioxide under high pressure. The fertilizer material is white or greenish and is usually marketed in pellet form. It contains 42 to 45 per cent nitrogen. Nitrogen in urea hydrolyzes to ammonium form of nitrogen in the soil. The ammonia is changed to nitrate, resulting in increased acidity.

Some of the important characteristics of the various nitrogen materials discussed are listed in Table 1.

GENERAL DESCRIPTION OF FIELD EXPERIMENTS

The Agricultural Experiment Station of the Alabama Polytechnic Institute has done a large amount of research on sources of nitrogen. This work dates back to 1911 when the sources of nitrogen were the natural organics, ammonium sulfate, calcium cyanamid, and sodium nitrate. This early work is covered in publications issued prior to 1933. Pierre *(2, 3)* reported the effects of various nitrogenous fertilizers on soil reaction and determined the equivalent acidity and basicity of the different sources of nitrogen, Table 1. Tidmore and Williamson *(4)* reported results from many field and laboratory experiments conducted prior to 1932 in a comprehensive bulletin. Volk and Tidmore *(5)* published data on the effect of different nitrogen sources on soil reaction, exchangeable ions, and yields of crops. The present

TABLE 1. NUTRIENT CONTENT AND EQUIVALENT ACIDITY OR BASICITY OF CERTAIN SOURCES OF NITROGEN

Treatment	Nutrient content		Equivalent acidity or basicity—lb. $CaCO_3$[1]			
	Nitrogen	Other nutrients	Per pound of nitrogen		Per 100 pounds of product	
			Acidity	Basicity	Acidity	Basicity
	Pct.	*Pct.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
Ammonium nitrate	33.5	----	1.80		60	
Ammonium nitrate-limestone	20.5	16 Ca	0	0	0	0
Ammonium sulfate	20.5	23 S	5.35		110	
Anhydrous ammonia	82.0	----	1.80		148	
Calcium cyanamid	22.0	38 Ca		2.85		63
Calcium nitrate	15.5	44 Ca		1.35		21
Cottonseed meal	6 to 9	2 P_2O_5 2 K_2O	1.45		10	
Diammonium phosphate	21.0	54 P_2O_5	3.50		74	
Monoammonium phosphate	11.0	48 P_2O_5	5.35		59	
Potassium nitrate	13.0	43 K_2O		2.00		26
Sodium nitrate	16.0	26 Na		1.80		29
Urea	45.0	----	1.80		81	

[1] Determined by method of Pierre *(2)*.

report covers the results of the continuation of some experiments included in the previously mentioned publications plus work that was started subsequently.

Long-term experiments on sources of nitrogen for cotton and corn at six locations are reported here. The soil types and their locations are: Decatur clay loam at the Tennessee Valley Substation and Alexandria Experiment Field, Hartsells fine sandy loam at the Sand Mountain Substation, Norfolk fine sandy loam at the Wiregrass Substation, Magnolia fine sandy loam at the Monroeville Experiment Field, and Chesterfield sandy loam at the Main Station at Auburn.

All except those on the Main Station were conducted on tiers consisting of 34 1/30-acre plots. Plots 1A to 17A were laid out from left to right, and duplicate plots 1B to 17B from right to left. Plots 1, 5, 9, 13, and 17 in each duplicate were check plots.

Fertilizer and lime treatments, and methods of application are given in the introductions to the various experiments and as footnotes to the tables. Pre-planting fertilizers were applied in a furrow and bedded on before planting. Sidedress applications were applied beside the row 35 to 40 days after planting.

In experiments that involved both cotton and corn, these crops were in a 2-year rotation. Both crops were planted each year on alternate tiers. Crop residues were left on the plots in all experiments.

Since the cost of nitrogen from the various sources and prices received by farmers for cotton and corn vary from year to year, relative returns per unit cost of nitrogen are not included in this publication. Returns may be calculated from the yield data presented, using prices that prevail at any time.

EXPERIMENTS WITH SEVERAL SOURCES OF NITROGEN, 1929-45

Sources of nitrogen experiments were conducted at the Sand Mountain, Tennessee Valley, and Wiregrass substations using a cotton-corn rotation. Sources used were ammonium nitrate, sodium nitrate, ammonium sulfate, urea, calcium nitrate, diammonium phosphate, cottonseed meal, and calcium cyanamid. Both limed and unlimed tiers were included at the Tennessee Valley and Wiregrass substations. Limed tiers received 2,250 pounds of calcitic limestone per acre when the experiments were begun and sufficient dolomitic limestone annually mixed with the fertilizer to neutralize the acid-forming sources of nitrogen. The limed tiers were adjacent to the unlimed tiers. Cotton received 36 pounds of N, 48 pounds of P_2O_5, and 24 pounds of K_2O per acre annually. Corn received 36 pounds of N, 24 pounds of P_2O_5, and 12 pounds of K_2O per acre annually. Nitrogen, phosphate, and potash treatments were the same on both limed and unlimed tiers. Sidedressed plots received one-fourth of the N at planting and three-fourths as a sidedressing.

Relative yield increases were calculated by using a value of 100 per cent for the yield increase from a split application of sodium nitrate. This source was selected as a base since it was used in all tests.

Results on Cotton

Sand Mountain Substation, Hartsells Fine Sandy Loam

UNLIMED (TABLE 2). Average yields at this location for the 1929-45 period show little or no differences between sodium nitrate, cottonseed meal, urea, and calcium nitrate. These sources

TABLE 2. COTTON YIELD INCREASES FROM VARIOUS SOURCES OF NITROGEN ON UNLIMED PLOTS IN A COTTON-CORN ROTATION, HARTSELLS FINE SANDY LOAM, SAND MOUNTAIN SUBSTATION, 1929-45

Nitrogen source[1]	Method of application	Seed cotton yield increases from different nitrogen sources by periods[2]								pH in 1946[3]
		1929-33		1934-37	1938-41	1942-45		1929-45 average		
		Yield increase	Relative increase	Yield increase	Yield increase	Yield increase	Relative increase	Yield increase	Relative increase	
		Lb.	*Pct.*	*Lb.*	*Lb.*	*Lb.*	*Pct.*	*Lb.*	*Pct.*	
None		*(624)*	--	*(513)*	*(565)*	*(575)*	--	*(572)*	--	5.0
Ammonium nitrate + limestone	Sidedress[4]	598	86	734	907	723	78	732	85	--
Sodium nitrate	Sidedress[4]	694	100	820	1,063	928	100	866	100	--
Sodium nitrate	Under	754	109	847	1,055	886	95	878	101	5.5
Ammonium sulfate	Sidedress[4]	649	93	556	718	309	33	563	65	--
Ammonium sulfate	Under	671	97	614	702	339	37	587	68	4.5
Urea	Sidedress[4]	699	101	785	971	789	85	804	93	5.2
Calcium nitrate	Sidedress[4]	731	105	781	935	763[5]	82	798	92	--
Diammonium phosphate	Under	519	75	380	441	235	25	401	46	4.8
Cottonseed meal	Under	651	94	825	1,025	902	97	839	97	5.1
Calcium cyanamid	Under	539	78	672	868	610	66	664	77	5.7

[1] All plots except checks received 36 lb. of N; 48 lb. of P_2O_5 from superphosphate except the diammonium phosphate plots, which received 93 lb. of P_2O_5; and 24 lb. of K_2O from muriate of potash.

[2] Check yields (in italics) are total yields per acre. All other yields are increases over calculated checks on the basis that soil fertility changes uniformly from one check plot to the next.

[3] The original pH in 1929 was 5.7.

[4] Sidedressed plots received ¼ of N at planting and ¾ as sidedressing.

[5] Changed to urea in 1942.

Cotton at right is nitrogen deficient, whereas rows at left received ample nitrogen. The soil is Magnolia fine sandy loam.

were superior to diammonium phosphate and ammonium sulfate, whereas ammonium nitrate plus limestone and calcium cyanamid occupied intermediate positions. The lower yields from ammonium sulfate and diammonium phosphate when used without lime were associated with their acidity as indicated by their effect on soil pH. Since all except the diammonium phosphate plots received calcium sulfate in the form of superphosphate, a part of the poor results from this material may have been caused by a sulfur deficiency on this sandy soil.

The cumulative effect of the sources is best measured by the yields in the last period, 1942-45. This period will be used throughout the discussion as a measure of the long-time effect from the sources. Sodium nitrate and cottonseed meal were superior to all other sources. The differences in yield between these and diammonium phosphate and ammonium sulfate were much greater than had been the case in the first period.

The only sources that maintained the pH near the original level were calcium cyanamid and sodium nitrate. Plots that received no nitrogen dropped in pH from 5.7 to 5.0. Ammonium sulfate lowered the pH to 4.5, which is far below optimum for cotton production.

Applying three-fourths of the nitrogen as sidedressing did not increase yields from either sodium nitrate or ammonium sulfate. Apparently leaching was not a serious problem on this soil.

TABLE 3. COTTON YIELD INCREASES FROM VARIOUS SOURCES OF NITROGEN ON UNLIMED PLOTS IN A COTTON-CORN ROTATION, NORFOLK FINE SANDY LOAM, WIREGRASS SUBSTATION, 1930-40

Nitrogen source[1]	Method of application	Seed cotton yield increases from different nitrogen sources by periods[2]							pH in 1946[3]
		1930-33		1934-37	1938-40		1930-40 average		
		Yield increase	Relative increase	Yield increase	Yield increase	Relative increase	Yield increase	Relative increase	
		Lb.	*Pct.*	*Lb.*	*Lb.*	*Pct.*	*Lb.*	*Pct.*	
None		*(793)*	--	*(774)*	*(602)*	--	*(734)*	--	5.2
Ammonium nitrate + limestone	Sidedress[4]	332	75	700	868	101	612	89	--
Sodium nitrate	Sidedress[4]	445	100	813	858	100	691	100	--
Sodium nitrate	Under	392	88	709	682	79	586	85	5.4
Ammonium sulfate	Sidedress[4]	457	103	761	768	90	652	94	--
Ammonium sulfate	Under	426	96	671	538	63	546	79	5.1
Urea	Sidedress[4]	489	110	773	817	95	682	99	5.3
Calcium nitrate	Sidedress[4]	513	115	835	808	94	710	103	--
Diammonium phosphate	Under	228	51	426	289	34	317	46	5.1
Cottonseed meal	Under	410	92	791	905	105	684	99	5.4
Calcium cyanamid	Under	403	91	741	832	97	643	93	5.7

[1] All plots except checks received 36 lb. of N; 48 lb. of P_2O_5 from superphosphate except the diammonium phosphate plots, which received 93 lb. of P_2O_5; and 24 lb. of K_2O from muriate of potash.

[2] Check yields (in italics) are total yields per acre. All other yields are increases over calculated checks on the basis that soil fertility changes uniformly from one check plot to the next.

[3] The original pH in 1929 was 5.7.

[4] Sidedressed plots received ¼ of N at planting and ¾ as sidedressing.

Wiregrass Substation, Norfolk Fine Sandy Loam

UNLIMED (TABLE 3). Similar yields were obtained from all sources with the exception of diammonium phosphate, which was inferior throughout the period. The lower yields from this material were probably the result of a lack of sulfur and of increased soil acidity. The sandy soils of this area do not contain much sulfur so that a deficiency may develop when no sulfur is added for long periods of time.

This experiment was conducted for only 11 years; therefore, the cumulative effects of acid-forming sources were not as extreme as those after 17 years at Sand Mountain. Low yields, however, were produced during all periods from diammonium phosphate.

Method of application was important at the Wiregrass Substation. In the 11-year averages, yields were increased about 100 pounds of seed cotton from split applications of both sodium nitrate and ammonium sulfate.

LIMED (TABLE 4). The sources produced similar yields except for diammonium phosphate, which resulted in low yields throughout all periods of the experiment.

All treatments where pH effects were determined maintained pH about constant except calcium cyanamid, which increased soil pH from 5.8 to 6.1. With liming to counteract acidity development, ammonium sulfate compared favorably with nonacid-forming sources.

There was an advantage from splitting the application of nitrogen, especially with ammonium sulfate.

Tennessee Valley Substation, Decatur Clay Loam

UNLIMED (TABLE 5). Yield responses to nitrogen on this soil were less than at the other locations, especially in the first few years of the experiment. There were no large differences between sources for the 1929-45 period. The acid-forming sources caused no change in pH on this red clay loam soil, which has an exchange capacity of about 12 m.e. per 100 gm.

During the 1942-45 period, cottonseed meal, sodium nitrate, and calcium cyanamid produced the highest yields. Ammonium sulfate, urea, diammonium phosphate, and calcium nitrate were less productive. Ammonium nitrate plus limestone was intermediate.

TABLE 4. COTTON YIELD INCREASES FROM VARIOUS SOURCES OF NITROGEN ON LIMED[1] PLOTS IN A COTTON-CORN ROTATION, NORFOLK FINE SANDY LOAM, WIREGRASS SUBSTATION, 1930-40

Nitrogen source[2]	Method of application	Seed cotton yield increases from different nitrogen sources by periods[3]							pH in 1946[4]
		1930-33		1934-37	1938-40		1930-40 average		
		Yield increase	Relative increase	Yield increase	Yield increase	Relative increase	Yield increase	Relative increase	
		Lb.	*Pct.*	*Lb.*	*Lb.*	*Pct.*	*Lb.*	*Pct.*	
None		*(992)*	--	*(1,067)*	*(799)*	--	*(967)*	--	5.7
Ammonium nitrate + limestone	Sidedress[5]	332	77	485	760	98	504	82	--
Sodium nitrate	Sidedress[5]	431	100	672	775	100	612	100	--
Sodium nitrate	Under	360	84	651	723	93	565	92	5.8
Ammonium sulfate	Sidedress[5]	442	103	674	863	111	641	105	--
Ammonium sulfate	Under	356	83	608	570	74	506	83	5.7
Urea	Sidedress[5]	409	95	590	727	94	562	92	5.8
Calcium nitrate	Sidedress[5]	434	101	675	742	96	606	99	--
Diammonium phosphate	Under	261	61	564	553	71	451	74	5.7
Cottonseed meal	Under	391	91	652	836	108	607	99	5.7
Calcium cyanamid	Under	374	87	644	727	94	568	93	6.1

[1] All plots limed with 2,250 lb. of calcitic lime in 1930. Sufficient dolomitic limestone mixed with fertilizer each year to neutralize acid-forming sources of nitrogen.

[2] All plots except checks received 36 lb. of N; 48 lb. of P_2O_5 from superphosphate except the diammonium phosphate plots, which received 93 lb. of P_2O_5; and 24 lbs. of K_2O from muriate of potash.

[3] Check yields (in italics) are total yields per acre. All other yields are increases over calculated checks on the basis that soil fertility changes uniformly from one check plot to the next.

[4] The original pH in 1930 was 5.8.

[5] Sidedressed plots received ¼ of N at planting and ¾ as sidedressing.

TABLE 5. COTTON YIELD INCREASES FROM VARIOUS SOURCES OF NITROGEN ON UNLIMED PLOTS IN A COTTON-CORN ROTATION, DECATUR CLAY LOAM, TENNESSEE VALLEY SUBSTATION, 1929-45

Nitrogen source[1]	Method of application	Seed cotton yield increases from different nitrogen sources by periods[2]								pH in 1946[3]
		1929-33		1934-37	1938-41	1942-45		1929-45 average		
		Yield increase	Relative increase	Yield increase	Yield increase	Yield increase	Relative increase	Yield increase	Relative increase	
		Lb.	*Pct.*	*Lb.*	*Lb.*	*Lb.*	*Pct.*	*Lb.*	*Pct.*	
None		*(1,240)*	--	*(1,075)*	*(1,078)*	*(1,088)*	--	*(1,127)*	--	5.6
Ammonium nitrate + limestone	Sidedress[4]	173	64	427	850	399	84	445	97	--
Sodium nitrate	Sidedress[4]	271	100	369	774	475	100	460	100	--
Sodium nitrate	Under	271	100	393	705	347	73	420	91	5.8
Ammonium sulfate	Sidedress[4]	177	65	375	844	304	64	410	89	--
Ammonium sulfate	Under	171	63	298	707	302	64	358	78	5.5
Urea	Sidedress[4]	199	73	388	815	337	71	421	91	5.7
Calcium nitrate	Sidedress[4]	205	76	355	851	354[5]	75	427	93	--
Diammonium phosphate	Under	185	68	351	740	343	72	392	85	5.5
Cottonseed meal	Under	190	70	277	704	496	104	403	88	5.7
Calcium cyanamid	Under	150	55	292	787	437	92	401	87	5.8

[1] All plots except checks received 36 lb. of N; 48 lb. of P_2O_5 from superphosphate except the diammonium phosphate plots, which received 93 lb. of P_2O_5; and 24 lb. of K_2O from muriate of potash.

[2] Check yields (in italics) are total yields per acre. All other yields are increases over calculated checks on the basis that soil fertility changes uniformly from one check plot to the next.

[3] The original pH in 1929 was 5.7.

[4] Sidedressed plots received ¼ of N at planting and ¾ as sidedressing.

[5] Changed to urea in 1942.

TABLE 6. COTTON YIELD INCREASES FROM VARIOUS SOURCES OF NITROGEN ON LIMED[1] PLOTS IN A COTTON-CORN ROTATION, DECATUR CLAY LOAM, TENNESSEE VALLEY SUBSTATION, 1929-45

Nitrogen source[2]	Method of application	Seed cotton yield increases from different nitrogen sources by periods[3]								pH in 1946[4]
		1929-33		1934-37	1938-41	1942-45		1929-45 average		
		Yield increase	Relative increase	Yield increase	Yield increase	Yield increase	Relative increase	Yield increase	Relative increase	
		Lb.	*Pct.*	*Lb.*	*Lb.*	*Lb.*	*Pct.*	*Lb.*	*Pct.*	
None		*(1,287)*	--	*(1,164)*	*(1,165)*	*(1,084)*	--	*(1,182)*	--	6.0
Ammonium nitrate + limestone	Sidedress[5]	190	80	319	780	419	96	413	96	--
Sodium nitrate	Sidedress[5]	237	100	366	732	438	100	431	100	--
Sodium nitrate	Under	231	97	345	641	379	87	389	90	6.1
Ammonium sulfate	Sidedress[5]	196	83	322	725	315	72	378	88	--
Ammonium sulfate	Under	180	76	335	679	437	100	394	91	5.9
Urea	Sidedress[5]	214	90	340	786	308	70	400	93	6.0
Calcium nitrate	Sidedress[5]	261	110	314	716	311[6]	71	392	91	--
Diammonium phosphate	Under	218	92	283	692	340	78	374	87	6.0
Cottonseed meal	Under	197	83	280	584	447	102	366	85	6.1
Calcium cyanamid	Under	217	92	343	654	401	92	393	91	6.3

[1] All plots limed with 2,250 lb. calcitic lime in 1929. Sufficient dolomitic limestone mixed with fertilizer each year to neutralize acid-forming sources of nitrogen.

[2] All plots except checks received 36 lb. of N; 48 lb. of P_2O_5 from superphosphate except the diammonium phosphate plots, which received 93 lb. of P_2O_5; and 24 lb. of K_2O from muriate of potash.

[3] Check yields (in italics) are total yields per acre. All other yields are increases over calculated checks on the basis that soil fertility changes uniformly from one check plot to the next.

[4] The original pH in 1929 was 5.8.

[5] Sidedressed plots received 1/4 of N at planting and 3/4 as sidedressing.

[6] Changed to urea in 1942.

LIMED (TABLE 6). The increases in cotton yields from the nitrogen sources ranged from 366 to 431 pounds of seed cotton. Differences in yields were much less than those obtained at most other locations.

Comparison of yields from the limed and unlimed tiers at this location shows very little difference due to lime. Lime tended to make the acid-forming nitrogen sources compare more favorably with the others than was the case on the unlimed tiers.

RESULTS ON CORN

Sand Mountain Substation, Hartsells Fine Sandy Loam

UNLIMED (TABLE 7). The list of yields obtained in all periods shows ammonium sulfate applied under, diammonium phosphate, cottonseed meal, and calcium cyanamid at the bottom.

The response of corn to 36 pounds of nitrogen was large at this location. The best sources increased the yield as much as 29 bushels per acre (17-year average). This yield increase is more than three-fourths of a bushel of corn per pound of nitrogen applied.

Wiregrass Substation, Norfolk Fine Sandy Loam

UNLIMED (TABLE 8). Yield differences in this experiment were not as large as those at the Sand Mountain Substation. In general, differences between sources were small. Cottonseed meal and cyanamid produced the lowest yields, as was found at Sand Mountain. These two sources were not nearly as effective on corn as they were on cotton.

LIMED (TABLE 9). Differences between sources at this location were small, but yield levels were so low that large differences could not be expected.

Tennessee Valley Substation, Decatur Clay Loam

UNLIMED (TABLE 10). Yields from all sources at this location were about equal.

LIMED (TABLE 11). Differences in corn yield between sources of nitrogen were small. Lowest yields were produced by diammonium phosphate, cottonseed meal, and cyanamid.

TABLE 7. CORN YIELD INCREASES FROM VARIOUS SOURCES OF NITROGEN ON UNLIMED PLOTS IN A COTTON-CORN ROTATION, HARTSELLS FINE SANDY LOAM, SAND MOUNTAIN SUBSTATION, 1929-45

Nitrogen source[1]	Method of application	Corn yield increases from different nitrogen sources by periods[2]							
		1929-33		1934-37	1938-41	1942-45		1929-45 average	
		Yield increase	Relative increase	Yield increase	Yield increase	Yield increase	Relative increase	Yield increase	Relative increase
		Bu.	*Pct.*	*Bu.*	*Bu.*	*Bu.*	*Pct.*	*Bu.*	*Pct.*
None		*(9.6)*	--	*(5.5)*	*(3.9)*	*(5.7)*	--	*(6.4)*	--
Ammonium nitrate + limestone	Sidedress[3]	19.9	75	29.3	31.7	26.8	90	26.5	89
Sodium nitrate	Sidedress[3]	26.5	100	31.3	32.6	29.8	100	29.8	100
Sodium nitrate	Under	22.9	86	28.4	28.5	29.8	100	27.1	91
Ammonium sulfate	Sidedress[3]	22.9	86	24.8	28.4	24.0	81	24.9	84
Ammonium sulfate	Under	19.8	75	22.9	25.4	22.7	76	22.5	76
Calcium nitrate	Sidedress[3]	25.2	95	30.7	32.2	27.0[4]	91	28.6	96
Urea	Sidedress[3]	22.3	84	24.9	27.3	26.2	88	25.0	84
Diammonium phosphate	Under	18.6	70	20.8	24.6	23.9	80	21.8	73
Cottonseed meal	Under	12.9	49	16.8	19.7	19.6	66	17.0	57
Calcium cyanamid	Under	16.2	61	23.8	22.3	18.7	63	20.0	67

[1] All plots except checks received 36 lb. of N; 24 lb. of P_2O_5 except the diammonium phosphate plots, which received 121 lb. of P_2O_5; and 12 lb of K_2O from muriate of potash.

[2] Check yields (in italics) are total yields per acre. All other yields are increases over calculated checks on the basis that soil fertility changes uniformly from one check plot to the next.

[3] Sidedressed plots received ¼ of N at planting and ¾ as sidedressing.

[4] Changed to urea in 1942.

TABLE 8. CORN YIELD INCREASES FROM VARIOUS SOURCES OF NITROGEN ON UNLIMED PLOTS IN A COTTON-CORN ROTATION, NORFOLK FINE SANDY LOAM, WIREGRASS SUBSTATION, 1930-40

Nitrogen source[1]	Method of application	Corn yield increases from different nitrogen sources by periods[2] 1930-33		1934-37	1938-40		1930-40 average	
		Yield increase	Relative increase	Yield increase	Yield increase	Relative increase	Yield increase	Relative increase
		Bu.	*Pct.*	*Bu.*	*Bu.*	*Pct.*	*Bu.*	*Pct.*
None		*(15.2)*	--	*(9.5)*	*(7.8)*	--	*(11.1)*	--
Ammonium nitrate + limestone	Sidedress[3]	10.3	77	13.6	20.4	101	14.3	84
Sodium nitrate	Sidedress[3]	13.3	100	18.7	20.2	100	17.1	100
Sodium nitrate	Under	10.2	77	18.7	18.2	90	15.5	91
Ammonium sulfate	Sidedress[3]	9.5	71	15.7	17.2	85	13.9	81
Ammonium sulfate	Under	8.0	60	18.6	17.7	88	14.5	85
Urea	Sidedress[3]	10.9	82	16.9	19.1	95	15.3	89
Calcium nitrate	Sidedress[3]	11.5	86	18.6	20.9	103	16.6	97
Diammonium phosphate	Under	11.3	85	14.6	18.6	92	14.5	85
Cottonseed meal	Under	7.6	57	15.1	16.7	83	12.8	75
Calcium cyanamid	Under	4.4	33	14.7	16.6	82	11.5	67

[1] All plots except checks received 36 lb. of N; 24 lb. of P_2O_5 except the diammonium phosphate plots, which received 93 lb. of P_2O_5; and 12 lb. of K_2O from muriate of potash.

[2] Check yields (in italics) are total yields per acre. All other yields are increases over calculated checks on the basis that soil fertility changes uniformly from one check plot to the next.

[3] Sidedressed plots received ¼ of N at planting and ¾ as sidedressing.

TABLE 9. CORN YIELD INCREASES FROM VARIOUS SOURCES OF NITROGEN ON LIMED[1] PLOTS IN A COTTON-CORN ROTATION, NORFOLK FINE SANDY LOAM, WIREGRASS SUBSTATION, 1930-40

Nitrogen source[2]	Method of application	Corn yield increases from different nitrogen sources by periods[3]						
		1930-33		1934-37	1938-40		1930-40 average	
		Yield increase	Relative increase	Yield increase	Yield increase	Relative increase	Yield increase	Relative increase
		Bu.	*Pct.*	*Bu.*	*Bu.*	*Pct.*	*Bu.*	*Pct.*
None		*(21.8)*	--	*(16.0)*	*(11.4)*	--	*(16.9)*	--
Ammonium nitrate + limestone	Sidedress[4]	7.5	93	12.0	19.7	108	12.5	103
Sodium nitrate	Sidedress[4]	8.1	100	11.6	18.2	100	12.1	100
Sodium nitrate	Under	5.8	72	13.2	16.6	91	11.4	94
Ammonium sulfate	Sidedress[4]	8.8	109	17.2	22.0	121	15.5	128
Ammonium sulfate	Under	5.9	73	16.4	18.8	103	13.2	109
Urea	Sidedress[4]	8.5	105	14.6	20.1	110	13.9	115
Calcium nitrate	Sidedress[4]	9.0	111	13.4	18.9	104	13.3	110
Diammonium phosphate	Under	6.5	80	15.4	19.8	109	13.4	111
Cottonseed meal	Under	5.3	65	12.7	16.1	88	10.9	90
Calcium cyanamid	Under	5.4	67	13.7	13.5	74	10.6	88

[1] All plots limed with 2,250 lb. calcitic lime in 1930. Sufficient dolomitic limestone mixed with fertilizer each year to neutralize acid-forming sources of nitrogen.

[2] All plots except checks received 36 lb. of N; 24 lb. of P_2O_5 from superphosphate except the diammonium phosphate plots, which received 93 lb. of P_2O_5; and 12 lb. of K_2O from muriate of potash.

[3] Check yields (in italics) are total yields per acre. All other yields are increases over calculated checks on the basis that soil fertility changes uniformly from one check plot to the next.

[4] Sidedressed plots received ¼ of N at planting and ¾ as sidedressing.

TABLE 10. CORN YIELD INCREASES FROM VARIOUS SOURCES OF NITROGEN ON UNLIMED PLOTS IN A COTTON-CORN ROTATION, DECATUR CLAY LOAM, TENNESSEE VALLEY SUBSTATION, 1929-45

Nitrogen source[1]	Method of application	Corn yield increases from different nitrogen sources by periods[2]							
		1929-33		1934-37	1938-41	1942-45		1929-45 average	
		Yield increase	Relative increase	Yield increase	Yield increase	Yield increase	Relative increase	Yield increase	Relative increase
		Bu.	*Pct.*	*Bu.*	*Bu.*	*Bu.*	*Pct.*	*Bu.*	*Pct.*
None		*(27.4)*	--	*(22.2)*	*(17.4)*	*(13.2)*	--	*(20.5)*	--
Ammonium nitrate + limestone	Sidedress[3]	5.2	75	17.3	27.7	16.4	89	16.0	91
Sodium nitrate	Sidedress[3]	6.9	100	18.8	28.7	18.4	100	17.5	100
Sodium nitrate	Under	7.5	109	18.1	28.1	17.2	93	17.1	98
Ammonium sulfate	Sidedress[3]	6.0	87	17.2	25.4	17.0	92	15.8	90
Ammonium sulfate	Under	7.7	112	19.6	29.0	17.8	97	17.9	102
Urea	Sidedress[3]	6.1	88	17.6	26.7	17.1	93	16.2	93
Calcium nitrate	Sidedress[3]	6.3	91	20.6	31.4	17.3[4]	94	18.2	104
Diammonium phosphate	Under	5.3	77	15.7	27.7	15.8	86	15.5	89
Cottonseed meal	Under	6.5	94	14.4	22.4	16.3	89	14.4	82
Calcium cyanamid	Under	5.1	74	16.1	24.4	15.1	82	14.6	83

[1] All plots except checks received 36 lb. of N; 24 lb. of P_2O_5 except the diammonium phosphate plots, which received 93 lb. of P_2O_5; and 12 lb. of K_2O from muriate of potash.

[2] Check yields (in italics) are total yields per acre. All other yields are increases over calculated checks on the basis that soil fertility changes uniformly from one check plot to the next.

[3] Sidedressed plots received ¼ of N at planting and ¾ as sidedressing.

[4] Changed to urea in 1942.

TABLE 11. CORN YIELD INCREASES FROM VARIOUS SOURCES OF NITROGEN ON LIMED[1] PLOTS IN A COTTON-CORN ROTATION, DECATUR CLAY LOAM, TENNESSEE VALLEY SUBSTATION, 1929-45

Nitrogen source[2]	Method of application	Corn yield increases from different nitrogen sources by periods[3]							
		1929-33		1934-37	1938-41	1942-45		1929-45 average	
		Yield increase	Relative increase	Yield increase	Yield increase	Yield increase	Relative increase	Yield increase	Relative increase
		Bu.	*Pct.*	*Bu.*	*Bu.*	*Bu.*	*Pct.*	*Bu.*	*Pct.*
None		*(32.2)*	--	*(26.4)*	*(20.3)*	*(16.0)*	--	*(24.2)*	--
Ammonium nitrate + limestone	Sidedress[4]	3.9	111	14.0	26.6	19.9	104	15.4	99
Sodium nitrate	Sidedress[4]	3.5	100	14.6	27.7	19.2	100	15.5	100
Sodium nitrate	Under	5.6	160	13.6	26.1	17.1	89	15.0	97
Ammonium sulfate	Sidedress[4]	5.1	146	15.0	24.6	16.3	85	14.7	95
Ammonium sulfate	Under	5.8	166	15.6	27.1	16.4	85	15.6	101
Urea	Sidedress[4]	4.0	114	18.3	26.6	16.8	87	15.7	101
Calcium nitrate	Sidedress[4]	4.7	134	17.7	28.4	16.5[5]	86	16.1	104
Diammonium phosphate	Under	5.1	146	13.4	22.6	12.5	65	12.9	83
Cottonseed meal	Under	4.4	126	13.7	21.5	15.8	82	13.3	86
Calcium cyanamid	Under	5.2	149	13.9	24.5	14.5	75	14.0	90

[1] All plots limed with 2,250 lb. calcitic lime in 1929. Sufficient dolomitic limestone mixed with fertilizer each year to neutralize acid-forming sources of nitrogen.

[2] All plots except checks received 36 lb. of N; 24 lb. of P_2O_5 from superphosphate except the diammonium phosphate plots, which received 93 lb. of P_2O_5; and 12 lb. of K_2O from muriate of potash.

[3] Check yields (in italics) are total yields per acre. All other yields are increases over calculated checks on the basis that soil fertility changes uniformly from one check plot to the next.

[4] Sidedressed plots received ¼ of N at planting and ¾ as sidedressing.

[5] Changed to urea in 1942.

EXPERIMENTS WITH AMMONIUM SULFATE AND SODIUM NITRATE, 1929-45

Experiments with ammonium sulfate and sodium nitrate were begun in 1929 at the Sand Mountain and Tennessee Valley substations, and in 1930 at the Wiregrass Substation and the Monroeville Experiment Field. They were conducted on cotton and corn in a 2-year rotation. Both crops were grown each year on alternate tiers. Treated plots received 36 pounds of nitrogen per acre for each crop. All plots received 48 pounds of P_2O_5 and 24 pounds of K_2O per acre for cotton and one-half these amounts for corn.

RESULTS ON COTTON

Wiregrass Substation, Norfolk Fine Sandy Loam

Treatment differences, as shown in Table 12, were small except for the unneutralized ammonium sulfate, which produced a relative yield increase of only 58 per cent in the last period. After 10 years of application, unneutralized ammonium sulfate was producing only 64 per cent as much cotton as sodium nitrate.

Basic slag with sodium nitrate increased the pH to 6.6 and slightly decreased the effectiveness of the sodium nitrate. Unneutralized ammonium sulfate decreased the pH from 6.0 to 5.2 in 16 years.

Monroeville Experiment Field, Magnolia Fine Sandy Loam

Results from all treatments on this soil were similar to those on the Norfolk fine sandy loam, Table 12. The effectiveness of unneutralized ammonium sulfate decreased with time. While the relative yield increase produced by ammonium sulfate in the first period, 1930-33, was 89 per cent of that of sodium nitrate, it decreased to 80 per cent in 1934-37 and to 55 per cent in 1942-45.

Sand Mountain Substation, Hartsells Fine Sandy Loam

The highest yields at this location were produced by sodium nitrate and by the combination of ¼ ammonium sulfate and ¾ sodium nitrate, Table 13. Sodium nitrate maintained soil pH about constant over the 16-year period. Basic slag, when used

TABLE 12. COTTON YIELD INCREASES FROM AMMONIUM SULFATE AND SODIUM NITRATE WITH LIMESTONE AND BASIC SLAG IN A COTTON-CORN ROTATION, WIREGRASS SUBSTATION AND MONROEVILLE EXPERIMENT FIELD, 1930-45

Nitrogen source and amendment[1]	Seed cotton yield[2] increases from nitrogen sources and amendments by periods								pH in Jan. 1946[3]
	1930-33		1934-37	1938-41	1942-45		1930-45 average		
	Yield increase	Relative increase	Yield increase	Yield increase	Yield increase	Relative increase	Yield increase	Relative increase	
	Lb.	*Pct.*	*Lb.*	*Lb.*	*Lb.*	*Pct.*	*Lb.*	*Pct.*	
Wiregrass Substation									
None	*(637)*	-	*(623)*	*(461)*	*(391)*	--	*(528)*	--	5.6
Sodium nitrate + basic slag	375	74	686	811	826	95	675	90	6.6
Ammonium sulfate + basic slag	464	92	800	840	900	104	751	100	5.9
Ammonium sulfate	463	92	702	544	502	58	553	74	5.2
Ammonium sulfate + limestone[4]	454	90	799	834	988	113	769	102	6.0
Sodium nitrate	504	100	795	844	871	100	754	100	5.9
Ammonium sulfate ¼ + sodium nitrate ¾[5]	515	102	807	852	935	107	777	103	5.7
Monroeville Experiment Field									
None	*(590)*	--	*(621)*	*(369)*	*(537)*	--	*(529)*	--	5.4
Sodium nitrate + basic slag	499	92	618	482	740	85	585	84	6.2
Ammonium sulfate + basic slag	532	98	603	637	866	100	659	94	5.8
Ammonium sulfate	484	89	574	492	474	55	506	72	5.1
Ammonium sulfate + limestone[4]	532	93	652	712	835	96	683	98	5.6
Sodium nitrate	545	100	725	654	871	100	699	100	5.7
Ammonium sulfate ¼ + sodium nitrate ¾[5]	610	112	775	684	849	97	730	104	5.4

[1] All plots except checks received fertilizer at rate of 600 lb. 6-8-4 per acre. Check plots received 600 lb. per acre of 0-8-4. Nitrogen applied in split application with ¼ under and ¾ as a sidedressing.

[2] Check yields (in italics) are total yields per acre. All other yields are increases over calculated checks on the basis that soil fertility changes uniformly from one check plot to the next.

[3] The original pH in 1930 was 6.0 at both locations.

[4] Limestone sufficient to neutralize acidity of nitrogen material.

[5] Ammonium sulfate applied under and sodium nitrate as a sidedressing.

TABLE 13. COTTON YIELD INCREASES FROM AMMONIUM SULFATE AND SODIUM NITRATE WITH LIMESTONE AND BASIC SLAG IN A COTTON-CORN ROTATION, SAND MOUNTAIN AND TENNESSEE VALLEY SUBSTATIONS, 1929-45

Nitrogen source and amendment[1]	Seed cotton yield[2] increases from nitrogen sources and amendments by periods								pH in Jan. 1946[3]
	1929-33		1934-37	1938-41	1942-45		1929-45 average		
	Yield increase	Relative increase	Yield increase	Yield increase	Yield increase	Relative increase	Yield increase	Relative increase	
	Lb.	*Pct.*	*Lb.*	*Lb.*	*Lb.*	*Pct.*	*Lb.*	*Pct.*	
Sand Mountain Substation									
None	*(585)*	--	*(500)*	*(552)*	*(584)*	--	*(557)*	--	5.3
Ammonium sulfate + basic slag	588	84	697	911	713	75	719	80	5.8
Sodium nitrate + basic slag	672	96	724	1,039	847	89	812	91	6.6
Ammonium sulfate	580	83	531	706	264	28	524	59	4.8
Ammonium sulfate + limestone[4]	681	97	791	984	807	85	808	90	5.6
Sodium nitrate	702	100	867	1,105	951	100	894	100	5.9
Ammonium sulfate ¼ + sodium nitrate ¾[5]	714	102	851	1,085	944	99	888	99	5.6
Tennessee Valley Substation									
None	*(1,267)*	--	*(1,146)*	*(1,130)*	*(1,112)*	--	*(1,170)*	--	5.6
Sodium nitrate + basic slag	183	86	271	633	408	130	363	93	6.3
Ammonium sulfate + basic slag	95	45	272	713	378	120	349	89	5.8
Ammonium sulfate	189	89	377	753	267	85	384	99	5.6
Ammonium sulfate + limestone[4]	260	123	445	853	379	121	471	121	5.7
Sodium nitrate	212	100	317	759	314	100	389	100	5.9
Ammonium sulfate ¼ + sodium nitrate ¾[5]	252	119	359	829	342	109	434	112	5.7

[1] All plots except checks received fertilizer at rate of 600 lb. 6-8-4 per acre. Check plots received 600 lb. per acre of 0-8-4. Nitrogen applied in split application with ¼ under and ¾ as a sidedressing.

[2] Check yields (in italics) are total yields per acre. All other yields are increases over calculated checks on the basis that soil fertility changes uniformly from one check plot to the next.

[3] Original pH values of these areas in 1929 were 6.0 at the Sand Mountain Substation and 5.9 at the Tennessee Valley Substation.

[4] Limestone sufficient to neutralize acidity of nitrogen material.

[5] Ammonium sulfate applied under and sodium nitrate as a sidedressing.

with sodium nitrate, increased soil pH to 6.6 and depressed the yield of cotton.

Ammonium sulfate without lime was 83 per cent as effective as sodium nitrate in the first period, 1929-33, but only 61 per cent as effective in the second period, 1934-37. In the last period the relative yield increase was only 28 per cent. The soil pH decreased from 6.0 to 4.8 in 16 years where ammonium sulfate was added without lime. Where limestone was added with ammonium sulfate, yields were similar to those obtained with sodium nitrate. Since some of the calcium requirements of the cotton could be obtained from superphosphate, the low yields with unneutralized ammonium sulfate are probably largely a result of the soil acidity produced.

Tennessee Valley Substation, Decatur Clay Loam

Yield increases from nitrogen at this location were low for the first few years of the experiment because of the high initial state of fertility of the soil. Differences between sources were not great under these conditions. The 17-year averages in Table 13 show that ammonium sulfate neutralized with limestone was the most productive treatment. Ammonium sulfate when not neutralized decreased soil pH from 5.9 to 5.6. This did not drastically reduce the yield on this heavy soil, even in the 1942-45 period. Basic slag when used with sodium nitrate increased pH to 6.3, but it had little effect on yields as compared to sodium nitrate alone.

Results on Corn

Wiregrass Substation, Norfolk Fine Sandy Loam

Yield differences between treatments were small. Unneutralized ammonium sulfate produced slightly less than the other sources in the last years of the experiment, Table 14.

Monroeville Experiment Field, Magnolia Fine Sandy Loam

Data in Table 14 show that all treatments were equally satisfactory on corn except that yields from sodium nitrate plus basic slag plots were lower than the others in the last few years of this experiment. Evidence obtained in later years indicated that this was caused by zinc deficiency resulting from increased pH on these plots.

TABLE 14. CORN YIELD INCREASES FROM AMMONIUM SULFATE AND SODIUM NITRATE WITH LIMESTONE AND BASIC SLAG IN A COTTON-CORN ROTATION, WIREGRASS SUBSTATION AND MONROEVILLE EXPERIMENT FIELD, 1930-45

Nitrogen source and amendment[1]	Corn yield[2] increases from nitrogen sources and amendments by periods							
	1930-33		1934-37	1938-41	1942-45		1930-45 average	
	Yield increase	Relative increase	Yield increase	Yield increase	Yield increase	Relative increase	Yield increase	Relative increase
	Bu.	*Pct.*	*Bu.*	*Bu.*	*Bu.*	*Pct.*	*Bu.*	*Pct.*
Wiregrass Substation								
None	*(14.1)*	--	*(8.1)*	*(6.6)*	*(6.0)*	--	*(8.7)*	--
Sodium nitrate + basic slag	12.1	97	15.9	15.3	23.4	92	16.7	91
Ammonium sulfate + basic slag	11.2	90	16.8	19.9	23.9	94	17.9	98
Ammonium sulfate	9.8	78	15.4	17.0	19.6	77	15.5	85
Ammonium sulfate + limestone[3]	11.7	94	17.5	20.1	23.5	93	18.2	99
Sodium nitrate	12.5	100	16.1	19.3	25.4	100	18.3	100
Ammonium sulfate ¼ + sodium nitrate ¾	11.4	91	16.6	19.9	25.3	100	18.3	100
Monroeville Experiment Field								
None	*(14.9)*	--	*(12.9)*	*(8.7)*	*(10.7)*	--	*(11.8)*	--
Sodium nitrate + basic slag	19.3	106	22.3	20.6	19.3	82	20.4	95
Ammonium sulfate + basic slag	18.2	100	22.3	22.9	24.8	105	22.0	103
Ammonium sulfate	17.7	97	20.0	23.4	25.4	108	21.6	101
Ammonium sulfate + limestone[3]	17.3	95	21.9	23.1	25.3	107	21.9	102
Sodium nitrate	18.2	100	23.4	20.5	23.6	100	21.4	100
Ammonium sulfate ¼ + sodium nitrate ¾	17.1	94	24.3	22.4	23.2	98	21.7	101

[1] All plots exept checks received fertilizer at rate of 600 lb. 6-4-2 per acre. Check plots received 600 lb. per acre of 0-4-2.
[2] Check yields (in italics) are total yields per acre. All other yields are increases over calculated checks on the basis that soil fertility changes uniformly from one check plot to the next.
[3] Limestone sufficient to neutralize acidity of nitrogen material.

TABLE 15. CORN YIELD INCREASES FROM AMMONIUM SULFATE AND SODIUM NITRATE WITH LIMESTONE AND BASIC SLAG IN A COTTON-CORN ROTATION, SAND MOUNTAIN AND TENNESSEE VALLEY SUBSTATIONS, 1929-45

Nitrogen source and amendment[1]	Corn yield[2] increases from nitrogen sources and amendments by periods							
	1929-33		1934-37	1938-41	1942-45		1929-45 average	
	Yield increase	Relative increase	Yield increase	Yield increase	Yield increase	Relative increase	Yield increase	Relative increase
	Bu.	*Pct.*	*Bu.*	*Bu.*	*Bu.*	*Pct.*	*Bu.*	*Pct.*
Sand Mountain Substation								
None	*(9.5)*	--	*(5.4)*	*(3.6)*	*(5.6)*	--	*(6.2)*	--
Sodium nitrate + basic slag	26.8	102	33.5	35.0	29.3	99	30.9	105
Ammonium sulfate + basic slag	22.8	87	29.2	32.7	28.8	97	28.0	95
Ammonium sulfate	21.0	80	22.9	28.5	22.9	77	23.7	80
Ammonium sulfate + limestone[3]	23.2	89	27.5	30.6	28.1	95	27.2	92
Sodium nitrate	26.2	100	30.2	32.6	29.7	100	29.5	100
Ammonium sulfate ¼ + sodium nitrate ¾	25.4	97	28.5	30.9	28.6	96	28.2	96
Tennessee Valley Substation								
None	*(28.5)*	--	*(24.3)*	*(19.6)*	*(15.0)*	--	*(22.2)*	--
Sodium nitrate + basic slag	5.6	86	18.3	31.6	20.1	106	18.1	102
Ammonium sulfate + basic slag	4.9	75	16.9	24.0	18.6	98	15.4	87
Ammonium sulfate	5.7	88	15.4	25.2	17.6	93	15.4	87
Ammonium sulfate + limestone[3]	6.2	95	18.7	25.2	19.4	102	16.7	94
Sodium nitrate	6.5	100	19.4	28.7	19.0	100	17.7	100
Ammonium sulfate ¼ + sodium nitrate ¾	6.3	97	19.2	26.7	17.0	89	16.7	94

[1] All plots except checks received fertilizer at rate of 600 lb. 6-4-2 per acre. Check plots received 600 lb. per acre of 0-4-2.
[2] Check yields (in italics) are total yields per acre. All other yields are increases over calculated checks on the basis that soil fertility changes uniformly from one check plot to the next.
[3] Limestone sufficient to neutralize acidity of nitrogen material.

Sand Mountain Substation, Hartsells Fine Sandy Loam

Unusually large responses to 36 pounds of nitrogen from all sources were produced at this location, Table 15. Yield increases of as much as 30.9 bushels per acre were obtained from 36 pounds of nitrogen for the entire 17 years of the experiment. Unneutralized ammonium sulfate produced less corn than the other sources.

Some soils are so deficient in nitrogen that no yield is produced without the addition of nitrogen, as shown in the plot on the right.

Tennessee Valley Substation, Decatur Clay Loam

As was the case with cotton, corn responded only slightly to nitrogen during the first few years of this experiment, Table 15. Satisfactory response was obtained after the first 5 years, but differences between sources were small.

EXPERIMENTS WITH AMMONIUM SULFATE, SODIUM NITRATE, AND AMMONIUM NITRATE, 1946-1955

The experiments with ammonium sulfate and sodium nitrate previously discussed were revised in 1946 and ammonium nitrate treatments were added. These revised experiments were conducted on the same plots as prior to 1946, therefore the previous treatments and their residual effect must be taken into consideration when comparing sources. The previous treatments are given in all tables discussed in this section.

In the revised experiment, rates of P_2O_5 and K_2O were increased to 60 pounds each for both cotton and corn. Rates of nitrogen were increased to 48 pounds per acre on all plots where sources were compared and former check plots received 36 pounds per acre from neutralized ammonium nitrate. Since the experiments contained no plots that received less than 36 pounds of nitrogen, it is impossible to calculate the total yield increase from nitrogen in the 1946-55 period. The relative yield percentages presented in Tables 16 through 19, therefore, are based on total yield rather than on yield increase from nitrogen as was the case in the previous tables.

Results on Cotton

Wiregrass Substation, Norfolk Fine Sandy Loam

Unneutralized ammonium sulfate was inferior to all other treatments, Table 16. When used with basic slag or limestone it produced satisfactorily. Ammonium nitrate produced as much as sodium nitrate during 1946-50, but during 1951-55 when unneutralized only 80 per cent as much as sodium nitrate. When used on land that was properly limed, ammonium nitrate produced satisfactorily.

Soil pH values in 1955 ranged from 5.1 on the ammonium sulfate plots to 6.5 on the sodium nitrate plus basic slag plots.

Monroeville Experiment Field, Magnolia Fine Sandy Loam

As shown in Table 16, there were no important differences in yields from the nitrogen sources when ammonium sulfate and ammonium nitrate were neutralized in 1946-55 period. Ammonium sulfate without limestone or basic slag produced only 55 per cent as much as sodium nitrate. Unneutralized ammonium nitrate resulted in a relative yield of 92 per cent.

Sand Mountain Substation, Hartsells Fine Sandy Loam

Unneutralized ammonium sulfate was much inferior to all other treatments. The 10-year average was only 196 pounds of seed cotton, Table 17. The pH on these plots had decreased to 4.4 by 1955. This was a cumulative effect of ammonium sulfate additions since 1929. A stand of cotton was difficult to maintain on these plots, and when cotton survived it was unthrifty. Crabgrass was always difficult to control on these plots, but it is not

TABLE 16. COTTON YIELDS FROM AMMONIUM NITRATE, AMMONIUM SULFATE, AND SODIUM NITRATE WITH LIMESTONE OR BASIC SLAG IN A 2-YEAR ROTATION OF COTTON AND CORN, WIREGRASS SUBSTATION AND MONROEVILLE EXPERIMENT FIELD, 1946-55

Nitrogen and amendment treatment[1]	Previous nitrogen and amendment sources[2] 1930-45	Seed cotton yields and soil pH, by location and period									
		Wiregrass Substation					Monroeville Experiment Field				
		1946-50 yield	1951-55 yield	1946-55 Yield	1946-55 Relative yield	pH in 1955	1946-50 yield	1951-55 yield	1946-55 Yield	1946-55 Relative yield	pH in 1955
		Lb.	*Lb.*	*Lb.*	*Pct.*		*Lb.*	*Lb.*	*Lb.*	*Pct.*	
Ammonium nitrate + 3,000 lb. limestone in 1946	Sodium nitrate + monoammonium phosphate for P_2O_5	828	1,286	1,057	98	5.5	1,429	1,713	1,571	104	6.2
Sodium nitrate + basic slag for P_2O_5	Same as 1946-55	901	1,385	1,143	106	6.5	1,367	1,647	1,507	100	6.9
Ammonium sulfate + basic slag for P_2O_5	Same as 1946-55	983	1,369	1,176	109	6.3	1,438	1,670	1,554	103	6.0
Ammonium sulfate	Same as 1946-55	504	716	610	57	5.1	656	1,002	829	55	5.0
Ammonium sulfate + limestone[3]	Same as 1946-55	886	1,184	1,035	96	5.9	1,342	1,662	1,502	99	5.4
Sodium nitrate	Same as 1946-55	818	1,334	1,076	100	5.6	1,367	1,659	1,513	100	5.8
Ammonium sulfate ¼ + sodium nitrate ¾	Same as 1946-55	888	1,420	1,154	107	5.8	1,545	1,739	1,642	109	5.8
Ammonium nitrate	Ammonium sulfate + limestone every four years	808	1,068	938	87	6.0	1,227	1,553	1,390	92	5.5

[1] All plots received 48 lb. of nitrogen, 60 lb. P_2O_5 from superphosphate or basic slag as noted, and 60 lb. K_2O from muriate of potash.
[2] Plots received fertilizer at rate of 600 lb. 6-4-2 to corn and 600 lb. 6-8-4 to cotton in 1930-45 period.
[3] Limestone sufficient to neutralize acidity of the nitrogen material.

TABLE 17. COTTON YIELDS FROM AMMONIUM NITRATE, AMMONIUM SULFATE, AND SODIUM NITRATE WITH LIMESTONE OR BASIC SLAG IN A 2-YEAR ROTATION OF COTTON AND CORN, SAND MOUNTAIN AND TENNESSEE VALLEY SUBSTATIONS, 1946-55

Nitrogen and amendment treatment[1]	Previous nitrogen and amendment source[2] 1929-45	Seed cotton yields and soil pH, by location and period									
		Sand Mountain Substation					Tennessee Valley Substation				
		1946-50 yield	1951-55 yield	1946-55 Yield	1946-55 Relative yield	pH in 1955	1946-50 yield	1951-55 yield	1946-55 Yield	1946-55 Relative yield	pH in 1955
		Lb.	*Lb.*	*Lb.*	*Pct.*		*Lb.*	*Lb.*	*Lb.*	*Pct.*	
Ammonium nitrate + 3,000 lb. limestone in 1946	Sodium nitrate + monoammonium phosphate	1,593	1,447	1,520	98	5.4	1,828	1,362	1,595	107	6.0
Sodium nitrate + basic slag	Same as 1946-55	1,539	1,449	1,494	97	6.6	1,739	1,323	1,531	102	6.7
Ammonium sulfate + basic slag	Same as 1946-55	1,465	1,531	1,498	97	5.7	1,727	1,397	1,562	104	5.8
Ammonium sulfate	Same as 1946-55	136	256	196	13	4.4	1,586	1,184	1,385	93	5.0
Ammonium sulfate + limestone[3]	Same as 1946-55	1,586	1,596	1,591	103	5.5	1,816	1,344	1,580	106	5.5
Sodium nitrate	Same as 1946-55	1,555	1,535	1,545	100	5.8	1,772	1,220	1,496	100	5.7
Ammonium sulfate ¼ + sodium nitrate ¾	Same as 1946-55	1,498	1,440	1,469	95	5.4	1,801	1,267	1,534	103	5.6
Ammonium nitrate	Ammonium sulfate + limestone every 4 years	1,464	1,482	1,473	95	5.1	1,729	1,339	1,534	103	5.3

[1] All plots received 48 lb. of nitrogen, 60 lb. P_2O_5 from superphosphate or basic slag as noted, and 60 lb. K_2O from muriate of potash.
[2] Plots received fertilizer at rate of 600 lb. 6-4-2 to corn and 600 lb. 6-8-4 to cotton in 1929-45 period.
[3] Limestone sufficient to neutralize acidity of the ammonium sulfate.

known whether this was caused by lack of competition from cotton plants or by an affinity of crabgrass to low pH. Yields of cotton from these plots represent the most severe loss due to acidity that has ever been obtained by the Agricultural Experiment Station.

Figure 1-A shows the relative yield increase from ammonium sulfate with and without neutralization with lime and from sodium nitrate from the beginning of the experiment in 1929 to 1955. In the 1951-55 period unneutralized ammonium sulfate produced only 17 per cent as much as did sodium nitrate. With the addition of enough lime for neutralization, however, the ammonium sulfate gave a relative yield of 103 per cent.

All other treatments produced about 1,500 pounds of seed cotton per acre. Sodium nitrate and ammonium nitrate were satisfactory sources both with and without lime; however, the plots fertilized with ammonium nitrate had received a neutral fertilizer prior to 1946. When the acidity of ammonium sulfate was neutralized with limestone, the yield was 1,591 pounds, an increase of 1,395 pounds over the unneutralized ammonium sulfate plots.

The pH values of the plots in 1955 ranged from 4.4 to 6.6. Continued use of ammonium sulfate after 1946 further decreased the pH from 4.8 to 4.4, while ammonium nitrate decreased the pH from 5.8 to 5.1 in the same period when no lime or basic slag was applied. Although ammonium nitrate without lime had not yet greatly affected the yield, it is expected that yields from this treatment would soon decline because of the low pH produced.

Tennessee Valley Substation, Decatur Clay Loam

Differences in yield between sources were relatively small, as shown in Table 17. Average yields ranged from 1,385 pounds of seed cotton from unneutralized ammonium sulfate to 1,595 pounds from ammonium nitrate plus lime. Soil pH values in 1955 ranged from 5.0 for unneutralized ammonium sulfate to 6.7 from sodium nitrate plus basic slag.

Figure 1-B shows that on this fine textured soil yields from unneutralized ammonium sulfate were as satisfactory as nonacid-forming sources, even after 27 years of application. A comparison of 1-A and 1-B clearly illustrates that acid-forming fertilizers may quickly lower yields on coarse textured soils, whereas yields may be satisfactory for much longer periods on fine textured soils.

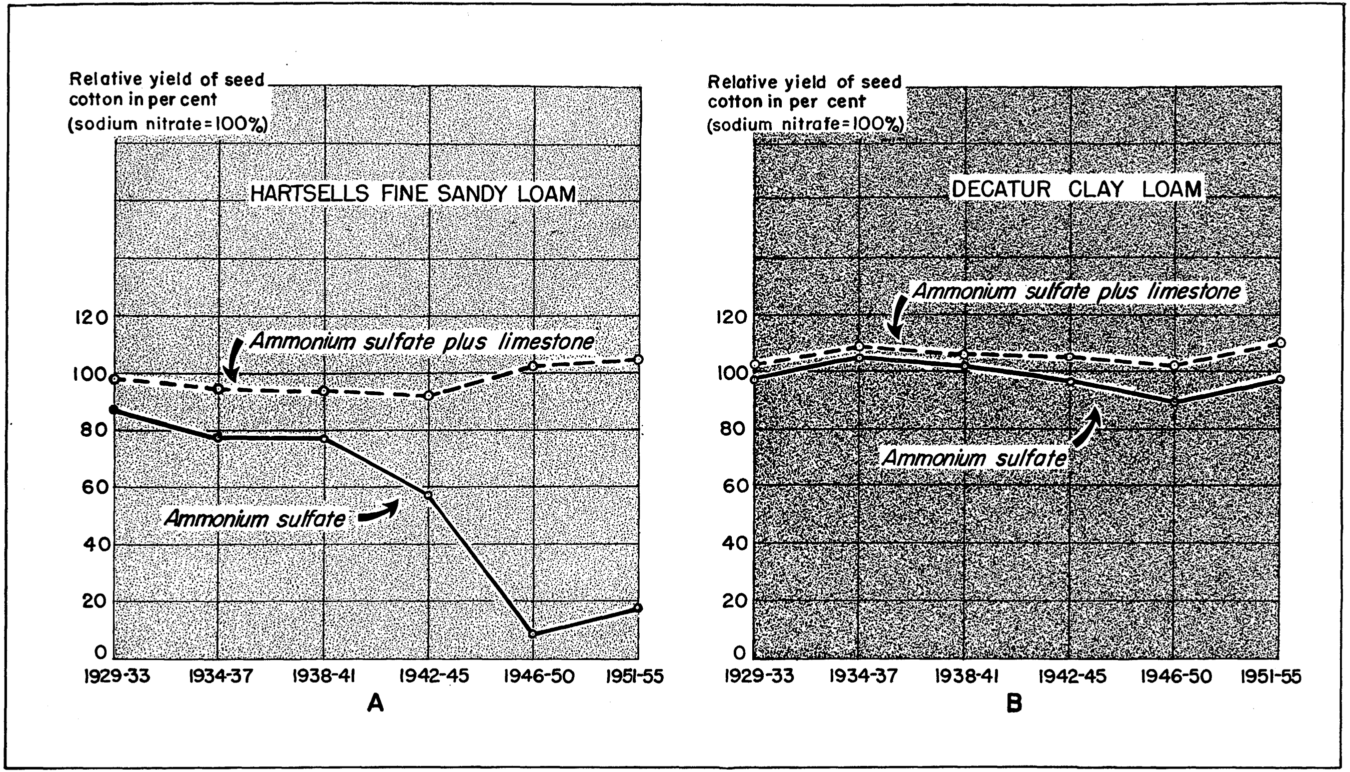

Figure 1. Acid-forming fertilizers may lower yields much faster on coarse textured than on fine textured soils, as illustrated in the above comparison.

Results on Corn

Wiregrass Substation, Norfolk Fine Sandy Loam

Average yields of corn at this location were low because of several drouthy years, Table 18. Yield differences between treatments were small and not considered to represent important differences between the sources tested. The maximum average yield was 27.4 bushels in the 1946-55 period. Yields that are limited to this level by weather or other uncontrollable factors do not represent reliable measures of differences between treatments.

Monroeville Experiment Field, Magnolia Fine Sandy Loam

Average yields in the 1946-55 period ranged from 41.7 bushels from ammonium sulfate plus basic slag to 48.2 bushels from ammonium nitrate plus lime, Table 18. Yields from sodium nitrate were intermediate. Within recent years, zinc deficiency symptoms occurred in corn on plots that received sodium nitrate plus basic slag. The pH of these plots in 1955 was 6.9. Zinc sulfate was added to corn plots in this experiment beginning in 1956. No zinc deficiency symptoms were noted during that season. This incident emphasizes the likelihood of zinc deficiency occuring in corn on sandy soil in which the pH gets too high.

Sand Mountain Substation, Hartsells Fine Sandy Loam

Highest yields of corn were obtained from sodium nitrate in the experiment at Sand Mountain. The three treatments that included this source produced the three highest yield averages, Table 19. Ammonium sulfate was not as effective as sodium nitrate, even when neutralized with dolomite or basic slag. The lowest yield was from unneutralized ammonium sulfate, which produced only 50 per cent as much corn as did sodium nitrate. The acidity produced by ammonium sulfate did not reduce corn yields as drastically as it did cotton yields. The final pH of these plots was 4.4 and corn has been unthrifty on these plots in recent years. Soil pH values of these plots are presented with the cotton yields in Table 17.

Tennessee Valley Substation, Decatur Clay Loam

All sources of nitrogen were equally satisfactory for corn at the Tennessee Valley Substation, Table 19. The decreases in soil pH caused by the acid-forming nitrogen sources were not great enough to affect corn yields on this heavy red Decatur clay loam.

TABLE 18. CORN YIELDS FROM AMMONIUM NITRATE, AMMONIUM SULFATE, AND SODIUM NITRATE WITH LIMESTONE OR BASIC SLAG IN A 2-YEAR ROTATION OF COTTON AND CORN, WIREGRASS SUBSTATION AND MONROEVILLE EXPERIMENT FIELD, 1946-55

Nitrogen and amendment treatment[1]	Previous nitrogen and amendment source[2] 1930-45	Corn yields by location and period							
		Wiregrass Substation				Monroeville Experiment Field			
		1946-50 yield	1951-55 yield	1946-55 Yield	1946-55 Relative yield	1946-50 yield	1951-55 yield	1946-55 Yield	1946-55 Relative yield
		Bu.	*Bu.*	*Bu.*	*Pct.*	*Bu.*	*Bu.*	*Bu.*	*Pct.*
Ammonium nitrate + 3,000 lb. limestone	Sodium nitrate + monoammonium phosphate for P_2O_5	23.6	30.2	26.9	113	48.1	48.3	48.2	108
Sodium nitrate + basic slag	Same as 1946-55	23.2	28.8	26.0	109	43.7	41.7	42.7	95
Ammonium sulfate + basic slag	Same as 1946-55	25.0	29.8	27.4	115	44.0	39.4	41.7	93
Ammonium sulfate	Same as 1946-55	19.1	24.5	21.8	92	43.8	43.4	43.6	97
Ammonium sulfate + limestone[3]	Same as 1946-55	22.6	27.2	24.9	105	46.2	43.0	44.6	100
Sodium nitrate	Same as 1946-55	20.9	26.7	23.8	100	45.1	44.5	44.8	100
Ammonium sulfate ¼ + sodium nitrate ¾[2]	Same as 1946-55	22.4	28.2	25.3	106	47.7	46.1	46.9	105
Ammonium nitrate	Ammonium sulfate + limestone every 4 years	21.1	24.7	22.9	96	48.5	47.5	48.0	107

[1] All plots received 48 lb. of nitrogen, 60 lb. P_2O_5 from superphosphate or basic slag as noted, and 60 lb. K_2O from muriate of potash.
[2] Plots received fertilizer at rate of 600 lb. 6-4-2 to corn and 600 lb. 6-8-4 to cotton in 1930-45 period.
[3] Limestone sufficient to neutralize acidity of the nitrogen material.

TABLE 19. CORN YIELDS FROM AMMONIUM NITRATE, AMMONIUM SULFATE, AND SODIUM NITRATE WITH LIMESTONE OR BASIC SLAG IN A 2-YEAR ROTATION OF COTTON AND CORN, SAND MOUNTAIN AND TENNESSEE VALLEY SUBSTATIONS, 1946-55

Nitrogen and amendment treatment[1]	Previous nitrogen and amendment source[2] 1929-45	Corn yields by location and period							
		Sand Mountain Substation				Tennessee Valley Substation			
		1946-50 yield	1951-55 yield	1946-55		1946-50 yield	1951-55 yield	1946-55	
				Yield	Relative yield			Yield	Relative yield
		Bu.	*Bu.*	*Bu.*	*Pct.*	*Bu.*	*Bu.*	*Bu.*	*Pct.*
Ammonium nitrate + 3,000 lb. limestone in 1946	Sodium nitrate + monoammonium phosphate for P_2O_5	47.1	32.5	39.8	88	50.3	37.1	43.7	103
Sodium nitrate + basic slag	Same as 1946-55	51.4	45.0	48.2	107	52.2	35.2	43.7	103
Ammonium sulfate + basic slag	Same as 1946-55	42.6	32.2	37.4	83	48.1	37.1	42.6	101
Ammonium sulfate	Same as 1946-55	29.7	14.9	22.3	50	46.7	36.5	41.6	98
Ammonium sulfate + limestone[3]	Same as 1946-55	42.2	31.6	36.9	82	46.8	36.8	41.8	99
Sodium nitrate	Same as 1946-55	47.0	43.0	45.0	100	49.5	35.1	42.3	100
Ammonium sulfate ¼ + sodium nitrate ¾[2]	Same as 1946-55	43.6	39.6	41.6	92	46.7	36.1	41.4	98
Ammonium nitrate	Ammonium sulfate + limestone every 4 years	42.6	31.6	37.1	82	50.7	36.9	43.8	104

[1] All plots received 48 lb. of nitrogen, 60 lb. P_2O_5 from superphosphate or basic slag as noted, and 60 lb. K_2O from muriate of potash.

[2] Plots received fertilizer at rate of 600 lb. 6-4-2 to corn and 600 lb. 6-8-4 to cotton in 1929-45 period.

[3] Limestone sufficient to neutralize acidity of the nitrogen material.

TABLE 20. COTTON YIELD INCREASES FROM VARIOUS SOURCES OF NITROGEN ON UNLIMED AND LIMED CHESTERFIELD SANDY LOAM, MAIN STATION, AUBURN, 1928-41

Source of nitrogen	Seed cotton yield increases from different nitrogen sources on unlimed soil by periods							pH
	1928-31		1932-36	1937-41		1928-41		
	Yield inc.	Relative inc.	Yield inc.	Yield inc.	Relative inc.	Yield inc.	Relative inc.	
	Lb.	*Pct.*	*Lb.*	*Lb.*	*Pct.*	*Lb.*	*Pct.*	
None[1]	*(490)*	--	*(431)*	*(283)*	--	*(395)*	--	6.0
Sodium nitrate	691	100	923	1,026	100	894	100	6.4
Sodium nitrate 3/5, ammonium sulfate 2/5	725	105	992	1,166	114	978	109	6.0
Ammonium sulfate	595	86	781	771	75	724	81	5.5
Calcium cyanamid	651	94	853	805	78	778	87	6.4
Monoammonium phosphate	458	66	547	506	49	507	57	5.3
Urea	672	97	972	953	93	879	98	5.8
Calcium nitrate	781	113	936	999	97	914	102	6.4
Cottonseed meal	638	92	852	1,002	98	844	94	5.8
	Seed cotton yield increases from different nitrogen sources on limed[2] soil by periods							
	1928-31		1932-36	1937-41		1928-41		pH
	Yield inc.	Relative inc.	Yield inc.	Yield inc.	Relative inc.	Yield inc.	Relative inc.	
	Lb.	*Pct.*	*Lb.*	*Lb.*	*Pct.*	*Lb.*	*Pct.*	
None[1]	*(493)*	--	*(440)*	*(325)*	--	*(414)*	--	7.0
Sodium nitrate	640	100	867	1,012	100	854	100	6.5
Sodium nitrate 3/5, ammonium sulfate 2/5	721	113	1,000	1,142	113	971	114	6.1
Ammonium sulfate	759	119	1,010	1,134	112	983	115	6.0
Calcium cyanamid	585	91	812	799	79	743	87	7.0
Monoammonium phosphate	659	103	897	909	90	833	98	5.6
Urea	757	118	861	1,003	99	882	103	6.4
Calcium nitrate	781	122	922	1,115	110	951	111	6.6
Cottonseed meal	604	94	827	929	92	800	94	5.8

Base treatment was 45 lb. of nitrogen from source shown, 600 lb. superphosphate except for the monoammonium phosphate plot, which received 195 lb. of P_2O_5, and 100 lb. of muriate of potash annually.

[1] Figures in italics are actual yields of check plots. All other figures are increases over checks.

[2] Limed to pH 6.5 in 1928. Lime to neutralize acidity from nitrogen sources added every 4 years.

OTHER EXPERIMENTS WITH SOURCES OF NITROGEN ON COTTON

SOURCES OF NITROGEN ON UNLIMED AND LIMED CHESTERFIELD SANDY LOAM AT AUBURN, 1928-1941

The experiment consisted of 16 plots, each of which was divided into a limed and unlimed half. Treatments were unreplicated except for the sodium nitrate treatment, which was replicated six times. Yield increases over the no nitrogen treatment are presented by periods, Table 20.

On unlimed plots, monoammonium phosphate was the lowest yielding treatment. The relative increase from this source was only 57 per cent of the average increase from the sodium nitrate plots. The pH of this plot in 1942 was 5.3, the lowest produced by any source. Ammonium sulfate produced a relative yield of 81 per cent and had a pH of 5.5 in 1942. Calcium cyanamid was slightly inferior to sodium nitrate, calcium nitrate, and urea. The latter three produced about the same yields.

Yields on the limed plots were about the same as on the unlimed, except on the monoammonium phosphate and the ammonium sulfate plots. Lime greatly improved the efficiency of these two sources.

An experiment was conducted on Chesterfield sandy loam at Auburn to determine the cause for the low yields obtained with ammonium phosphates. Diammonium phosphate was found to be a satisfactory source of nitrogen and phosphorus when lime and sulfur were applied. With 36 pounds of nitrogen and 48 pounds of P_2O_5 from urea and diammonium phosphate, the 5-year average seed cotton yield was 501 pounds. The addition of lime increased the yield to 755 pounds and lime plus a source of sulfur (gypsum) increased the yield to 947 pounds. This compares favorably with yields of 929 pounds from superphosphate and sodium nitrate.

SODIUM NITRATE AND AMMONIUM SULFATE WITH AND WITHOUT LIME ON CHESTERFIELD SANDY LOAM, AUBURN, 1925-55

In 1925 an experiment was started on the Main Station Agronomy Farm at Auburn to compare sodium nitrate and ammonium sulfate at two rates of nitrogen with and without lime. All treat-

TABLE 21. SEED COTTON YIELD INCREASES FROM SODIUM NITRATE AND AMMONIUM SULFATE WITH AND WITHOUT LIME, CHESTERFIELD SANDY LOAM, MAIN STATION, AUBURN, 1925-55

Nitrogen treatment[1] pounds per acre	Seed cotton yield increases[2] from nitrogen by periods							1925-55 average		pH in 1956
	1925-33		1934-39	1940-45	1946-50	1951-55				
	Yield increase	Relative increase	Yield increase	Yield increase	Yield increase	Yield increase	Relative increase	Yield increase	Relative increase	
	Lb.	*Pct.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Pct.*	*Lb.*	*Pct.*	
Unlimed										
None	*(708)*	--	*(468)*	*(236)*	*(290)*	*(302)*	--	*(437)*	--	5.7
400 Sodium nitrate	503	100	730	809	852	881	100	724	100	5.8
300 Ammonium sulfate	193	38	518	612	762	562	64	489	68	4.7
200 Sodium nitrate	408	100	677	552	716	713	100	587	100	5.9
150 Ammonium sulfate	264	65	550	503	594	504	57	458	78	5.1
Limed[3]										
None[4]	*(725)*	--	*(364)*	*(194)*	*(296)*	*(329)*	--	*(419)*	--	6.4
400 Sodium nitrate[5]	433	100	654	564	896	894	100	650	100	6.6
300 Ammonium sulfate[5]	553	128	786	793	1,041	895	100	779	120	6.0
200 Sodium nitrate[4]	393	100	576	414	730	660	100	530	100	6.4
150 Ammonium sulfate[4]	422	93	575	452	724	601	91	535	101	5.8

[1] 1925-33 All plots received 600 lb. of superphosphate and 100 lb. muriate per acre.
1934-50 All plots received 800 lb. of superphosphate and 200 lb. muriate per acre.
1951-55 All plots received 300 lb. of superphosphate, 100 lb. muriate, and 100 lb. of a minor element mixture per acre.

[2] Check yields (in italics) are total yields per acre. Other yields are increases over checks.

[3] Limestone was applied in 1914 at the rate of 5,300 lb. per acre.

[4] Beginning in 1934, these plots received 180 lb. of lime annually.

[5] Beginning in 1934, these plots received 360 lb. of lime annually.

ments were replicated twice. A summary of 31 years' results from this experiment is presented in Table 21.

On the unlimed plots, sodium nitrate was superior to ammonium sulfate at both nitrogen rates throughout the 31 years. The relative increases for the entire period from ammonium sulfate were only 78 and 68 per cent as much as from sodium nitrate at the acre rate of 32 and 64 pounds of nitrogen, respectively. The 300-pound rate of ammonium sulfate reduced soil pH to 4.7 in 31 years. The final pH on the 150-pound rate was 5.1, while the sodium nitrate and no nitrogen plots had pH values of 5.7 to 5.9. The original soil pH of this area is not known.

When ammonium sulfate was added to limed soils, yields were about the same as from similar rates of nitrogen from sodium nitrate on unlimed soil.

On the limed plots, the two sources produced about the same yields at the low nitrogen rate throughout the 31 years. However, at the high nitrogen rate, ammonium sulfate was superior to sodium nitrate in each period through 1950. In 1951 the superphosphate and muriate applications were reduced and a minor element mixture was added to all plots because it was feared that the high pH on the sodium nitrate plus lime plots was causing a minor element deficiency. Yields from 1951 through 1955 averaged the same for these two treatments, indicating that minor elements may have been in deficient supply. The final soil pH on the limed plots ranged from 5.8 on the 150-pound ammonium sulfate treatment to 6.6 on the 400-pound sodium nitrate treatment.

Comparison of the limed and unlimed treatments shows the effect of lime on cotton yields. The average response to lime when used with 150 and 300 pounds of ammonium sulfate were 77 and 390 pounds of seed cotton, respectively. Small and probably insignificant yield decreases from lime were produced on the 200- and 400-pound sodium nitrate treatments.

Ratios of Organic to Inorganic Nitrogen in Fertilizers for Cotton on Decatur Clay Loam, Alexandria Experiment Field, 1929-43

An experiment to determine the relative efficiencies of organic and inorganic nitrogen for cotton was conducted on the Alexandria Experiment Field for 15 years. Cottonseed meal and sodium nitrate were used as sources of nitrogen. Each treatment was

TABLE 22. SEED COTTON YIELD INCREASES FROM VARIOUS PERCENTAGES OF ORGANIC AND INORGANIC NITROGEN, DECATUR CLAY LOAM SOIL, ALEXANDRIA EXPERIMENT FIELD, 1929-43

Percentage nitrogen[1] from		Seed cotton yield increases by periods[2]							
		1929-33		1934-38		1939-43		1929-43	
Cottonseed meal	Sodium nitrate	Yield increase	Relative increase	Yield increase	Relative increase	Yield increase	Relative increase	Yield increase	Relative increase
		Lb.	*Pct.*	*Lb.*	*Pct.*	*Lb.*	*Pct.*	*Lb.*	*Pct.*
--	--	*(466)*	--	*(430)*	--	*(382)*	--	*(426)*	--
75	25	399	92	452	91	626	72	492	82
50	50	375	87	435	88	627	72	479	80
35	65	448	103	508	103	728	83	561	93
20	80	439	101	493	100	805	92	579	96
10	90	456	105	546	110	853	98	618	103
--	100	433	100	495	100	873	100	601	100

[1] All nitrogen was applied at the rate of 36 lb. per acre before planting. All plots received 60 lb. of P_2O_5 and 24 lb. K_2O annually.

[2] Check yields (in italics) are total yields per acre. All other yields are increases over calculated checks for each plot based on uniform soil variation between four evenly spaced check treatments.

replicated twice except the no nitrogen treatment, which was replicated eight times.

Results showed that yields were related to the percentage of inorganic nitrogen used in the fertilizer, Table 22. Treatments receiving 90 and 100 per cent of their nitrogen from sodium nitrate produced the highest yields. Plots receiving 50 per cent or more of their nitrogen from cottonseed meal were decidedly inferior. Since inorganic nitrogen is normally cheaper than organic nitrogen, fertilizers should be formulated with inorganic nitrogen unless some organic material is needed for conditioning the fertilizer.

GENERAL DISCUSSION

Efficient production of cotton and corn in Alabama is impossible without a source of nitrogen in addition to that occurring in soil organic matter.

Although the value of the nitrogen sources in the experiments reported here varied with soil conditions and management practices, all increased yields over those obtained without added nitrogen.

Several sources of nitrogen were satisfactory for cotton and corn. The effectiveness of nitrogen sources on crop growth was influenced by soil properties other than the supply of available nitrogen. Yields became progressively lower when acid-forming sources of nitrogen were applied without neutralization. However, when adequately neutralized with lime, yields were satisfactory unless some other factor was limiting. The cost of sufficient lime for neutralization is small. With cropping, soils tend to become more acid and the use of neutral fertilizers will not prevent a gradual reduction in soil pH. The soil should be tested every few years and lime applied according to recommendation. Such a liming program will supply the requirements for efficient crop production and prevent development of excessive acidity from acid-forming fertilizers with no danger of overliming.

The risk of using acid-forming fertilizers without adequate liming is that they gradually reduce yields as the soil becomes more acid. Thus the grower may not be aware of the loss of yield until the yield level has become seriously reduced. Acid-forming fertilizers may cause low yields in a few years on coarse textured soils, such as sands and sandy loams. On the other hand, it may take many years before yields are affected on fine textured soils, such as clays and clay loams. However, reduced yields will eventually occur if acid-forming fertilizers are used without the addition of adequate lime.

The use of basic slag with sodium nitrate on certain sandy soils produced symptoms on corn indicating zinc deficiency. After inclusion of zinc in the fertilizer, no deficiency symptoms appeared. Since the zinc supply in these soils is low and becomes less available with increasing basicity, the higher pH produced by continuous use of these two basic materials apparently caused the deficiency symptom.

Where cotton and corn received 24 and 12 pounds per acre of potash, greater response was obtained from nitrogen fertilizers when phosphorus was supplied as superphosphate than when basic slag was used. When the rate of potash was increased to 60 pounds per acre, the plots receiving basic slag produced as well as those receiving superphosphate. The low yields obtained from low rates of potash on plots receiving basic slag may be attributed to an increase in potash deficiency caused by the added calcium and the increase in pH.

Some loss of nitrogen may have occurred by volatilization of ammonia from the ammonium nitrate-limestone mixtures. This mixture was slightly less efficient than some other sources in several of the experiments. Application of this mixture on the surface of moist soil without immediately covering with soil could result in some loss of ammonia.

The low yields produced by the ammonium phosphates were the result of developed acidity and/or sulfur deficiency. Where these materials were the source of phosphate, the plots received no sulfur, whereas ample sulfur was applied on the plots receiving superphosphate (about one-half of superphosphate is calcium sulfate). Unless sulfur is added, cotton yields are often reduced on Alabama soils. Plots receiving the ammonium phosphates often had poor stands, but the cause of the reduced stands is not known.

Cottonseed meal, the only natural organic source used in the experiments, was satisfactory on cotton but was no better than the inorganic sources. It did not produce as much corn as some of the inorganic sources. Accordingly, these experiments furnish no basis for the purchase of expensive natural organic materials for cotton and corn.

A split application of nitrogen was generally superior to all nitrogen applied before planting. This was probably a result of leaching losses of nitrogen applied before planting, particularly on coarse textured soils in years when heavy spring rains were received. The increased yields as a result of the split application averaged about 8 per cent.

SUMMARY

This bulletin summarizes the results from 1925 through 1955 of field experiments on sources of nitrogen for cotton and corn. Experiments were conducted on the Main Station, substations, and experiment fields of the Agricultural Experiment Station.

Summary tables of the relative yield increases from the nitrogen sources reported in the results section are given in Tables 23 through 26. **In making comparisons between percentage figures in these tables, valid comparisons can be made only between sources that appear together in experiments.**

Ammonium nitrate, ammonium nitrate-limestone mixtures, ammonium sulfate, calcium nitrate, sodium nitrate, and urea are satisfactory sources of nitrogen for cotton and corn provided the acidity produced by the acid-forming sources is neutralized. The ammonium phosphates are satisfactory sources of nitrogen provided the acidity produced is neutralized and the sulfur requirements of the crop are met from other materials. Other sources not used in these experiments may be equally satisfactory.

Cottonseed meal as a nitrogen source was satisfactory on cotton, but it was unsatisfactory on corn.

Calcium cyanamid and the ammonium phosphates often produced low yields of cotton and corn. Low yields from the ammonium phosphates were probably due to (1) the acidifying effect of the material, and/or (2) sulfur deficiency, since no sulfur was applied to these plots.

A primary cause of reduced yields was the low pH produced by the acid-forming sources. Reduced yields resulting from increased acidity were obtained much more rapidly on coarse textured than on fine textured soils. For example, the addition of 36 pounds of nitrogen from ammonium sulfate for 17 years reduced the pH of Hartsells fine sandy loam from about 5.7 to about 4.5, while the pH of Decatur clay loam remained practically unchanged. Yields were reduced after about 5 years of application on the Hartsells soil but were not noticeably affected after 17 years on the Decatur soil. Continued use of acid-forming sources of nitrogen without the addition of lime will, however, eventually cause reduced yields on nearly all soils in Alabama.

Sodium nitrate, at the rates applied in the experiments reported, maintained the soil pH at an approximately constant level without the addition of lime.

Placing a portion of the nitrogen from sodium nitrate or ammonium sulfate under at planting and the remainder as a side dressing usually produced higher yields than when all nitrogen was applied under at planting, especially on sandy soils.

A combination of ¼ nitrogen from ammonium sulfate and ¾ from sodium nitrate produced as high yields as any single material and maintained the original soil pH at an approximately constant value.

The application of limestone at rates determined by the method of Pierre (2) was effective in neutralizing the acidity of the acid-forming materials.

These experiments show no evidence of a superiority of either the ammonia or nitrate forms of nitrogen for cotton and corn provided other factors, such as soil acidity, are not limiting yields.

The major consideration in selecting a source of nitrogen after supplying the lime requirement of the soil, is to use the source that can be purchased and applied at the lowest cost per pound of nitrogen. A price conversion table for sources of nitrogen is found on page 51.

TABLE 23. SUMMARY OF RELATIVE EFFICIENCY OF VARIOUS SOURCES OF NITROGEN FOR PRODUCING COTTON ON UNLIMED SOILS, 14 LONG-TERM EXPERIMENTS

Source of N and placement[1]	Relative efficiency by soil type						
	Hart-sells fsl	Decatur cl	Norfolk fsl	Hart-sells fsl	Decatur cl	Norfolk fsl	Mag-nolia fsl
	Pct	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Ammonium sulfate-sodium nitrate, sidedress				99	112	103	104
Sodium nitrate, sidedress	100	100	100	100	100	100	100
Calcium nitrate, sidedress	92	93	103				
Urea, sidedress	93	91	99				
Cottonseed meal, under	97	88	99				
Sodium nitrate, under	101	91	85				
Ammonium nitrate-limestone, sidedress	85	97	89				
Calcium cyanamid, under	77	87	93				
Ammonium sulfate, under	68	78	79				
Ammonium sulfate, sidedress	65	89	94	59	99	74	72
Diammonium phosphate, under	46	85	46				
Reference table	(2)	(5)	(3)	(13)	(13)	(12)	(12)
Nitrogen applied annually, lb.	(36)	(36)	(36)	(36)	(36)	(36)	(36)
Length of experiment, yr.	(17)	(17)	(11)	(17)	(17)	(16)	(16)
	Hart-sells fsl[2]	Decatur cl[2]	Norfolk fsl[2]	Mag-nolia fsl[2]	Ches-terfield sl	Ches-terfield sl	Ches-terfield sl
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Ammonium sulfate-sodium nitrate, sidedress	95	103	107	109	109		
Sodium nitrate, sidedress	100	100	100	100	100	100	100
Calcium nitrate, sidedress					102		
Urea, sidedress					98		
Cottonseed meal, under					94		
Ammonium nitrate, sidedress	95	103	87	92			
Calcium cyanamid, under					87		
Ammonium sulfate, sidedress	13	93	57	55	81	68	78
Monoammonium phosphate, under					57		
Reference table	(17)	(17)	(16)	(16)	(20)	(21)	(21)
Nitrogen applied annually, lb.	(48)	(48)	(48)	(48)	(45)	(64)	(32)
Length of experiment, yr.	(10)	(10)	(10)	(10)	(14)	(31)	(31)

[1] All sidedress treatments had part of the nitrogen applied before planting.
[2] Relative total yields. Others are relative increases.

TABLE 24. SUMMARY OF RELATIVE EFFICIENCY OF VARIOUS SOURCES OF NITROGEN FOR PRODUCING COTTON ON LIMED SOILS, 14 LONG-TERM EXPERIMENTS

Source of N and placement[1]	Relative efficiency by soil type						
	Decatur cl	Norfolk fsl	Hart-sells fsl[2]	Decatur cl[2]	Norfolk fsl[2]	Mag-nolia fsl[2]	Hart-sells fsl[2]
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Ammonium sulfate, sidedress	88	105	100	130	114	117	106
Ammonium sulfate-basic slag, sidedress			89	96	111	113	100
Ammonium nitrate, sidedress							102
Sodium nitrate, sidedress	100	100	100[3]	100[3]	100[3]	100[3]	100[3]
Calcium nitrate,sidedress	91	99					
Monoammonium phosphate, under							
Urea, sidedress	93	92					
Cottonseed meal, under	85	99					
Sodium nitrate, under	90	92					
Ammonium nitrate-limestone, sidedress	96	84					
Calcium cyanamid, under	91	93					
Ammonium sulfate, under	92	83					
Diammonium phosphate, under	87	74					
Reference table	(6)	(4)	(13)	(13)	(12)	(12)	(17)
Nitrogen applied annually, lb.	(36)	(36)	(36)	(36)	(36)	(36)	(48)
Length of experiment, yr.	(17)	(11)	(17)	(17)	(16)	(16)	(10)

Source of N and placement[1]	Decatur cl[2]	Norfolk fsl[2]	Mag-nolia fsl[2]	Chester-field sl	Chester-field sl	Chester-field sl
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Sodium nitrate-sulfate, sidedress				114		
Ammonium sulfate, sidedress	103	91	100	115	120	101
Ammonum sulfate-basic slag, sidedress	102	103	103	89		
Ammonum nitrate, sidedress	104	92	104			
Sodium nitrate, sidedress	100[3]	100[3]	100[3]	100	100	100
Calcium nitrate, sidedress				111		
Monoammonium phosphate, under				98		
Urea, sidedress				103		
Cottonseed meal, under				94		
Calcium cyanamid, under				87		
Reference table	(17)	(16)	(16)	(20)	(21)	(21)
Nitrogen applied annually, lb.	(48)	(48)	(48)	(45)	(64)	(32)
Length of experiment, yr.	(10)	(10)	(10)	(14)	(31)	(31)

[1] All sidedress treatments had part of the nitrogen applied before planting.
[2] Basic slag used as the source of phosphorus on these sodium nitrate plots. They did not receive lime.
[3] Relative total yield. Others are relative increases.

TABLE 25. SUMMARY OF RELATIVE EFFICIENCY OF VARIOUS SOURCES OF NITROGEN FOR PRODUCING CORN ON UNLIMED SOILS, 11 LONG-TERM EXPERIMENTS

Source of N and placement[1]	Relative efficiency by soil type					
	Hartsells fsl	Decatur cl	Norfolk fsl	Hartsells fsl	Decatur cl	Norfolk fsl
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Sodium nitrate, sidedress	100	100	100	100	100	100
Ammonium sulfate-sodium nitrate, sidedress				96	94	100
Calcium nitrate, sidedress	96	104	97			
Ammonium nitrate, sidedress						
Sodium nitrate, under	91	98	91			
Urea, sidedress	84	93	89			
Ammonium sulfate, under	76	102	85			
Ammonium nitrate-limestone, sidedress	89	91	84			
Ammonium sulfate, sidedress	84	90	81	80	87	85
Diammonium phosphate, under	73	89	85			
Calcium cyanamid, under	67	83	67			
Cottonseed meal, under	57	82	75			
Reference table	(7)	(10)	(8)	(15)	(15)	(14)
Nitrogen applied annually, lb.	(36)	(36)	(36)	(36)	(36)	(36)
Length of experiment, yr.	(17)	(17)	(11)	(17)	(17)	(16)

Source of N and placement[1]	Magnolia fsl	Hartsells fsl[2]	Decatur cl[2]	Norfolk fsl[2]	Magnolia fsl[2]
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Sodium nitrate, sidedress	100	100	100	100	100
Ammonium sulfate-sodium nitrate, sidedress	101	92	98	106	105
Calcium nitrate, sidedress					
Ammonium nitrate, sidedress		82	104	96	107
Sodium nitrate, under					
Urea, sidedress					
Ammonium sulfate, under					
Ammonium nitrate-limestone, sidedress					
Ammonium sulfate, sidedress	101	50	98	92	97
Diammonium phosphate, under					
Calcium cyanamid, under					
Cottonseed meal, under					
Reference table	(14)	(19)	(19)	(18)	(18)
Nitrogen applied annually, lb.	(36)	(48)	(48)	(48)	(48)
Length of experiment, yr.	(16)	(10)	(10)	(10)	(10)

[1] All sidedress treatments had part of the nitrogen applied before planting.
[2] Relative total yields. Others are relative increases.

TABLE 26. SUMMARY OF RELATIVE EFFICIENCY OF VARIOUS SOURCES OF NITROGEN FOR PRODUCING CORN ON LIMED SOILS, 10 LONG-TERM EXPERIMENTS

Source of N and placement[1]	Relative efficiency by soil type				
	Decatur cl	Norfolk fsl	Hartsells fsl[2]	Decatur cl[2]	Norfolk fsl[2]
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Calcium nitrate, sidedress	104	110			
Urea, sidedress	101	115			
Ammonium sulfate, under	101	109			
Ammonium nitrate-limestone, sidedress	99	103			
Sodium nitrate, sidedress	100	100	100[3]	100[3]	100[3]
Ammonium nitrate, sidedress					
Ammonium sulfate, sidedress	95	128	88	92	109
Diammonium phosphate, under	83	111			
Ammonium sulfate + basic slag, sidedress			91	85	107
Sodium nitrate, under	97	94			
Cottonseed meal, under	86	90			
Calcium cyanamid, under	90	88			
Reference table	(11)	(9)	(15)	(15)	(14)
Nitrogen applied annually, lb.	(36)	(36)	(36)	(36)	(36)
Length of experiment, yr.	(17)	(11)	(17)	(17)	(16)

Source of N and placement[1]	Magnolia fsl[2]	Hartsells fsl[2]	Decatur cl[2]	Norfolk fsl[2]	Magnolia fsl[2]
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Calcium nitrate, sidedress					
Urea, sidedress					
Ammonium sulfate, under					
Ammonium nitrate-limestone, sidedress					
Sodium nitrate, sidedress	100[3]	100[3]	100[3]	100[3]	100[3]
Ammonium nitrate, sidedress		82	100	103	113
Ammonium sulfate, sidedress	108	76	96	96	104
Diammonium phosphate, under					
Ammonium sulfate + basic slag, sidedress	105	77	97	105	98
Sodium nitrate, under					
Cottonseed meal, under					
Calcium cyanamid, under					
Reference table	(14)	(19)	(19)	(18)	(18)
Nitrogen applied annually, lb.	(36)	(48)	(48)	(48)	(48)
Length of experiment, yr.	(16)	(10)	(10)	(10)	(10)

[1] All sidedress treatments had part of the nitrogen applied before planting.
[2] Basic slag used as the source of phosphorus on these sodium nitrate plots. They did not receive lime.
[3] Relative total yield. Others are relative increases.

RELATIVE COST PER POUND OF NITROGEN IN VARIOUS NITROGEN FERTILIZERS

Price per ton of material	Cost per pound of nitrogen						
	Sodium nitrate 16% N	Ammonium sulfate 20.5% N	Ammonium nitrate 33.5% N	Nitrogen solution 37% N	Urea 45% N	Nitrogen solution 49% N	Anhydrous ammonia 82.2% N
Dollars	*Cents*	*Cents*	*Cents*	*Cents*	*Cents*	*Cents*	*Cents*
30	9.4	7.3					
35	10.9	8.5	5.2				
40	12.5	9.8	6.0	5.4			
45	14.1	11.0	6.7	6.1	5.0		
50	15.6	12.2	7.5	6.8	5.6	5.1	
55	17.2	13.4	8.2	7.4	6.1	5.6	
60	18.8	14.6	9.0	8.1	6.7	6.1	
65	20.3	15.9	9.7	8.8	7.2	6.6	
70	21.9	17.1	10.5	9.5	7.8	7.1	
75	23.4	18.3	11.2	10.1	8.3	7.7	
80	25.0	19.5	11.9	10.8	8.9	8.2	
85		20.7	12.7	11.5	9.4	8.7	5.2
90		22.0	13.4	12.2	10.0	9.2	5.5
95		23.2	14.2	12.8	10.6	9.7	5.8
100		24.4	14.9	13.5	11.1	10.2	6.1
105		25.6	15.7	14.2	11.7	10.7	6.4
110			16.4	14.9	12.2	11.2	6.7
115			17.2	15.5	12.8	11.7	7.0
120			17.9	16.2	13.3	12.2	7.3
125			18.7	16.9	13.9	12.8	7.6
130			19.4	17.6	14.4	13.3	7.9
135			20.2	18.2	15.0	13.8	8.2
140			20.9	18.9	15.6	14.3	8.5

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** Deceased
*** Retired

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