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Starter Fertilizer Combinations and Placement For Conventional and No-Tillage Corn[1]

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ABSTRACT

This three-year (1983-1985) field study was conducted to compare the effects of starter fertilizer combinations and placement methods on growth and yield of corn grown in conventional- and conservation-tillage systems. Tillage systems were disk-chisel plow and no-till into killed rye. Corn was planted with and without in-row subsoiling. Nutrient combinations were: no starter fertilizer, N, N-P and N-P-K. Rates of N, P and K were 22, 9.7 and 6.6 lb/ac, respectively. Fertilizer placement treatments were 1) deep placed 6 to 10 inches below the seed in the in-row subsoil channel, 2) shallow placement (2 x 2 or 3 x 2) with in-row subsoiling and 3) shallow placement without in-row subsoiling. The study was located on a Decatur silt loam in the Limestone Valley of north Alabama and on a Dothan sandy loam in the Coastal Plains of south Alabama. Starter fertilizers improved early season plant growth in both tillage systems on both soils. Plant height increases six weeks after planting from starter fertilizers averaged 50 and 27% for conventional and no-tillage, respectively, on the Decatur soil and 26 and 43%, respectively, on the Dothan soil. The N alone generally resulted in plant heights equal to N-P or N-P-K. There was no difference among placement treatments on the Decatur soil, but shallow placement with in-row subsoiling was the superior treatment on the Dothan soil. Neither striking nor consistent differences in whole-plant nor earleaf nutrient concentrations were found among treatments. On the Decatur soil, starter fertilizers improved yields a maximum of 11 and 14 bu/ac in 1983 and 1984, respectively, but decreased yields a maximum of 24 bu/ac in 1985. The yield reduction resulted from the deep placed N-P and N-P-K starter fertilizers. The yield increase on the Decatur soil occurred primarily within the no-tillage system and N alone was adequate. On the Dothan soil, starter fertilizers increased yields a maximum of 32 bu/ac in 1984, but had no effect in 1985. Although N alone increased yields over the no-starter check, the N-P combination was required for substantial yield increases. On the Dothan soil, the 3 x 2 placed starter fertilizers used in combination with in-row subsoiling resulted in higher yields than deep placed starters. On soils with root-restricting hard pans, subsoiling in conjunction with shallow incorporation of N-P applications is necessary to achieve the maximum benefit of the starter application. Yield increases to starter applications occur frequently enough to justify the practice.

Additional index words: **Conservation tillage, In-row Subsoiling, Band Applied Fertilizer.**

ACCEPTANCE of conservation tillage systems by corn growers has been hampered by erratic crop performance with these systems. Early season plant growth is often poorer than in conventionally-tilled systems (Karlen and Sojka, 1985; Mock and Erbach, 1977; Touchton, 1980) and reductions in grain yields have also been reported (Mock and Erbach, 1977; Ketcheson, 1980; Karlen and Sojka, 1985; Hallauer and Colvin, 1985).

On some Southeastern soils, root-restricting traffic or tillage pans may exacerbate poor crop growth and grain yields in conservation-tillage systems. In-row subsoiling at planting has been shown to increase grain yields where root-restricting hardpans exist (Box and Langdale, 1984; Kamprath *et al.*, 1979; Thurlow and Elkins, 1983). Current no-till planters now have in-row subsoilers incorporated in their design.

Placing small amounts of soluble fertilizers in close proximity to the seed at planting, *i.e.* starter fertilizer applications, has been shown to increase early season plant growth and yields of cotton (Touchton *et al.*, 1984b), grain sorghum (Touchton *et al.*, 1984a) and soybean (Touchton, 1984) in both tilled and no-till production systems. Various N-P-K combinations have been used in starter fertilizer studies, but a strict definable starter fertilizer combination does not exist.

Starter fertilizers have traditionally been applied in shallow incorporated bands close to the seed at planting (2 x 2 inch placement). However, when in-row subsoilers are used at planting, the easiest (from a mechanical standpoint) placement of starter fertilizers is directly behind the subsoil shanks in the channel below the seed. Placement of starter fertilizers in the subsoil channel might lessen plant response to starter applications if young plant roots do not reach the zone of application early in the growing season.

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The purposes of this study were to determine if starter fertilizers would improve the growth and yield of corn grown in a conservation-tillage system, to compare placement of starter fertilizer in the in-row subsoiler channel to traditional 2 x 2 inch placement, and to determine if corn response to various starter combinations would vary among tillage systems and subsoiling practices.

MATERIALS AND METHODS

The study was conducted in 1983, 1984 and 1985 on a Decatur silt loam (clayey, kaolinitic, thermic, Rhodic Paleudults) at the Tennessee Valley Substation, Belle Mina, AL and in 1984 and 1985 on a Dothan sandy loam (fine-loamy, siliceous, thermic Plinthic Paleudults) at the Wiregrass Substation, Headland, AL. Both soils are deep and well drained. The Dothan soil has a 1.5 to 3-inch tillage or traffic pan located approximately 10 inches below the surface.

At Belle Mina, the initial soil pH, organic matter and cation exchange capacity were 6.4, 1.4% and 11.0 meq/100 g, respectively. Soil test ratings for P and K remained high (43-45 lb P and 304-348 lb K/ac, respectively) throughout the duration of the test. In February 1985, 20 lb P/ac and 40 lb K/ac were broadcast applied to the experimental site at Belle Mina. At Headland, the initial soil pH, organic matter and cation exchange capacity were 6.0, 1.0% and 4.8 meq/100 g, respectively. Soil test ratings for P and K remained high (74-96 lb P and 122-134 lb K/ac, respectively) throughout the duration of the test at this location also. In November 1984, 1 ton dolomitic limestone/ac, 18 lb P/ac, 33 lb K/ac and 10 lb S/ac were broadcast applied to the experimental site.

Treatment variables included 1) tillage systems (no-till or conventional tillage), 2) starter fertilizer placement (6-10 inches below the seed in the subsoil channel or shallow incorporation near seed row), 3) starter fertilizer combinations (N, N-P, N-P-K or none), and 4) in-row subsoiling (subsoiled or not subsoiled). One to two weeks prior to planting, the conventional-tilled plots were tilled. Rye (*Secale cereale* L.) in the no-till plots was killed with paraquat (0.5 lb/ac ai). Tillage consisted of disk-chisel plow (8-inch depth)-disk at Belle Mina and disk-chisel plow (8-inch depth)-roterra at Headland. A no-tillage planting unit with in-row subsoilers (Brown-Harden Ro-till[3]) was used to plant all plots. The subsoilers were removed to plant the nonsubsoiled plots. Subsoiler depth was 8 and 12 inches at the Belle Mina and Headland locations, respectively. Starter fertilizer combinations were made from 32% urea ammonium nitrate solution (UAN), ammonium polyphosphate (10-34-0) and muriate of potash (0-0-62) to supply 22 lb N/ac, 9.7 lb P/ac and 6.6 lb K/ac where applicable. For the subsoil-placed fertilizer treatment, the starter fertilizers were dropped into the subsoil channel through a 0.5-inch diameter tube welded to the rear of the subsoiler shanks, and mixed with the soil directly under the seed at a depth of 6 to 10 inches. For the shallow placed treatment, the fertilizers were incorporated with a double disk two inches deep in close proximity to the seed. At Belle Mina, this shallow placement was two inches from the row, while at Headland, where corn was planted in twin seven inch rows, the starter fertilizers were incorporated between the twin rows resulting in a 3 x 2 inch placement.

At Belle Mina, the experimental design was a randomized complete block replicated four times. Within the no-till system, all combinations of starters and placements were included and compared to identical starter combinations placed 2 x 2 in conventionally tilled, nonsubsoiled plots. At this location, there is no well-defined tillage pan. Conventionally tilled plots with 2 x 2 starter fertilizer placement would be considered the standard practice.

The coarser textured Dothan soil at Headland is subject to formation of a tillage pan. In-row subsoiling is a common practice on this soil. Consequently, treatments were expanded to include all starter combinations, subsoiling treatments and fertilizer placements in both no-till and conventional tillage systems. The experimental design was a split plot within a randomized complete block replicated four times. Tillage systems were the whole plot treatments. Starter combinations-subsoiling-starter placement variables were split plot treatments. Plots were 12 x 40 ft, cotton was the previous crop and rye was grown as a winter cover crop.

At Belle Mina, Pioneer 3369A corn was planted May 2, 1983, April 13, 1984 and March 26, 1985. Seeding rate was 24,000 seeds/ac. The population was thinned to 20,000 plants/ac after stand establishment. Row width was 36 inches in 1983 and 30 inches in 1984 and 1985. At Headland, Dekalb-Pfizer Genetics T-1230 corn was seeded at 32,000 seeds/ac on March 20, 1984 and March 26, 1985. The population was thinned to 28,000 plants/ac. Row spacing at Headland was twin seven inch rows on 36-inch centers. Weeds were effectively controlled each year with Aatrex (1.2 lb/ac ai) plus Dual (1.2 lb/ac ai) at Headland, and Aatrex (1 lb/ac ai) and Lasso (1.5 lb/ac ai) at Belle Mina. At Belle Mina, 32% UAN was knifed beside the row four weeks after planting to deliver 120 lb N/ac in 1983 and 130 lb N/ac

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in 1984 and 1985. At Headland, 200 lb N/ac as 32% UAN, 20 lb S/ac, 4.5 lb Zn/ac and 2 lb B/ac was knifed beside the row four weeks after planting in 1984. In 1985, 180 lb N/ac and 10 lb S/ac was knifed beside the row four weeks after planting. The corn at Headland was irrigated 6.5 inches in 1984 and in 1985 during an eight week period starting approximately four weeks before silking. The corn at Belle Mina was not irrigated. Rainfall and supplemental irrigation distribution throughout the growing season are shown in Table 1.

Table 1. Rainfall and irrigation distribution by location and year during growing season.

Date	Headland 1984	Headland 1985	Belle Mina 1983	Belle Mina 1984	Belle Mina 1985
	inches				
March 15-21	1.09	1.02	1.29	2.56	0.06
22-31	0.39	0.03	0.96	3.32	1.69
April 1- 7	2.17	1.19	4.53	1.99	0.72
8-14	1.28	0.00	1.75	0.23	0.03
15-21	1.29	0.56	0.70	0.36	1.06
22-30	1.46	0.02	1.31	4.01	1.26
May 1- 7	0.74	1.64*	0.87	4.04	3.86
8-14	1.00*	2.95	0.51	2.92	1.70
15-21	1.75*	1.07*	6.97	0.01	0.06
22-31	1.55	2.05*	1.83	0.81	0.55
June 1- 7	1.00	1.00*	2.51	0.00	0.00
8-14	3.14*	2.35*	0.01	1.83	0.17
15-21	0.20	0.99	3.18	0.59	1.96
22-30	6.73*	1.43*	0.65	3.10	1.01
July 1- 7	0.64	2.53	0.50	0.04	0.84
8-14	0.85	1.47	0.01	1.39	0.94
15-21	0.80	0.88	0.06	1.04	0.55
22-31	2.08	0.72	0.00	1.75	3.55
August 1- 7	2.96	0.00	0.18	1.19	0.32
8-15	0.09	2.02	0.13	0.04	0.90

* Irrigation applications (1-2 inches) supplemented rainfall.

Plant heights were measured (top of whorl) and whole plant samples were taken for nutrient analyses six weeks after planting in 1984 and 1985 at both locations. Earleaf samples were taken at early silking and analyzed for nutrient concentrations in all years. The inner 30 ft of the two middle rows of each plot were hand harvested and grain yields adjusted to 15.5% moisture. Data were analyzed using analysis of variance for the appropriate model at each location and means were separated using Fishers protected least significant difference. The 10% level of probability was used to declare differences significant.

RESULTS AND DISCUSSION

Decatur Soil, Belle Mina

Plant heights, averaged over tillage systems, starter combinations and placements, were increased 33% in 1984 and 39% in 1985 by starter fertilizers (Table 2). With the exception of the N-P combination in the conventional-tilled plots in 1985, N alone was as effective in increasing plant height as N-P or N-P-K. In 1985 there were no differences in plant height with placement methods, but in 1984 deep-placed N was inferior to 2 x 2 placed N. In both years, N-P and N-P-K combinations were equally effective when placed 2 x 2 or in the subsoil channel. Subsoiling without application of starter fertilizer had little effect on plant heights in 1984 and 1985.

In 1984 N, and in 1985 N and P were the only nutrient concentrations significantly affected by treatments in whole plant samples six weeks after planting. Nitrogen concentrations ranged from 2.60-3.33% in whole plant tissue in 1984, and from 4.59-5.26% in 1985. The only discernible relationships between N concentration and treatments was a dilution effect in which treatments that resulted in the best growth had lower N concentrations (data not shown). Tillage affected P concentration in 1985. Phosphorus averaged 0.43 vs 0.37% in tilled and no-tilled plots, respectively. The only earleaf nutrient affected by treatments was Mn in 1984. Mn was significantly lower in conventional-till plots than in no-till plots (78 vs 88 ppm).

Grain yields in 1983 were limited by severe drought in July (Table 1), but yield responses to starter fertilizers occurred (Table 2). The only response in the conventional-till system was to N-P-K. Deep-placed N-P and 2 x 2-placed N-P-K combinations in the no-till system increased yield. Within the no-till system, yields from N-P applications were equivalent to those from N-P-K applications (57 bu/ac and 59 bu/ac, respectively). Starter placement and tillage system did not affect yields.

In 1984, starter fertilizers did not affect yields in the conventional-till plots (Table 2). Within no-till plots, there was a nonsignificant trend for starter fertilizers to increase yields. The trend was similar for all starter combinations and placement methods. The primary yield response was to tillage and subsoiling, but within no-till plots starter fertilizer applications could substitute in part for subsoiling in increasing yields. Yields from no-till plots without subsoiling were 125, 136, 140 and 140 bu/ac for no-starter, N, N-P and N-P-K treatments, respectively, compared to 158 bu/ac in the no-till, no-starter, subsoiled treatment. Subsoiling no-till plots did not result in yield increases over conventional-tilled nonsubsoiled plots unless starter fertilizers were applied.

In 1985, the beneficial effects of starter fertilizers on early season plant growth did not result in increased grain yields (Table 2). Within no-till subsoiled plots, N-P and N-P-K starter combinations reduced grain yields an average of 16 bu/ac when applied in the subsoil channel compared to subsoiled plots where starters were not applied. Since this site was not irrigated, it is possible that the larger plants resulting from application of starter fertilizers were more sensitive to short term droughts or initiated silking earlier (at a time coinciding with an 18-day drought) than plants not fertilized with starters. Rainfall records indicated that plants silking before June 15 would have been subject to drought stress, while those silking after June 15 would not have been. This date coincides with the observed period for silking in 1985.

Dothan Soil, Headland

In 1984, subsoiling increased early season plant height in both tillage systems only when starter fertilizers were applied (Table 3). With the exception of reduced plant heights in the no-till 3 x 2-placed N-P starter treatment, tillage systems did not affect plant heights. In 1985, subsoiling increased early season plant growth in the no-till system. Within the conventional-tilled system, early season plant growth responded to deep placed N-P and N-P-K starter combinations in 1984 and 1985. In the no-till system, the only deep-placed starter combination that increased plant heights was the N-P-K. This response occurred both years. The 3 x 2 placement proved best for applying starter fertilizer in both tillage systems in both years. Maximum plant height was obtained by in-row subsoiling and applying starter fertilizers in 3 x 2 placement. Generally, in both years within the conventional-tilled system, application of N alone resulted in plant heights equivalent to those resulting from N-P or N-P-K applications. In 1985, however, deep-placed N-P and N-P-K increased plant height over deep-placed N in the conventional-tilled system.

In 1984, in no-till system subsoiled plots, N-P or N-P-K combinations resulted in greater plant heights than N alone when applied in 3 x 2 placement. In 1985, in the no-till system, the N-P combination resulted in increased plant heights compared to N alone when in-row subsoiling was used. However, the N-P-K combination was no better than N-P.

Concentrations of N, P, K, Ca, Mg and Mn in whole plants sampled six weeks after planting were significantly affected by treatments. However, as at Belle Mina, the primary effect was a dilution effect in which treatments that resulted in the best plant growth (3 x 2-placed starters with in-row subsoiling) had lower

Table 2. Effect of tillage system, starter fertilizer combination and placement, and in-row subsoiling on early season growth and corn grain yield at Belle Mina, AL.

Tillage	Starter fertilizer† combination	In-row subsoiling	Starter fertilizer‡ placement	Plant height§ 1984	Plant height§ 1985	Grain yield 1983	Grain yield 1984	Grain yield 1985
				inches		bu/ac		
Conventional	None	No	—	11	17	50	153	104
Conventional	N	No	2 x 2	17	23	48	152	92
Conventional	N-P	No	2 x 2	16	33	51	150	94
Conventional	N-P-K	No	2 x 2	15	23	59	153	94
No-till	None	Yes	—	14	17	51	158	97
No-till	None	No	—	13	15	51	125	104
No-till	N	Yes	deep	15	20	55	169	99
No-till	N	Yes	2 x 2	17	20	56	165	100
No-till	N	No	2 x 2	19	22	54	136	91
No-till	N-P	Yes	deep	17	22	58	167	83
No-till	N-P	Yes	2 x 2	17	22	56	168	87
No-till	N-P	No	2 x 2	17	22	57	140	91
No-till	N-P-K	Yes	deep	16	21	56	172	80
No-till	N-P-K	Yes	2 x 2	17	22	60	171	87
No-till	N-P-K	No	2 x 2	17	22	61	140	93
$LSD_{0.10}$ any two values				1.9	2.0	6.6	14.0	12.0

† N = 22 lb/ac, P = 9.7 lb/ac, K =6.6 lb/ac.
‡ Deep placement was in subsoil track.
§ Height to top of whorl six weeks after planting.

concentrations of these elements. Slight treatment differences in earleaf K, Ca and Mg concentrations occurred in 1984 and again in 1985 for Mg and Mn, but there were no discernible relationships between treatment effects on the concentrations of these elements and yield in either year (data not shown).

In both 1984 and 1985, grain yields did not vary between tillage systems; therefore grain yields were averaged over both tillage systems for presentation in Table 3. In 1984, lack of any rainfall during the two week period coinciding with silking amplified subsoiling treatment effects on grain yield despite supplemental irrigation (Table 3). Yield increases to subsoiling generally occur when drought stress periods are of short duration (Box and Langdale, 1984; Trouse, 1983). Moisture stress at silking can reduce grain yield by 50% (Denmead and Shaw, 1960). Averaged over tillage systems and starter fertilizer treatments, in-row subsoiling increased grain yields 116%. In nonsubsoiled treatments, yields were increased an average of 37% by application of starter fertilizers. The N-P or N-P-K combinations did not increase yields more than applications of N alone in the nonsubsoiled treatments. Grain yields of in-row subsoiled plots were also increased by the use of starter fertilizers. However, N alone increased yields only when applied in a 3 x 2 placement. The N-P and N-P-K combinations increased yields when applied in the subsoil channel or in a 3 x 2 placement. Regardless of starter combination, the 3 x 2 placement resulted in higher yields.

In 1985, the only yield response was to in-row subsoiling. Yields averaged 176 bu/ac with and 147 bu/ac without subsoiling.

CONCLUSIONS

Starter fertilizers increased early season plant growth in both conventional-till and no-till corn production systems. Crop response to starter applications and placement methods was dependent on tillage systems, climatic conditions, and soil conditions, viz. soil moisture, texture and presence of a root-restricting hardpan. Response of early season crop growth to starter fertilizer applications may be greater in conservation tillage systems. On the coarse-textured Dothan soil with a root-restricting hardpan, maximum response was obtained when both N and P were applied in a 3 x 2 placement in conjunction with in-row subsoiling. On the finer textured Decatur soil, generally, the best growth was obtained with N-P starter applications, although N seemed more essential. Neither starter placement nor subsoiling proved critical on this soil.

Early season plant growth was not always indicative of grain yields. On the Dothan soil, yield responses to starter applications, placement and subsoiling were similar to plant growth responses in a year of insufficient rainfall. When rainfall was more adequate, only

Table 3. Effect of tillage system, starter fertilizer combination and placement, and in-row subsoiling on early season growth and corn grain yield at Headland, AL.

Starter fertilizer† combination	In-row subsoiling	Starter fertilizer‡ placement	Plant height§ 1984 Conventional	Plant height§ 1984 No-till	Plant height§ 1985 Conventional	Plant height§ 1985 No-till	Grain yield¶ 1984	Grain yield¶ 1985
			inches				bu/ac	
None	Yes	——	18	17	20	18	109	174
None	No	——	19	15	18	15	40	147
N	Yes	deep	21	19	20	19	114	173
N	Yes	3 x 2	26	22	26	25	128	178
N	No	3 x 2	20	18	24	21	51	147
N-P	Yes	deep	24	20	24	19	124	174
N-P	Yes	3 x 2	29	29	26	28	141	176
N-P	No	3 x 2	28	17	26	23	57	152
N-P-K	Yes	deep	22	24	23	21	125	178
N-P-K	Yes	3 x 2	28	27	26	26	137	178
N-P-K	No	3 x 2	22	20	23	23	56	140
$LSD_{0.10}$ within tillage			3.9		2.6			
$LSD_{0.10}$ any two values			4.3		2.9		10.0	12.0

† N = 22 lb/ac, P = 9.7 lb/ac, K =6.6 lb/ac.
‡ Deep placement was in the in-row subsoil track.
§ Height to top of whorl six weeks after planting.
¶ Grain yields are average over tillage systems.

subsoiling improved yields. On the Decatur soil, optimal yields were generally obtained with applications of N either in the subsoil channel or in a 2 x 2 placement. Response to subsoiling was erratic on this soil. Subsoiling silt loam soils with no distinct tillage or hardpan does not usually result in yield increases (Tyler and McCutchen, 1980; Ide *et al.*, 1984; Jamison *et al.*, 1952). Our data indicate that yield increases to starter applications occur frequently enough to justify the practice, and that generally N and P should be applied in a shallow incorporated band (2 x 2 or 3 x 2 inch placement). On soils with root-restricting hardpans, subsoiling in conjunction with shallow incorporation of N-P applications is necessary to achieve the maximum benefit of the starter application.

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