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Starter Fertilizer Combinations and Placement for Conventional and No-tillage Cotton[1]

J. T. Touchton, D. H. Rickerl, C. H. Burmester and D. W. Reeves[2]

The use of starter fertilizers is becoming a common practice in many areas of the Southeast. Nutrient combinations, rates and placement methods vary widely. The purpose of this study was to compare the effects of nutrient combinations in starter fertilizers on growth and yield of cotton (*Gossipium hirsutum* L.) and to evaluate potential interactions of starter fertilizers with tillage systems and fertilizer placement. The study was conducted for three years on a Decatur silt loam (Rhodic Paleudult) and a Dothan sandy loam (Plinthic Paleudult). Treatments consisted of primary tillage systems (chisel plow and no tillage), subsoiling at planting (in-row and none), starter fertilizer combinations (150 lb/ac of 15-0-0, 15-15-0 and 15-15-5), and fertilizer placement (deep in the subsoil tract and two inches beside and below the seed, 2 x 2).

Early season plant heights were not affected by treatments on the silt loam soil, but the starter fertilizers increased plant height each year on the sandy loam soil. In one year, N alone was adequate, hut, in the other two years, the N-P combination resulted in greater plant heights as compared to N alone. The 2 x 2 placed fertilizers were generally more effective than the deep placed fertilizers except in the no-tillage system without in-row subsoiling.

Seed cotton yields were not related to early season growth. Yield response to treatments was not consistent among soils or years, but did occur in two out of three years on both soils. When comparing across years, the optimum treatment combinations for the silt loam soil were conventional or no tillage with 2 x 2 placed N but without in-row subsoiling; when averaged across tillage systems for the two years in which yield responses occurred, the 2 x 2 placement resulted in yields of 2490, 2720, 2760 and 2790 lb/ac for no starter, N, N-P and N-P-K, respectively. For the sandy loam soil, best treatment combinations were. conventional or no tillage, in-row subsoiling regardless of tillage, and 2 x 2 or deep placed N-P and occasionally N-P-K; in the two years in which yield responses occurred, yields with in-row subsoiling averaged across tillage and placement were 3930, 4050, 4l50 and 4250 lb/ac, for no starter, N, N-P and N-P-K, respectively.

[1] Research partially supported by grant funds from the Fluid Fertilizer Foundation and Alabama Cotton Commission.

[2] Associate Professor; Research Associates; and Research Agronomist, USDA-ARS; respectively, Department of Agronomy and Soils, Alabama Agricultural Experiment Station, Auburn University, AL 36849.

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THERE are two primary reasons why plants grown on highly fertile soils will respond to band-applied fertilizers at planting. Firstly, nutrients are generally in the solid phase (residual fertility) and only relatively small amounts are in the solution (plant available) phase (Adams, 1974). Plant roots take nutrients primarily from the solution phase (Barber, 1984); therefore, solution phase nutrients must be continuously replaced from the solid phase nutrients. The conversion of nutrients from the solid to the solution phase, or vice versa, is through biological and chemical processes, and these processes are highly dependent on environmental and edaphic conditions such as moisture, temperature and aeration or compaction. With low soil temperatures, nutrient availability can be low (Ketcheson, 1968: Reyes et al., 1977; Sutton, 1969) due to slow conversion of nutrients from the solid to the solution phase. Secondly root growth is often poor or slow in cold and/or compacted soils (Knoll et al., 1964; Beauchamp and Lathwell, 1967). With poor root growth and slow development, plant roots are in contact with less soil volume and are unable to reach available soil nutrients.

In recent years, there has been a trend toward earlier planting dates and reduced tillage systems. Within acceptable planting periods, early planting dates generally result in higher cotton (*Gossypium hirsutum* L.) yields (Galanopoulou-Sendouka et al., 1980). The advantages of reduced tillage are numerous and include water-runoff control, soil erosion control and energy conservation (Gallaher, 1977; Langdale et al, 1978; Tyler and Overton, 1982: Vaughan et al., 1977) and in some instances higher yields.

With early planting dates and reduced tillage systems, young plants must endure cold and wet soil conditions (Gauer et al, 1982; Khera et al., 1976). Reduced tillage can result in more compacted soils than conventional tillage (Douglas et al., 1980; Voorhees and Linstrom, 1983). Therefore, the response to starter fertilizers should be greater with reduced tillage. Data comparing plant growth and yield response to starter fertilizer between tillage systems suggest that greater yield responses will occur with no tillage than with conventional tillage (Touchton, 1983).

Methods of fertilizer placement vary with available equipment. The standard for years has been two inches beside and two inches below the seed (2 x 2). The purpose of the 2 x 2 placement is to place the fertilizer far enough away from the seed to prevent toxicities (Mortvedt, 1983), but close enough so that the fertilizer is readily accessible by small seedlings. In the Southern Coastal Plains where root restricting hardpans exist (Campbell et ah, 1974) planting units with in-row subsoilers are generally used in conservation tillage systems. Starter fertilizers can easily be applied behind the subsoil shank which results in a placement 8 to 12 inches directly under the seed. There is some concern that roots cannot reach this deep placed fertilizer early enough for maximum benefits.

The selection of nutrients and the amount to apply as starter fertilizers have been and still are highly debatable. Over the years, many nutrient combinations have been suggested and used (Brown, 1968; Mortvedt, 1983). Although many combinations have been suggested, the ammonium polyphosphates and ammonium phosphates are probably the most common sources. These sources contain 2 to 3 times more P_2O_5 than N. Recent data, however, indicate that N is more important than P especially for corn (*Zea Mays* L.) grown on soils high in residual P (Touchton and Karim, 1986).

Research data on the use of starter fertilizers with cotton are not readily available. Research conducted during the 1950's (Hood and Ensminger, 1959) indicate that favorable yield responses to band applied N-P-K (8-8-8 and 18-18-18) can be obtained, provided the fertilizers are not placed too close to the seed. Other researchers (Adams, 1966; Hood and Ensminger, 1964) have reported that germinating cotton and young cotton seedlings are highly sensitive to fertilizer, especially ammonium phosphates banded too close to the seed.

The purpose of this study was to compare the effects of starter fertilizer combinations on cotton growth and yield and to evaluate the interacting effects of fertilizer combinations with tillage systems, planting methods and fertilizer placement.

MATERIALS AND METHODS

Field studies were conducted for three years (1983-1985) on a Decatur silt loam (clayey, kaolinitic, thermic, Rhodic Paleudults) in the Limestone Valley of north Alabama and a Dothan sandy loam (fine-loamy, siliceous, thermic, Plinthic Paleudult in the Coastal Plain of southern Alabama. The original soil test levels for P, K, Ca and Mg were high (Table 1) and were maintained in the high range with winter applications of fertilizer. Winter applications of 45 lb/ac of P_2O_5 and K_2O were broadcast on the silt loam soil in 1984 and on the sandy loam soil in 1983 and 1985. Cotton was grown in a two-year rotation with corn on the silt loam soil and in a three-year rotation (corn-peanuts, *Arachis hypogaea* L.,-cotton) on the sandy loam soil. After harvest, the experimental area was mowed and disked (3 to 4 inches deep) and seeded in rye (*Secale cereale* L.). Rye was not fertilized unless analysis of soil samples taken the previous spring indicated that soil P or K were dropping out of the high range.

Treatment variables were preplant tillage, in-row subsoiling, starter fertilizer and fertilizer placement. On the sandy loam soil, the experimental design was a split plot within a randomized complete block with four replications. Tillage was in whole plots and the other treatments (Table 2) were in split plots. On the silt loam soil, the experimental design was also a randomized complete block. Each treatment listed in Table 2 was located within the no-tillage system, but none of the in-row subsoil treatments were located in the conventional tillage system.

Preplant tillage consisted of conventional and conservation tillage. Conventional tillage was disk-chisel roterra 1 to 3 weeks prior to planting cotton each year. Shanks on the chisel plow used for conventional tillage were spaced 10 inches apart and fractured the soil approximately eight inches deep. Rye on the conservation-tillage plots was killed with paraquat 1 to 3 weeks prior to planting. All other treatments (Table 2) were imposed at planting with a no-till planting unit with in-row subsoilers. Depth of subsoiling was 12 inches on the sandy loam soil which contained a root

Table 1. Soil test information for each soil and year.

Variable	Unit	Silt loam soil			Sandy loam soil		
		1983	1984	1985	1983	1984	1985
pH	—	6.3	6.5	6.2	6.0	5.9	5.9
Organic matter	%	1.3	1.4	1.3	1.1	1.1	1.1
CEC	meq/100 g	12.0	11.0	11.0	4.0	4.0	5.0
P	lb/ac	86.0	46.0	46.0	72.0	72.0	71.0
K	lb/ac	280.0	349.0	200.0	114.0	112.0	96.0
Ca	lb/ac	2090.0	2140.0	1400.0	860.0	736.0	790.0
Mg	lb/ac	152.0	144.0	160.0	50.0	88.0	60.0

Table 2. Seed cotton yield on the silt loam soil in the Limestone Valley as affected by tillage, in-row subsoiling, starter fertilizer and fertilizer placement.

Tillage	Starter† fertilizer	In-row subsoiling	Fertilizer placement	Year 1983	1984	1985
				seed cotton, lb/ac		
Conventional	0-0-0	no	—	960	4180	4520
	15-0-0	no	2 x 2	1040	4310	4200
	15-15-0	no	2 x 2	960	4520	4590
	15-15-5	no	2 x 2	1090	4480	4480
No tillage	0-0-0	yes	—	880	3720	4170
		no	—	1010	3820	4650
	15-0-0	yes	deep	940	3690	4570
		yes	2 x 2	900	4320	4140
		no	2 x 2	970	4570	4220
	15-15-0	yes	deep	800	3880	4000
		yes	2 x 2	900	4510	4500
		no	2 x 2	1000	4570	4450
	15-15-5	yes	deep	940	3540	4080
		yes	2 x 2	940	4190	4120
		no	2 x 2	1200	4390	4460
$LDS_{0.10}$				140	330	NS

† Application rate was 150 lb/ac.

restricting hardpan approximately eight inches deep, and eight inches on the silt loam soil which did not contain a root restricting hardpan. Subsoiler shanks shattered a wedge of soil 6 to 8 inches wide at the soil surface and 2 inches wide at the bottom of the shank. Row width was was 36 inches. Due to shattering or tilling the soil several inches on each side of the row, use of in-row subsoilers is commonly referred to as strip tillage. For the non-subsoiled treatments, the subsoil shanks were removed and the same planting unit used. In effect, three tillage systems were used: conventional, no tillage and strip tillage.

The starter fertilizers were made with combinations of urea-ammonium nitrate, ammonium polyphosphate and muriate of potash. Application rate was 150 lb/ac of material and actual N, P_2O_5 and K_2O rates were 22, 22 and 8 lb/ac, respectively. The deep application was placed at the bottom of the subsoil channel through tubes attached to the back of the subsoil shank. Placement depth was approximately six inches on the silt loam soil and 10 inches on the sandy loam soil. The 2 x 2 application was approximately two inches beside and below the seed.

Cotton 'McNair 235' was planted in late April or early May each year. Seeding rate was eight seed per foot of row and row width was 36 inches. Temik and Terrachlor Super X were applied in the seed furrow at planting. Weeds were effectively controlled with pre-emergence application of Cotoran and Prowl, and post-emergence applications of Bladex and MSMA. The cotton was scouted weekly for insect infestations, and when needed, either Dimethioate, Bolstar, Pydrin or Fundal was applied. Sidedress N at 60 lb/ac on the silt loam soil and 90 lb/ac on the sandy loam soil was applied 3 to 4 weeks after planting. On the sandy loam soil, S (9 lb/ac), Zn (4 lb/ac) and B (0.5 lb/ac) were applied with the N. The sidedress fertilizer solution was knifed approximately four inches deep on the sandy loam soil and surface applied in the silt loam soil.

Data collected included early season canopy heights, plant populations, leaf samples for nutrient analyses and seed cotton yields at maturity. Early season plant heights were taken 4 to 5 weeks after planting and again at 7 weeks if height differential among treatments was apparent. Uppermost mature leaves were collected during mid bloom which was in mid to late August each year. The leaf tissue was dried. ground and analyzed for N with a Leco N Analyzer and analyzed for P, K, Ca, Mg, Mn, Zn, Cu. Fe and B with an inductively coupled argon plasma atomic emmission spectrometer. When 60 to 70% of the bolls were opened, plots were trimmed to 30 ft lengths and the two center rows of each plot were mechanically picked. The second and final picking ranged from 5 to 6 weeks after the first picking. Statistical analyses used to separate treatment means were the analysis of variance and Fishers Least Significant Difference (FLSD). The 10% level of probability was used to separate treatments means.

RESULTS AND DISCUSSION

Silt Loam Soil

Plants receiving starter fertilizers were a darker green in the early growing season each year than plants not receiving starter fertilizers. Differences in plant heights and plant populations five weeks after planting were not detectable.

Seed cotton yields were low in 1983 but high in 1984 and 1985 (Table 2). Low yields in 1983 were due to low rainfall in July and August (Table 3) and extended dry periods in June, July and August. Yield responses to treatments occurred in 1983 and 1984, but not in 1985.

In 1983, there was not a yield response to any of the starter fertilizers within the conventional tillage system, but within the no-tillage system, the N-P-K applied 2 x 2 without in-row subsoiling increased yields 19% when compared to the no starter check. When averaged across starter fertilizer and placement treatments, no-tillage with in-row subsoiling (strip tillage) resulted in lower yields than conventional tillage (900 vs 1010 lb/ac). No-tillage without in-row subsoiling resulted in yields comparable to conventional tillage (1040 vs 1010 lb/ac).

In 1984, there was a yield response to starter fertilizers in both tillage systems, but the response was greater in the no-tillage system. Yield responses were as high as 8 and 20% in the conventional and no-tillage systems, respectively. Differences in yield responses between tillage systems were due to lower yields with no-tillage when 2 x 2 starters were not applied. When 2 x 2 starters were applied, there were no differences between tillage systems. In comparing starter combinations, N alone was statistically equal to N-P, but yields were generally higher with N-P than N alone. Including K in the starter did not affect yields which was a direct contrast to 1983 where the only response was due to the N-P-K combination. Differences among starter placement were found. The deep application, at the bottom of the subsoil channel, was completely ineffective. Equal yields were obtained with subsoiled and not subsoiled when 2 x 2 placed starters were used. In contrast to 1983, in-row subsoiling did not reduce yields. The percentage of the total cotton yield which was picked at first harvest (an indication of maturity) was affected by treatments (P = 0.10) in 1984 but not in 1983 or 1985 (data not shown). In 1984, the percent first pick was higher when starter fertilizers were applied. In the conventional tillage system, 78% of the cotton was picked on the first harvest date without starter fertilizer and up to 85% was picked when a starter was used. In the no-tillage system, the 2 x 2 placed starters increased first picking percentage from 75 to 88%. As with yields, deep placed starter had no effect on maturity. Nitrogen alone was as effective as the N-P combinations.

Average leaf-nutrient concentrations are listed in Table 4. Isolated differences in leaf nutrient concentrations during early bloom were detected in 1984 but not in 1983 or 1985. Differences in leaf nutrients occurred with Ca, Mn and Zn but neither of these could be related to yield differences obtained in 1984. Primary differences in Mn concentrations occurred with starter vs no starter (147 vs 120 ppm). Zinc concentrations were increased from 35 to 42 ppm when some form of tillage, either conventional or strip tillage, was used. Although all leaf Zn concentrations were adequate in this test, the differences in leaf Zn between no-till treatments and treatments with some tillage indicate that Zn availability can be poorer in no-tillage systems Differences in leaf Ca did not follow logical trends and were probably due to artifacts rather than treatment effects.

Sandy Loam Soil

Plant populations were affected by treatments in 1983 and 1984 (Table 5) but not in 1985. Plant populations did not vary among primary tillage systems in either year. The final populations each year were approximately 50% of the seeding rate which is not unexpected for cotton. In 1983, populations averaged 24% higher without than with in-row subsoiling, but in 1984, they averaged 53% higher with than without in-row subsoiling. Contrasting effects of subsoiling on populations is not uncommon, and is most likely related to soil conditions which influence seed-soil con-

Table 3. Rainfall by months during the peak cotton growing season.

Month	Silt loam soil				Sandy loam soil			
	1983	1984	1985	20 year avg	1983	1984	1985	20 year avg
	inches							
May	10	8	6	6	3	3	4	5
June	6	6	3	4	8	7	3	5
July	1	4	6	5	4	4	6	6
August	1	4	6	4	4	4	6	5

Table 4. Average leaf-nutrient concentrations in cotton during midbloom for each soil and year.

Nutrient	Silt loam soil 1983	Silt loam soil 1984	Silt loam soil 1985	Sandy loam soil 1983	Sandy loam soil 1984	Sandy loam soil 1985
	%					
N	4.00	3.62	4.18	4.68	4.51	4.70
P	0.37	0.39	0.24	0.27	0.36	0.33
K	1.65	1.19	1.32	1.35	1.04	1.01
Ca	2.68	2.83	2.07	2.72	3.30	2.27
Mg	0.45	0.39	0.26	0.50	0.76	0.54
	ppm					
Zn	42	40	29	48	45	48
Mn	137	142	161	272	178	132
Cu	7	1	12	6	17	12
Fe	195	257	240	142	301	165
B	53	68	40	40	63	17

tact at planting. The effects of starter fertilizers on plant populations occurred only with the non-subsoiled treatment. In 1983, N alone had no effect on populations, but N-P and N-P-K combinations improved populations 13%. In 1984, fertilizers reduced plant populations 23% and it appears that N was responsible for the reduction. Fertilizers were mixed and applied the same way with the same equipment each year.

Early season plant growth response to treatment varied among years (Table 6). In 1983, plant heights five weeks after planting were not affected by tillage. The N-P applied 2 x 2 with (strip till) and without (no till) subsoiling and the N-P-K applied 2 x 2 without subsoiling resulted in taller plants than the other treatments. Nitrogen applied alone regardless of method of application did not affect plant height. Plant growth responses to the 2 x 2, but not the subsoil-placed (deep) fertilizers suggest that the subsoil application was too deep for initial growth responses.

Table 5. Plant populations and seed cotton yield on the sandy loam soil as affected by tillage, in-row subsoiling, starter fertilizer and fertilizer placement.

Starter† fertilizer	In-row subsoiling	Fertilizer placement	Population 1983	Population 1984	Yield 1983	Yield 1984	Yield 1985 Till	Yield 1985 No-till
			1000/ac		seed cotton, lb/ac			
0-0-0	yes	—	39	42	1590	4380	3460	3500
	no	—	45	32	1560	4030	3610	3100
15-0-0	yes	deep	38	40	1430	4530	3720	3530
	yes	2 x 2	35	37	1570	4280	3690	3870
	no	2 x 2	45	21	1570	4110	3770	3500
15-15-0	yes	deep	38	43	1610	4510	3650	3810
	yes	2 x 2	39	41	1480	4490	3770	3950
	no	2 x 2	50	24	1430	4230	3680	3350
15-15-5	yes	deep	39	38	1350	4530	3980	3850
	yes	2 x 2	42	38	1690	4520	4010	4040
	no	2 x 2	52	27	1590	4200	3860	3140
$FLSD_{0.10}$			5	4	NS	150	300	300

† Application rate was 150 lb/ac.

Seven weeks after planting, plant heights averaged 12.6 and 13.8 inches for the conventional and conservation-tillage treatments, respectively (Table 6). When starter fertilizers were not applied, there were no differences in plant heights among tillage systems. When starter fertilizers were applied, there were some isolated treatments where no tillage resulted in greater heights than conventional tillage. Within conventionally tilled subsoil treatments, all of the starter fertilizers except the subsoiled applied 15-0-0 and 2 x 2 applied N-P-K resulted in taller plants than the no fertilizer checks. Within the no-till subsoiled treatment, the 2 x 2 applied N-P and 2 x 2 and deep applied N-P-K improved plant heights. Generally, within the non subsoil treatments in both tillage systems, all fertilizer treatments improved heights. Subsoiling increased plant height in the no-till system, when fertilizer was not applied.

In 1984, there were some isolated differences in plant heights four weeks after planting (Table 61, but when comparing individual heights with the controls, a definite response pattern could not be established. Seven weeks after planting, there was no consistent difference in heights among tillage systems, starter fertilizers or methods of placement, but plants averaged two inches taller with than without in-row subsoiling.

In 1985, there was no difference in plant heights between tillage systems. With the subsoil treatments, the N-P and N-P-K fertilizers, especially the 2 x 2 application, resulted in greater plant heights five weeks after planting than N alone and the no fertilizer control (Table 6). Without in-row subsoiling, the N alone improved plant heights over the no starter control. but the addition of P and K to the starter fertilizer resulted in incremental decreases in heights.

Although some isolated differences in leaf nutrient concentrations during midbloom were detected, differences did not follow treatment patterns and did not correspond to growth or yield response. The average nutrient concentrations are listed in Table 4.

Seed cotton yield response to treatments (Table 5) also varied with years. In 1983, yields were low and highly variable, and consistent trends among common sets of treatments did not exist. In 1984, seed cotton yields were consistently higher with than without in-row subsoiling (4460 vs 4140 lb/ac) which directly reflects differences in plant heights seven weeks after planting (Table 6). Although starter fertilizers did not consistently affect early season plant growth, there were some positive yield responses to the application methods. The deep placed fertilizer consistently improved yields (as much as 150 lb/ac.) and N alone was adequate. The 2 x 2 placed fertilizers with in-row subsoiling also improved yields, but N alone was not adequate.

In 1985, interactions existed between tillage and starter fertilizers. Several treatment combinations resulted in yields equivalent to the absolute highest yield (4040 lb/ac, Table 5). In both tillage systems, the

Table 6. Plant heights 4 to 7 weeks after planting on the sandy loam soil as affected by tillage, in-row subsoiling, starter fertilizer and fertilizer placement.

Starter† fertilizer	In-row subsoiling	Fertilizer placement	1983 5 week‡	1983 7 week Till	1983 7 week No-till	1984 4 week Till	1984 4 week No-till	1984 7 week	1985 5 week
			inches						
0-0-0	yes	—	7.9	11	13	7.4	6.7	18	17
	no	—	8.3	12	11	7.1	7.1	17	15
15-0-0	yes	deep	7.9	12	14	6.7	7.1	19	16
	yes	2 x 2	7.9	13	13	8.3	7.1	19	18
	no	2 x 2	8.7	14	13	7.0	7.1	17	18
15-15-0	yes	deep	8.3	13	13	7.4	7.1	18	19
	yes	2 x 2	9.0	15	16	7.9	6.7	20	19
	no	2 x 2	9.4	14	13	7.1	6.7	17	17
15-15-5	yes	deep	8.7	13	15	6.7	6.7	19	17
	yes	2 x 2	8.7	12	15	6.7	8.7	19	19
	no	2 x 2	10.2	13	15	6.7	7.1	17	16
$FLSD_{0.10}$			1.1	2	2	1.0	1.0	1	1

† Application rate was 150 lb/ac.
‡ Week is weeks after planting. When differences between tillage systems were not found, values were averaged over tillage systems.

N-P-K fertilizer applied 2 x 2 in conjunction with in-row subsoiling resulted in the absolute highest yield. The yield increase over the no starter check was 550 and 540 lb/ac with conventional and no tillage, respectively. This treatment was also one of the ones that resulted in the best early season plant growth. Differences in plant growth between subsoiling treatments without fertilizers were also reflected in seed cotton yield within the no-tillage system (3500 vs 3100 lb/ac with and without subsoiling), but not within the conventional-tillage system. Without subsoiling within the no-tillage system, N alone improved yields over the no fertilizer control (3500 vs 3100 lb/ac), but the addition of P and K resulted in incremental decreases in yield (3350 and then 3140 lb/ac). The same trend was observed with plant heights.

CONCLUSIONS

Although visual differences occurred between treatments on the silt loam soil, measurable differences in early season plant growth (population and height) did not occur in any year. On the sandy loam, measurable differences in early season plant growth occurred each year. In one year, the starter fertilizers improved plant populations 13%, reduced populations 23% in another year, and had no effect the third year. Plant height responses to treatments were as erratic as population responses. There was not much difference in plant heights among tillage systems and no strong evidence to suggest that starter fertilizers improved or would improve early season plant growth more with conservation than conventional tillage. In two of the three years, the N-P and N-P-K fertilizers resulted in more rapid early season plant growth than N alone or no starter controls. With the conventional tillage system, and also the combination of in-row subsoiling with no tillage, the 2 x 2 placed starters were generally more effective than the deep placed starters. Without in-row subsoiling in the no-till system, the N-P and N-P-K starters resulted in reduced plant height in one year.

Yield responses to treatments occurred in two out of three years on both soils, but the yield responses were not always related to the early season plant growth responses. On the silt loam soil, in-row subsoiling reduced yields in one of the two response years, but had no effect the other year. Higher yields were obtained with conventional than conservation tillage both years when starter fertilizers were not used. When starter fertilizers were used, yields were as high or higher with no tillage than conventional tillage. In one year, yield improvements occurred only with N-P-K, but in the other year, N alone was as effective as N-P or N-P-K. Yield improvements only occurred with the 2 x 2 placement and deep placement was ineffective.

On the sandy loam soil, in-row subsoiling improved yields in both of the two response years. In one year, deep placed fertilizer was superior to the 2 x 2 placement, but with N-P or N-P-K, the 2 x 2 placement resulted in yield responses equal to the deep placement. In the other year, the 2 x 2 placed N-P or N-P-K with in-row subsoiling was the superior treatment and the yield increase obtained with the starter fertilizer was greater with conservation than conventional tillage. With the no-till system (without in-row subsoiling), the N-P and N-P-K treatments reduced yields in one year, and this was the only indication, from yield data, that the starter fertilizer may have been placed too close to the seed.

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