JOURNAL OF FERTILIZER ISSUES Volume 3, Number 1, January - March, 1986, Pages 1-6

Fluid Fertilization Practices for Corn in the Atlantic Coastal Plain[1]

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ABSTRACT

The efficiency of fertilizer use by corn (*Zea mays* L.) may be improved by combining fluid fertilization with in-row subsoiling. The purpose of our research in 1983 was to evaluate the effects of supplemental N-P-K fertilizer applied behind a subsoil shank prior to planting in a disked or non-disked seedbed. In 1984 our objectives were modified to compare traditional band placement (2 inches over and 2 inches below the seed), subsoil placement and broadcast application as methods for applying starter fertilizers rather than evaluating supplemental fertilization. All treatments were evaluated with and without irrigation on Norfolk (fine-loamy, siliceous, thermic, Typic Paleudult) loamy sand. Grain and silage yield as well as ear leaf concentration and aerial accumulation of N-P-K were measured in 1983. Seedling weight and nutrient concentrations, ear leaf nutrient concentrations and grain yield were measured in 1984. Results show that deep placement of fluid fertilizer behind the subsoil shank was not optimum for a starter fertilizer nor beneficial for supplemental deep fertilization. Poor response to subsoil placement was probably caused by the fluid fertilizer flowing along the subsoil shank and being placed in a narrow zone approximately 18 inches below the seed. This was too deep for optimum fertilizer efficiency and may have prevented root penetration because of acidification or the salt concentration. For placement of fluid fertilizers behind subsoil shanks to be effective and advantageous, uniform distribution of the fertilizer throughout the physically-disturbed zone is necessary.

***Additional index words:* *Zea mays,* L., Nitrogen, Phosphorus, Tillage systems, Fertilizer placement, Subsoil fertilization, Deep fertilization.**

MANY Atlantic Coastal Plain soils have traffic, tillage or genetic pans that can restrict root growth. This restricted root growth reduces the volume of plant available water and decreases the soil volume from which available plant nutrients can be obtained. To alleviate the physical restrictions to roots, annual in-row subsoiling has been incorporated into conventional- and conservational-tillage systems (3, 4, 5, 10).

Subsoil shanks disrupt an inverted triangular zone approximately 10 inches wide at the surface and 14 to 18 inches deep at the apex (10). Physical characteristics of the disturbed zone are very favorable for root growth, but in previous corn (*Zea mays* L.) experiments, this has resulted in root proliferation in a very small portion of the Ap and B soil horizons (4). Those observations suggest that since root growth is restricted to a small portion of the surface soil, optimum fertilization practices for the disturbed zone should be determined.

The use of starter fertilizer on Coastal Plain soils generally improves early-season growth and increases yield (9, 11). This occurs in dry years because high soil strength restricts root exploration and in wet years because N, S and even K (7) are leached from surface to subsoil horizons.

Band placement, approximately 2 inches to the side and 2 inches below the seed (2 x 2), is the traditional method for applying starter fertilizer. However, in production systems which utilize subsoiling, fluid fertilizers can be injected through tubes attached to the backside of each subsoil shank. This "subsoiler" placement may permit higher fertilization rates because a larger soil volume can be treated. It may also help alleviate the low P fertility of subsoil horizons (7, 11) and prevent stratification of P when conservation tillage systems are used. Subsoil fertilization may also benefit soybean (*Glycine max* L. Merr.), cotton (*Gossypium hirsutum* L.) and other row crops which respond to in-row subsoiling in this region. The objectives in these studies were to evaluate subsoil placement of fluid fertilizer as a method for supplemental deep fertilization and as a placement method for starter fertilizer.

MATERIALS AND METHODS

These field studies were conducted in 1983 and 1984 on a Norfolk (fine-loamy, siliceous, thermic Typic Paleudult) loamy sand at the Clemson University Research and Education Center near Florence, SC. Mehlich I soil test nutrient concentrations in the Ap and B horizons are listed in Table 1 for both years. Soil test ratings (Ap horizon) based on those analyses indicated high P and Mg, medium K and Ca, and adequate Mn and Zn for corn production (1). Dolomitic lime was applied at a rate of 1500 lb/ac each year to raise soil pH to approximately 6.0.

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[1] Contribution of the Coastal Plains Soil and Water Conservation Research Center, U.S. Department of Agriculture — Agricultural Research Service, Florence, SC, and Clemson University Cooperative Extension Service, Clemson, SC 29631.

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Table 1. Initial soil test analyses for Ap and B horizons of a Norfolk loamy sand in 1983 and 1984.

Soil horizon	Year	Water pH	Mehlich 1 extractable					
			P	K	Ca	Mg	Mn	Zn
			lb/ac					
Ap	1983	5.4	110	170	600	100	20	8
B	1983	4.9	6	245	720	160	2	1
Ap	1984	5.7	115	145	650	120	24	6
B	1984	4.8	12	185	625	150	2	1

Water management, tillage and fertilization treatments were evaluated in a stripped split-plot experimental design that was replicated five times. Water management (nonirrigated and irrigated) whole plots were split in strips for conventional (disked) and conservation (nondisked) tillage treatments. Fertilization treatments were randomly assigned within each tillage subplot.

The three fertilization treatments evaluated in 1983 were deep placement of 0, 28 or 56 gal/ac of an 8-22-0 suspension directly behind the subsoil shank just before planting. The fertilizer was applied through one tube attached to each subsoil shank with an intended application depth of approximately 12 inches. The 28 and 56 gal/ac treatments supplied 25 and 68 or 50 and 136 lb/ac of N and P_2O_5, respectively, and were considered "supplemental" because 60, 60 and 180 lb/ac of N, P_2O_5 and K_2O had been broadcast prior to planting.

In 1984, the three "starter" fertilization treatments were band (2 x 2) or subsoiler placement of 60 lb/ac N and P_2O_5 using fluid 18-18-0 and broadcast application of 600 lb/ac 10-10-10. To balance the K_2O application, 100 lb/ac of 0-0-60 was broadcast on the band and subsoil placement plots prior to planting. A second modification, implemented to improve fertilizer distribution in 1984, was to use three tubes behind each subsoil shank. The intended application depths for those tubes were 2, 6 and 12 inches below each row.

Pioneer Brand[3] 3382 and McCurdy 84AA corn hybrids were grown in 1983 and 1984, respectively. Nonirrigated and irrigated blocks were thinned to populations of 22,500 or 32,500 plants/ac, respectively, for both tillage systems. Supplemental irrigation water was applied when the average of 10 tensiometers placed in the row showed soil-water tensions at the 8-inch depth to be 25 centibars (cb) or greater. All treatments were sidedressed with 140 lb/ac of N using anhydrous ammonia about five weeks after planting to complete the seasonal fertilization which is summarized in Table 2.

Table 2. Subsoil and total N, P and K fertilizer applied to a Norfolk loamy sand in 1983 and 1984.

Year	Subsoil		Total		
	N	P_2O_5	N	P_2O_5	K_2O
	lb/ac				
1983	0	0	200	60	180
1983	25	68	225	108	180
1983	50	136	250	196	180
1984	60	60	200	60	180

Leaves opposite and below the ear were collected at silking for N, P and K determinations. At physiological maturity in 1983, plants from 7 ft of row were collected and weighed. Eight stalks from each plot were shredded and subsampled for dry matter determination and N, P and K analyses. All plant samples were dried at 160° F, ground and digested using sulfuric and selenous acids in a Technicon block digestor. Nitrogen and P concentrations were measured colorimetrically while K was measured by flame emission. Silage yield was calculated by adjusting dry matter measurement to a 70% water content. Grain yield was measured by harvesting two 30-inch rows, 85 ft long with an Almaco plot combine. Grain moisture was measured using a Steinlite SS250 meter, and yields were adjusted to a 15.5% water content. Statistical analyses for the stripped-split-plot experimental design included ANOVA and LSD's. The 10% level of probability was used for separating treatment means.

RESULTS AND DISCUSSION

Supplemental Fertilizer Response, 1983

Effects of supplemental, subsoil-placed fertilizer in 1983 are presented in Table 3. When averaged for

[3] Mention of trademark, proprietary product, or vendor does not constitute a guarantee of warranty of the product by the U.S. Dept. of Agriculture or the South Carolina Agricultural Experiment Station and does not imply its approval to the exclusion of other products or vendors that may also be suitable.

tillage and water management treatments, grain and silage yields were not affected by the fertilization treatments. However, ear leaf N, P and K concentrations, as well as total P in the silage, were lower with the supplemental fertilizer than where only broadcast fertilizer was applied. Visual observations throughout the growing season also indicated that the supplemental, subsoil-applied fertilizer resulted in poorer plant growth. The reason for poorer growth with than without subsoil-applied fertilizer is not known, but may have been caused by root pruning due to the concentrated band of fertilizer at the bottom of the subsoil track.

Visual observation indicated that most of the fertilizer solution followed the subsoil shank and was concentrated at the bottom of the subsoil zone. Concentrated placement of 25 or 50 lb/ac of N fertilizer in such a small soil volume apparently created an adverse chemical environment for root growth because of salt effects and/or acidification of a weakly-buffered acid subsoil. This adverse chemical environment presumably slowed early-season root growth and exploration of the subsoil for plant available water.

Norfolk soils retain approximately 2.5 inches of available water in an effective 30-inch root zone. In 1983, seasonal precipitation (April 15 to August 15) totaled only 12.4 inches which, because of poor distribution, caused several short-term periods of water stress. Irrigated blocks received an additional 7.7 ac-inches of water during the growing season. Irrigation alleviated plant water stress which was enhanced by the subsoil fertilization and resulted in significant water management by fertilization interactions for silage yield, ear leaf P, and whole plant nutrient accumulation (Table 4).

Table 3. Grain and silage yield, ear leaf N, P and K concentrations and whole plant N, P and K accumulation as influenced by supplemental subsoil fertilization in 1983.

Subsoil fert.		Yield		Ear leaf			Accumulation		
N	P_2O_5	Grain	Silage	N	P	K	N	P	K
— lb/ac —		bu/ac	ton/ac	— % —			— lb/ac —		
0	0	145	37.8	3.02	0.35	2.58	199	44	260
25	68	144	36.3	2.63	0.25	2.40	208	42	264
50	136	146	35.9	2.68	0.25	2.38	195	38	256
$LSD_{0.10}$		NS	NS	0.13	0.02	0.11	NS	3	NS
CV (%)		7	9	9	11	8	13	16	14

Table 4. Interactive effect of subsoil fertilizer placement and supplemental irrigation water on corn yield, nutrient status at silking and total nutrient accumulation in 1983.

Subsoil		Water	Yield		Ear leaf			Accumulation		
N	P_2O_5	Management	Grain	Silage	N	P	K	N	P	K
— lb/ac —			bu/ac	ton/ac	— % —			— lb/ac —		
0	0	NI[†]	126	35.9	3.09	0.33	2.56	197	41	258
25	68	NI	123	30.9	2.64	0.25	2.45	182	34	235
50	136	NI	130	32.2	2.66	0.25	2.32	179	33	228
0	0	I	165	39.6	2.95	0.38	2.60	201	46	261
25	68	I	165	41.7	2.62	0.25	2.35	235	50	294
50	136	I	161	39.5	2.70	0.24	2.45	211	43	285
$LSD_{0.10}$			NS	2.6	NS	0.02	NS	20	5	28
CV (%)			7	9	9	11	8	13	16	14

[†] NI = nonirrigated; I = irrigated

Fertilizer Placement Comparisons, 1984

In 1984, subsoil N-P fertilization was compared to broadcast or band application. Subsoiler placement resulted in slowest seedling growth, while 2 x 2 placement resulted in the best seedling growth (Table 5). There was no difference in seedling N concentration among treatments, but because of growth differences, the band-applied fertilizer resulted in 25 lb/ac (0.35 g/plant) more plant N than the subsoil placement. Other plant nutrient concentrations were within normal ranges (6, 8, 12), although acidification effects of UAN (2) in the starter fertilizer were indicated by higher Mn concentrations in plants receiving the band treatment.

The subsoil placement technique was changed in 1984 from 1 to 3 discharge tubes of varying length in order to increase the fertilized soil volume. However, it appeared that once again the fertilizer solution followed the subsoil shank and was concentrated about 18 inches beneath the soil surface. Plants were therefore able to benefit from the fertilizer placed behind the subsoil shank only after roots reached that zone with residual fertility. At silking, ear leaf nutrient concentrations (Table 6) were generally not significantly different, although increased ear-leaf K concentration in plants receiving subsoil-placed fertilization suggests that by this growth stage root proliferation in the upper part of the B horizon was greater, because that is where K tends to accumulate in these soils (7).

A significant interaction between fertilizer placement and water management occurred in 1984, even though seasonal rainfall totaled 25.1 inches and only 4.4 ac-inches of supplemental irrigation water were applied. A short period of water stress occurred during early June. The enhanced early-season growth with the band placed N-P fertilizer caused those plants to initiate pollination when water stress was most severe. Without supplemental irrigation, the enhanced early-season growth benefit of banded fertilizer became a detriment for grain yield (Table 7). Irrigation prevented water stress and resulted in highest grain yield where fertilizer was banded. This response emphasizes the importance of water management on Coastal Plain soils and demonstrates how a normally beneficial fertilization practice can be nullified by seasonal weather patterns.

Table 5. N-P placement effects on early-season growth and nutrient concentrations in corn grown with conventional tillage on Norfolk loamy sand in 1984.

N-P placement	Shoot weight	Seedling concentrations									
		N	P	K	Ca	Mg	S	B	Cu	Mn	Zn
	g	%						ppm			
Broadcast	24.3	2.64	0.34	5.11	0.43	0.36	0.31	15	8	33	46
Subsoil	20.3	2.58	0.38	5.24	0.38	0.31	0.27	9	8	34	36
Band (2 x 2)	32.0	2.74	0.39	4.59	0.42	0.35	0.32	11	7	50	38
$LSD_{0.10}$	3.5	NS	0.04	0.48	0.03	NS	0.03	4	NS	6	8
CV (%)	12	8	9	8	7	21	10	30	16	13	16

Table 6. N-P placement effects on ear leaf nutrient concentrations in corn grown with conventional tillage on Norfolk loamy sand in 1984.

N-P placement	Ear leaf								
	N	P	K	Ca	Mg	Cu	Fe	Mn	Zn
	%					ppm			
Broadcast	2.44	0.25	2.31	0.40	0.20	9	114	30	14
Subsoiler	2.48	0.26	2.52	0.43	0.19	8	119	32	14
Banded	2.45	0.26	2.37	0.41	0.21	7	113	25	13
$LSD_{0.10}$	NS	NS	0.14	NS	NS	NS	NS	NS	NS
CV(%)	4	5	5	14	22	18	14	40	29

Table 7. Interactive effect of N-P placement and water management on yield of corn grown on Norfolk loamy sand in 1984.

Water management	N-P placement	Grain yield bu/ac
Nonirrigated	broadcast	157
Nonirrigated	banded	129
Nonirrigated	subsoiler	160
Irrigated	broadcast	154
Irrigated	banded	166
Irrigated	subsoiler	154
$LSD_{0.05}$		24
CV (%)		12

Band placement was not evaluated in the conservation tillage blocks because attaching the Nutri-till system to the Brown-Harden Superseeder prevented crop residues from passing beneath the implement. However, subsoil and broadcast placement of N-P fertilizer were compared for both tillage systems. Plant growth with subsoil placement was slower than with broadcast placement under both conventional and conservation tillage (Table 8). This response is also attributed to placement of fertilizer nutrients 18 inches deep rather than distributing them uniformly throughout the subsoiled zone. Early-season N concentrations for both placement techniques were lower than average for whole plant samples (6, 8, 12), suggesting that nutrient use efficiency was not optimum even though 600 lb/ac of 10-10-10 had been broadcast.

Ear leaf analyses (Table 9) and grain yield indicate that the plant roots eventually reached the fertilizer placed behind the sub-soil shanks. Significant differences in K concentrations probably occurred because of greater root proliferation in the top of the B horizon. In general, ear leaf-N concentrations were lower than desired (6, 8, 12) suggesting that marginal early-season N concentrations were never corrected. This suggests low N may have limited grain yield, because other plant nutrients were within acceptable ranges.

Table 8. Fertilizer placement and tillage interaction effects on early-season growth and nutrient concentrations in corn grown on Norfolk loamy sand in 1984.

N-P placement	Tillage system	Shoot weight	Seedling concentration									
			N	P	K	Ca	Mg	S	B	Cu	Mn	Zn
		g	%						ppm			
29 days after planting												
Broadcast	conventional	1.5	3.01	0.32	3.94	0.50	0.43	0.26	18	28	32	48
Subsoiler	conventional	1.0	3.10	0.31	4.09	0.44	0.39	0.25	20	32	25	52
Broadcast	conservation	1.3	3.35	0.35	4.26	0.42	0.38	0.30	15	67	27	53
Subsoiler	conservation	0.8	3.74	0.35	4.40	0.43	0.36	0.35	12	78	35	54
$LSD_{0.10}$†		0.2	0.26	0.05	0.21	0.05	0.08	0.09	15	38	16	12
CV (%)		12	7	13	4	9	16	26	82	63	47	20
Significance of F												
Tillage		NS	*	*	**	**	NS	*	NS	**	NS	NS
Placement		***	**	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction		NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS
45 days after planting												
Broadcast	conventional	24	2.64	0.34	5.11	0.43	0.36	0.31	15	8	33	46
Subsoiler	conventional	20	2.58	0.38	5.24	0.38	0.31	0.27	9	8	34	36
Broadcast	conservation	22	2.52	0.36	5.15	0.42	0.33	0.31	15	9	42	46
Subsoiler	conservation	17	2.73	0.38	4.81	0.38	0.26	0.28	9	9	39	32
$LSD_{0.10}$		4	0.20	0.03	0.32	0.03	0.05	0.05	3	1	4	9
CV (%)		15	6	8	5	7	14	14	19	14	8.5	19
Significance of F												
Tillage		**	NS	NS	NS	NS	*	NS	NS	NS	**	NS
Placement		***	NS	**	NS	***	**	*	***	NS	NS	***
Interaction		NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS

† LDS, least significant difference; CV, coefficient of variation; Significance = NS if not significant, *, **, *** if significant at 10%, 5% or 1%, respectively.

Table 9. N-P placement and tillage interaction effects on ear leaf nutrient concentrations and grain yield of corn grown on Norfolk loamy sand in 1984.

N-P placement	Tillage system	Grain yield	Ear leaf concentration									
			N	P	K	Ca	Mg	S	Cu	Fe	Mn	Zn
		bu/ac	%						ppm			
Broadcast	conventional	155	2.44	0.35	2.31	0.40	0.20	—	9	114	30	14
Subsoiler	conventional	157	2.48	0.26	2.52	0.43	0.19	—	8	119	32	14
Broadcast	conservation	151	2.34	0.26	2.24	0.40	0.21	—	7	112	25	12
Subsoiler	conservation	144	2.51	0.25	2.31	0.40	0.20	—	7	107	24	12
$LSD_{0.10}$†		14	0.22	0.03	0.10	0.06	0.05	—	2	11	13	3
CV (%)		11	8	9	4	12	21	—	18	8	40	22
Significance of F												
Tillage		*	NS	NS	NS	NS	NS	—	NS	NS	NS	NS
Placement		NS	NS	NS	***	NS	NS	—	NS	NS	NS	NS
Interaction		NS	NS	NS	NS	NS	NS	—	NS	NS	NS	NS

† LDS, least significant difference; CV, coefficient of variation; Significance = NS if not significant, *, **, *** if significant at 10%, 5% or 1%, respectively.

CONCLUSIONS

Subsoiler placement of fluid fertilizers on Atlantic Coastal Plain soils has potential, provided some type of deflection technique is used to uniformly distribute plant nutrients throughout the physically disturbed zone. Residual fertility of these soils is low and if fertilizers are concentrated at the base of the subsoiled zone, early-season corn growth will be slow and the full yield potential will not be realized.

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