PRODUCTION AGRICULTURE

Agronomic and Economic Analyses of Cotton Starter Fertilizers

Craig W. Bednarz,* Glen H. Harris, and W. Don Shurley

ABSTRACT

None of the published literature has focused on the response of cotton (*Gossypium hirsutum* L.) to various starter fertilizer sources. This study was conducted to determine (1) if cotton grown on Coastal Plain soils in South Georgia would respond to different starter fertilizer sources and (2) if use of starter fertilizers would result in an economic gain. Experiments were conducted in 1997 and 1998 at the Coastal Plain Experiment Station in Tifton on a Tifton loamy sand (fine-loamy, kaolinitic, thermic Plinthic Kandiudults), the Southeast Georgia Branch Station in Midville on a Dothan loamy sand (fine-loamy, kaolinitic, thermic Plinthic Kandiudults), and the Southwest Branch Experiment Station in Plains on a Greenville sandy clay loam (fine, kaolinitic, thermic Rhodic Kandiudults). Five starter fertilizer sources were applied 5 cm to the side of and 5 cm below the seed drill at planting in each study. Total shoot N and Ca were increased in two of the six studies with starter fertilizers. Likewise, plant height, leaf area index, and shoot dry weight was increased with starter fertilizers in two of the six studies. With the exception of micronaire, starter fertilizers did not significantly influence the fiber properties investigated. Differences in fiber properties did result in small differences in cotton price premiums or discounts. Lint yields were significantly increased with starter fertilizers at Midville and Plains in 1997, when the crop was exposed to an extended period of cool weather immediately after planting. The most appropriate cotton starter fertilizer appeared to depend on soil type.

THE RESPONSE OF COTTON to starter fertilizer has been investigated across much of the eastern half of the U.S. Cotton Belt (Funderburg, 1988 and 1993; Guthrie, 1991; Hodges and Baker, 1990; Hutchinson and Howard, 1997; Mullins and Burmester, 1997; Rickerl et al., 1987; Stewart and Edmisten, 1997 and 1998; Touchton et al., 1986). Most of these studies investigated the effects of ammonium polyphosphate starter fertilizer in relation to planting date (Guthrie, 1991; Stewart and Edmisten, 1997), tillage practice (Hutchinson and Howard, 1997; Touchton et al., 1986), fertilizer placement (Guthrie, 1991; Hodges and Baker, 1990; Stewart and Edmisten, 1998; Touchton et al., 1986), or fertilizer rate (Mullins and Burmester, 1997; Stewart and Edmisten, 1998). None of the published literature, however, has focused on the response of cotton to various starter fertilizer sources.

Due to reduced soil P mineralization, P-containing starter fertilizers are the reasonable source when planting under cool environmental conditions. Maples and Keogh (1973) reported increased lint yields from banded P when cool weather prevailed for several weeks after planting. Historical weather records from the Coastal Plain Experiment Station, however, indicate that the average 10-cm soil temperature at Tifton for the month of April is 18°C. Application of P-containing starter fertilizers to counter the effects of depressed soil mineralization at this temperature would be unnecessary. In addition, most soils in South Georgia contain medium to high levels of available P (Reich et al., 1981). Thus, ammonium polyphosphates may not be the ideal starter fertilizer choice. Finally, Touchton (1990) reported the lack of nutrient holding capacity in many southeastern U.S. soils could result in loss of some preplant applied N to leaching. Starter fertilizers may therefore be an environmentally and economically attractive method of preplant N fertilization. Our objectives were to determine (i) if cotton grown on Coastal Plain soils in South Georgia would respond to different starter fertilizer sources and (ii) if the use of starter fertilizers would result in an economic gain.

C.W. Bednarz, Univ. of Georgia, Coastal Plain Experiment Station, P.O. Box 748, Tifton, GA 31793; G.H. Harris and W.D. Shurley, Univ. of Georgia, Rural Development Center, P.O. Box 1209, Tifton, GA 31793. Received 30 July 1999. *Corresponding author (cbednarz@tifton.cpes.peachnet.edu).

Published in Agron. J. 92:766–771 (2000).

MATERIALS AND METHODS

Agronomic Analysis

Experiments were conducted in 1997 and 1998 at the Coastal Plain Experiment Station in Tifton, GA, on a Tifton loamy sand, the Southeast Georgia Branch Station in Midville, GA, on a Dothan loamy sand, and the Southwest Branch Experiment Station in Plains, GA, on a Greenville sandy clay loam. Preseason soil analysis results from all studies are presented in Table 1.

Fertility practices in each study were in accordance with the University of Georgia Cooperative Extension Service guidelines (Brown et al., 1997). In March of each year, 672 kg ha^{-1} of 3–9–18 N–P–K plus micronutrients (8% Ca, 2% Mg, 9% S, 0.13% B, 0.10% Fe, 1% Mn, and 0.35% Zn) was applied and harrow incorporated at Tifton, 417 kg ha^{-1} of 8–8–16 was applied and harrow-incorporated at Midville, and 336 kg ha^{-1} of 3–18–9 plus micronutrients (8% Ca, 2% Mg, 9% S, 0.13% B, 0.25% Fe, 0.60% Mn, and 0.35% Zn) was applied and harrow-incorporated at Plains. Trifluralin (α,α,α-trifluoro-2,6-dinitro-*N*,*N*-dipropyl-*p*-toluidine; 3.5 L ha^{-1}) was then applied and harrow-incorporated in all studies prior to ripping and bedding. At Midville, 18.7 L ha^{-1} of 1,3-dichloropropene was injected under the row while ripping and bedding for nematode control. Water stress was minimized in all studies with overhead sprinkler irrigation systems.

In 1997, cotton (cv. Deltapine 5690) was planted on 24 April at Midville and 25 April at Plains. Ensuing cold and wet environmental conditions delayed planting at Tifton until 10

Abbreviations: DAP, days after planting; LAI, leaf area index.

May. In 1998, Midville, Plains, and Tifton were planted with Deltapine 5690 on 11, 13, and 6 May, respectively. The seeding rate in all studies was 11.6 seeds m^{-2}. While planting, 6.7 kg ha^{-1} Aldicarb [2-methyl-2-(methylthio) propionaldehyde *O*-(methylcarbamoyl)oxime] was applied in furrow for insect control.

The starter fertilizer treatments (Table 2) were applied 5 cm to the side of and 5 cm below the seed drill at planting in all studies. Treatments were applied while planting at Tifton and Plains with a Monosem air planter (Lenexa, KS) fitted with fertilizer coulters (Pearman Enterprises, Chula, GA). A John Deere air planter (Moline, IL) unequipped for starter fertilizer application was used for the Midville study. Treatments were applied at Midville immediately after planting by fitting the same fertilizer coulters to a cultivator frame. Different planters and methods of treatment application were employed because row spacing at the Tifton and Plains locations (91 cm) differed from the Midville location (97 cm). After planting, fluometuron (1,1-dimethyl-3-(α,α,α-trifluoro-*m*-toly)urea; 3.5 L ha^{-1}) was broadcast for weed control. Insects were controlled as recommended by the University of Georgia Cooperative Extension Service (Brown et al., 1997).

In 1997, growth analyses were conducted 53 days after planting (DAP) at Midville, 54 DAP at Plains, and 38 DAP at Tifton. In 1998, growth analyses were conducted 31 DAP at Midville, 29 DAP at Plains, and 36 DAP at Tifton. During each growth analysis, plants from 4.4 m^2 were removed from each plot and plant height, leaf area index, and main stem nodes were recorded. The plants were then dried to uniformity and assayed for total plant N, P, Ca, and S.

Cotton was sidedressed with ammonium nitrate in early July in all studies. A total of 101 kg N ha^{-1} was applied to all treatments during each growing season (Table 3). All tests were defoliated in October with 0.4 L ha^{-1} tribufos plus 1.5 L ha^{-1} ethephon and 0.112 kg ha^{-1} thidiazuron. Lint yields were determined following machine harvest.

Statistical Analysis

Preliminary examination of the data showed that all variables except the four lint-quality variables (fiber length, uniformity ratio, fiber strength, and micronaire) produced a significant ($P < 0.05$) result when Bartlett's test for homogeneity of variances was applied to the six location–year combinations. Even transformation of the data by square root or log base 10 (when appropriate) did not alter the significance of Bartlett's test. Therefore, these data were analyzed using PROC MIXED (Littell et al., 1996) for each location-year group as a randomized complete block design where block and starter fertilizer were random and fixed effects, respectively. For the four quality variables, PROC MIXED was used to analyze the data as a split-plot in space and time, where location-year groups were the main plots and within each group, replications and starter fertilizers were the subplots. For this analysis, the fixed effect was starter fertilizer and random effects were year, location (year), and block (year location). Three replicates were used in the studies at Plains and Tifton in 1997. Four replicates were used in all other studies. Mean separation was done using Fisher's protected LSD ($P = 0.05$). Significant treatment differences were not found in 7 of the 14 variables analyzed (main stem node number, height-to-node ratio, shoot P concentration, shoot S concentration, fiber length, uniformity ratio, and fiber strength).

Economic Analyses

Seed cotton samples were ginned and quality factors obtained on lint from each of the six treatments. Quality factors were determined by high-volume instrumentation, and included fiber length, fiber strength, uniformity, and micronaire. Color and leaf grades were not obtainable; thus, all cotton was assumed to be color grade 41 and leaf grade 4.

Costs and net return were calculated for each fertilizer treatment and the untreated check for 1997 and 1998. The net return is defined as

$$NR(y, t) = L(y, t) \times [P(y, q, m) - GW(t, m)] - S(y, t) - ME - LF - PH(y, t) - I(y, t)$$

where NR is the net return above treatment costs (dollars ha^{-1}) in year (y) for treatment (t), L is lint yield (kg ha^{-1}) in year (y) for treatment (t), P is price (dollars kg^{-1}) in year (y) for quality factors (q) and marketing (m), GW is gin and warehousing costs (dollars kg^{-1}) for treatment (t) and marketing (m), S is starter fertilizer cost (dollars ha^{-1}) in year (y) for treatment (t), ME is additional machinery and equipment expenses (dollars ha^{-1}), LF is additional labor and fuel expenses (dollars ha^{-1}), PH is additional picking and handling costs (dollars kg^{-1}) on difference in yield between starter treatment (t) and the untreated check in year (y), and I is interest on S, LF, and PH for treatment (t) in year (y). Expenses S, LF, ME, PH, and I are zero for the untreated check.

The price received for cotton is dependent on quality, method, and time of marketing. For this study, it was assumed that half of the cotton was contracted on 1 June for harvest delivery and half was sold from warehouse storage on 1 March. These assumptions are reasonable and consistent with farmer decision-making. Contracted cotton received no price premiums for above-base-grade factors, but, if applicable, was discounted using the 1997 and 1998 Commodity Credit Corporation loan schedules for quality below base grade. Cotton sold from storage on 1 March received quality premiums and discounts, if applicable, based on spot market differentials reported by the USDA Agricultural Marketing Service.

The untreated check was not charged with the cost of starter fertilizer. The cost of starter fertilizer was calculated for each of the five treatments for both 1997 and 1998 (Table 4). Fertilizer costs are highly variable depending on location, local availability, quantity purchased, and method of delivery or pickup. Estimated fertilizer costs were calculated based on a survey of several fertilizer suppliers.

Use of starter fertilizer requires rental expenses or investment in the fertilizer injection coulter–knife units. Spray tank(s) and associated fittings and pumps are also required. Many farmers may already have this equipment and its cost may be *sunken* and irrelevant to the fertilizer use decision. Arguably, even if this equipment already exists, its use during cotton planting makes it unavailable elsewhere; thus, there may be hidden opportunity costs. For the purposes of this analysis, an investment in eight injection units (for an eight-row planter), pump, spray tank, and fittings totaling $2030 was assumed. Assuming 162-ha annual use, machinery and

Table 1. Soil analysis results from the starter fertilizer test sites in Midville, Plains, and Tifton, GA, in 1997 and 1998.

Study	pH	P	K	Ca	Mg	Zn	Mn
		kg ha^{-1}					
Plains 1997	6.2	40	189	887	211	1	44
Plains 1998	6.4	31	129	902	195	5	29
Midville 1997	6.1	38	198	753	61	9	19
Midville 1998	6.0	40	257	607	81	3	14
Tifton 1997	6.2	68	93	382	48	1	15
Tifton 1998	6.1	48	130	486	59	1	16

Table 2. Treatments applied to the starter fertilizer studies in Midville, Plains, and Tifton, GA, in 1997 and 1998. All treatments were applied 5 cm to the side of and 5 cm below the seed drill at planting.

Treatment		Starter fertilizer applied	Nutrients applied
		L ha^{-1}	kg ha^{-1}
10–34–0 + 32–0–0	(ammonium polyphosphate solution)	85 + 63	38 N + 38 P_2O_5
10–34–0	(ammonium polyphosphate solution)	85	11 N + 38 P_2O_5
32–0–0	(urea ammonium nitrate solution)	91	38 N
28–0–0–5 (S)	(urea ammonium nitrate solution)	103	38 N + 7 S
9–0–0–11 (Ca)	(calcium nitrate solution)	85	11 N + 13 Ca
Untreated		0	0

equipment costs (depreciation, interest, insurance, and repairs) were estimated at \$407.73 year^{-1}, or \$2.52 ha^{-1}.

Starter fertilizer is applied at planting without the need for an additional trip over the field. There are, however, labor and fuel costs associated with hauling and handling of the fertilizer, attaching and detaching the starter fertilizer row units, and tank cleaning. These hours and cost are minor when spread over several hundred hectares, but should nevertheless be considered. In this analysis, 162-ha annual use was assumed. Labor and fuel expenses were considered constant across years and treatments. It was estimated that 33 labor hours and 8 machinery (truck and/or tractor) hours were necessary on 162 ha of use, which cost \$2.25 ha^{-1}.

Several costs in cotton production are yield- and marketing-related. Thus, farmers do not receive the full price-income benefit from yield increasing inputs. Such costs include ginning, warehousing, interest, picking, and handling. For this analysis, net ginning, warehouse, and interest costs were assumed to be \$0.110 kg^{-1} for contracted cotton and \$0.176 kg^{-1} for stored cotton after deducting the value of cottonseed. Assuming half of the cotton was contracted and half sold from warehouse storage, the average cost would be \$0.143 kg^{-1}. Picking and handling costs were assumed to be \$0.066 kg^{-1}. The full cost of machine-picking ranges from \$0.198 to \$0.330 kg^{-1} (Givan and Shurley, 1999; Givan and Westberry, 1998), but much of this cost is fixed and not yield-related.

RESULTS AND DISCUSSION

Agronomic Analysis

Rickerl et al. (1987) reported 17 kg ha^{-1} of deep-placed urea ammonium nitrate as a starter solution increased whole-plant N concentration at 6 wk after planting. At Tifton in 1997 and 1998, side-banded urea ammonium nitrate solutions (32–0–0 and 28–0–0–5[S]) increased whole-plant N concentration at approximately 5 wk after planting relative to the untreated check and the side-banded ammonium polyphosphate (10–34–0 + 32–0–0 and 10–34–0) starter fertilizer (Table 5). In all studies, however, whole-plant N concentration was never below the sufficiency range (Plank, 1979).

Side-banded calcium nitrate (9–0–0–11[Ca]) increased whole-plant Ca concentration over the ammonium polyphosphate starter fertilizers at 5 wk after planting at Tifton in 1998 (Table 5). At Plains in 1998, calcium nitrate (9–0–0–11[Ca]) and 28–0–0–5(S) resulted in increased whole-plant Ca concentration at 4 wk after planting relative to the ammonium polyphosphate starter solutions. Whole-plant Ca was never deficient in any study or starter treatment (Plank, 1979).

Hutchinson and Howard (1997) reported side-banded ammonium polyphosphate increased plant height in conventional-tilled cotton relative to in-furrow and surface-banded starter fertilizer. No treatment in their study, however, increased plant height over broadcast fertilization without starter fertilizer application. Burmester et al. (1993) also observed no consistent height response to starter fertilizer. Touchton et al. (1986) observed that starter fertilizers increased plant height more consistently on a sandy loam soil. Increased plant height was observed in only two of the six studies (Table 5), once on the Tifton loamy sand and once on the Greenville sandy clay loam. In both instances, the increase could be attributed to side-banded ammonium polyphosphate.

Hutchinson and Howard (1997) also observed inconsistent increases in leaf area from side-banded ammonium polyphosphate in conventionally tilled cotton. At Midville in 1997, 28–0–0–5(S) resulted in increased leaf area index (LAI) relative to the untreated, 9–0–0–11(Ca), and 32–0–0 solutions (Table 6). Several starter solutions also resulted in increased LAI at Plains in 1997. At Tifton in 1998, however, 32–0–0 resulted in significantly lower LAI than the untreated as well as the ammonium polyphosphate starter solutions.

Shoot dry weight responded to starter fertilizer similarly to LAI and plant height (Table 6). At Midville in 1997, 28–0–0–5(S) increased shoot dry weight over the untreated and 32–0–0 and 9–0–0–11(Ca) starters. Ammonium polyphosphate resulted in increased shoot dry

Table 3. Amount of preplant incorporated (PPI), starter fertilizer (SF), sidedress (SD), and total N applied in the starter fertilizer tests conducted in Midville, Plains, and Tifton, GA, in 1997 and 1998.

	"Nitrogen applied"											
	Midville 1997–98				Plains 1997–98				Tifton 1997–98			
Treatment	PPI	SF	SD	Total	PPI	SF	SD	Total	PPI	SF	SD	Total
	kg ha^{-1}											
10–34–0	33	11	57	101	10	11	80	101	20	11	70	101
32–0–0	33	38	30	101	10	38	53	101	20	38	43	101
10–34–0 + 32–0–0	33	38	30	101	10	38	53	101	20	38	43	101
28–0–0–5 (S)	33	38	30	101	10	38	53	101	20	38	43	101
9–0–0–11 (Ca)	33	11	57	101	10	11	80	101	20	11	70	101
Untreated	33	0	68	101	10	0	91	101	20	0	81	101

Table 4. Cost of the starter fertilizers used in the tests conducted at Midville, Plains, and Tifton, GA, in 1997 and 1998.

Treatment	1997	1998
	\$ ha^{-1}	
10–34–0 + 32–0–0	40.16	38.46
10–34–0	27.79	26.55
32–0–0	17.86	17.19
28–0–0–5 (S)	20.20	19.46
9–0–0–11 (Ca)	27.39	27.39

Table 5. Shoot N and Ca and plant height at squaring in the starter fertilizer tests conducted at Plains and Tifton, GA, in 1997 and 1998.

Treatment	Tifton 1997	Tifton 1998	Plains 1998	Tifton 1998	Plains 1998	Tifton 1998
	— N (g kg^{-1}) —		– Ca (g kg^{-1}) –		– height (cm) –	
10–34–0 + 32–0–0	40.2b†	42.4bc	22.0b	20.2c	29.4ab	27.6ab
10–34–0	42.4b	42.1bc	21.1b	21.9bc	31.0a	32.0a
32–0–0	49.3a	50.5a	25.8ab	25.1ab	27.0c	29.6ab
28–0–0–5 (S)	50.4a	49.4a	27.8a	24.6ab	28.4bc	24.8bc
9–0–0–11 (Ca)	44.5ab	47.5ab	28.3a	28.0a	28.8abc	25.8bc
Untreated	42.1b	39.1c	26.5ab	24.5ab	28.2bc	21.1c
LSD (0.05)	6.0	6.3	5.5	4.2	2.3	4.8

† Within a column, numbers followed by the same letter are not significantly different as determined by Fisher's protected LSD ($P = 0.05$). Mean separation tests were conducted using the transformed data, but data presented are the untransformed means (Steel and Torrie, 1980).

weights at Plains and Tifton in 1998, but not greater than the untreated check.

Several authors have reported increased lint yields from side-banded starter fertilizer applications (Guthrie, 1991; Hodges and Baker, 1990; Stewart and Edmisten, 1997; Touchton et al., 1986). In this study, starter fertilizers resulted in greater yields in two of the six tests (Table 7). At Midville in 1997, 28–0–0–5(S) resulted in a greater yield than the untreated and the 9–0–0–11(Ca) starters. Ammonium polyphosphate resulted in a greater yield than the untreated check, urea ammonium nitrate, and calcium nitrate at Plains in 1997.

It is interesting to note that the increases in lint yield from starter fertilizer applications occurred when the crop experienced a period of cool weather immediately after planting. As indicated earlier, prevailing weather conditions were cool for several weeks immediately after planting at Midville and Plains in 1997. Accumulated degree-days {Σ[average daily T(°C) – 15]} for the first 2 wk after planting were 39.5 and 36.8 at Midville and Plains, respectively, in 1997. Accumulated degree-days for the first 2 wk after planting in the other studies were 135.9 (Tifton, 1997), 145.1 (Midville, 1998), 142.9 (Plains, 1998), and 135.9 (Tifton, 1998).

The study revealed no statistical differences in fiber length or fiber strength between the fertilizer treatments and the untreated check (data not shown). Differences were observed in fiber micronaire in only one study. Ammonium polyphosphate at Plains in 1998 resulted in greater fiber micronaire (4.2) than 10–34–0 + 32–0–0 (4.0), 32–0–0 (3.9), 9–0–0–11(Ca) (3.9), and the untreated check (3.9).

Table 6. Leaf area index (LAI) and shoot dry weight (DWT) at squaring in the starter fertilizer tests conducted at Midville, Plains, and Tifton, GA, in 1997 and 1998.

Treatment	1997 Midville	1997 Plains	1998 Tifton	1997 Midville	1998 Plains	1998 Tifton
	LAI (m^2 m^{-2})			DWT (g m^{-2})		
10–34–0 + 32–0–0	0.31ab†	0.51a	0.59a	34.1ab	33.4a	42.5ab
10–34–0	0.29abc	0.45abc	0.64a	28.4abc	33.5a	54.3a
32–0–0	0.24bc	0.50a	0.34b	26.3bc	25.5b	23.2c
28–0–0–5 (S)	0.35a	0.46ab	0.48ab	35.1a	28.3ab	33.0bc
9–0–0–11 (Ca)	0.22c	0.38bc	0.49ab	22.0c	26.1b	36.9bc
Untreated	0.24bc	0.36c	0.60a	23.2bc	28.4ab	42.7ab
LSD (0.05)	0.09	0.09	0.19	8.1	5.9	15.5

† Within a column, numbers followed by the same letter are not significantly different as determined by Fisher's protected LSD ($P = 0.05$). Mean separation tests were conducted using the transformed data, but data presented are the untransformed means (Steel and Torrie, 1980).

Table 7. Final seed cotton yield from the starter fertilizer tests conducted at Midville, Plains, and Tifton, GA, in 1997 and 1998.

Treatment	Midville 1997	Midville 1998	Plains 1997	Plains 1998	Tifton 1997	Tifton 1998
	"Yield" kg ha^{-1}					
10–34–0 + 32–0–0	3759abc†	2741a	3030ab	3328a	3714a	3642a
10–34–0	3805ab	2698a	3294a	3515a	3812a	3492a
32–0–0	4228ab	2526a	2655c	3553a	4038a	3577a
28–0–0–5 (S)	4395a	2797a	2713bc	3538a	4044a	3792a
9–0–0–11 (Ca)	3683bc	2807a	2823bc	3607a	3941a	3802a
Untreated	3212c	2430a	2624c	3465a	3816a	3453a
LSD (0.05)	603	650	337	413	706	359

† Within a column, numbers followed by the same letter are not significantly different as determined by Fisher's protected LSD ($P = 0.05$). Mean separation tests were conducted using the transformed data, but data presented are the untransformed means (Steel and Torrie, 1980).

Economic Analysis

Quality factors available from the study that influence price were fiber length, strength, and micronaire. Fiber uniformity data was also collected but does not influence the price received for cotton by the farmer. The base value (no price premium or discount) for fiber length is 2.72 cm. The base value for fiber strength is 230 to 278 kN m kg^{-1}. The base value for fiber micronaire is 3.5 to 4.9 with a premium range from 3.7 to 4.2. Across all locations and years, fiber length ranged from 2.67 to 2.95 cm, fiber strength ranged from 248 to 308 kN m kg^{-1}, and fiber micronaire ranged from 3.3 to 4.2.

Price premiums and discounts were assigned to the mean staple length, fiber strength, and micronaire of each treatment. Table 8 shows the sum of all premiums and discounts applied to each treatment. The price discount from Midville in 1998 was due to high micronaire, while discounts from Plains in 1997 were due to low micronaire. The price discount from Tifton in 1997 was due to short fiber length. As previously noted, these differences were statistically insignificant. The only significant difference in lint quality throughout the study period was for micronaire at Plains in 1998. However, all micronaire means at Plains in 1998 were within the

Table 8. Cotton price premiums and discounts from the starter fertilizer tests conducted at Midville, Plains, and Tifton, GA, in 1997 and 1998.

Treatment	Midville 1997	Midville 1998	Plains 1997	Plains 1998	Tifton 1997	Tifton 1998
	cents 100 kg^{-1}					
10–34–0 + 32–0–0	11.0	71.5	−506.0	82.5	5.5	71.5
10–34–0	0.0	71.5	0.0	93.5	−357.5	82.5
32–0–0	5.5	71.5	−506.0	93.5	5.5	82.5
28–0–0–5 (S)	0.0	71.5	−506.0	93.5	5.5	82.5
9–0–0–11 (Ca)	0.0	16.5	0.0	93.5	5.5	82.5
Untreated	0.0	−803.0	0.0	93.5	5.5	93.5

Base price was \$1.536 kg^{-1} for 1997 and \$1.436 kg^{-1} for 1998 and was the average of the December contract price on June 1 and the spot market price on March 1. Quality premiums and discounts were applied to these base prices to calculate net returns.

Table 9. Net return above treatment costs from the starter fertilizer tests conducted at Midville, Plains, and Tifton, GA, in 1997 and 1998.

	Midville			Plains			Tifton		
Treatment	1997	1998	Avg.	1997	1998	Avg.	1997	1998	Avg.
	$ ha^{-1}								
10–34–0 + 32–0–0	1882	1270	1576	1450	1564	1507	1875	1707	1791
10–34–0	1917	1262	1588	1650	1665	1657	1885	1652	1769
32–0–0	2134	1193	1665	1297	1689	1494	2058	1699	1880
28–0–0–5 (S)	2213	1314	1764	1321	1685	1502	2058	1796	1927
9–0–0–11 (Ca)	1857	1304	1581	1420	1704	1561	2001	1791	1897
Untreated	1660	1092	1376	1356	1675	1514	1971	1667	1820

Net return is cotton income (price times yield) minus ginning and warehousing and treatment costs. Treatment costs include starter fertilizer, additional labor and fuel in handling and hauling of starter fertilizer and application equipment, annual fixed costs of investment in application equipment, additional picking and hauling for difference in yield between the treatments and the untreated check, and interest on additional expenses. All costs except ginning and warehousing were zero for the untreated check.

acceptable range and received no price premium or discount.

At Midville in 1997 and 1998, net returns above treatment costs were higher for the starter fertilizer treatments than the untreated check (Table 9). Starter fertilizers resulted in higher net returns, ranging from $200 to $388 ha^{-1}. Results at Plains and Tifton, however, were mixed. Over the 2-yr period, two of the five treatments at Plains and three of the five treatments at Tifton resulted in higher mean net returns than the untreated check. Over the 2-yr period, 28–0–0–5(S) resulted in highest mean net returns at Midville and Tifton, while 10–34–0 resulted in highest mean net returns at Plains.

Figure 1 illustrates the break-even yield increase needed to cover all added costs of using starter fertilizers based on the cost of the fertilizer and the price of cotton. This illustration assumes no price premiums or discounts for fiber quality. Depending on the cost–price relationship, the break-even yield increase ranges from 12 to 49 kg lint ha^{-1}. Mean yield differences observed in this study were mostly above break-even levels, but, as noted, many of the treatments were not statistically different from the untreated check.

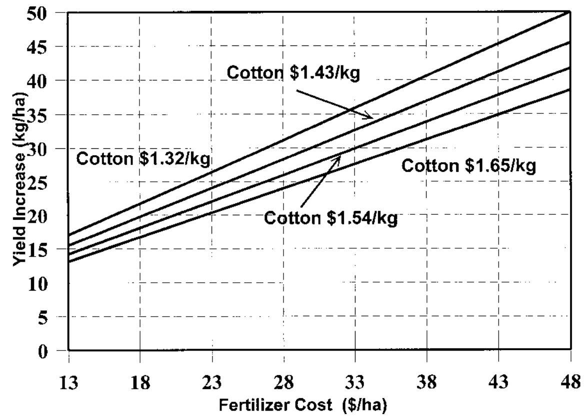

Fig. 1. Break-even yield increase for starter fertilizer. Figure assumes no price premiums or discounts for fiber quality. Break-even yield increase includes fertilizer as shown plus other added costs, including labor and fuel of hauling and handling fertilizer, annual equipment cost, ginning and warehousing, picking and hauling, and interest.

CONCLUSIONS

At Plains in 1997, the 10–34–0 and 10–34–0 + 32–0–0 starter fertilizers significantly increased yields over the control. Gascho et al. (1997) indicated that Greenville soils have a high P fixation capacity. Therefore, the Greenville soil at Plains may respond more favorably to P-containing starter fertilizers. In addition, the period of cool weather immediately after planting at Plains in 1997 may have depressed soil P mineralization, which could have also resulted in the favorable response from P-containing starter fertilizers. The starter fertilizer that resulted in the greatest yields at Midville in 1997 was 28–0–0–5(S). The University of Georgia Extension Service recommends 11 kg ha^{-1} of S for cotton production on Coastal Plain soils (Brown et al., 1997). Thus, starter fertilizers may be an efficient method of S application on these soils. These results indicate the most appropriate cotton starter fertilizer may depend on soil type and weather conditions at planting and stand establishment.

Significant yield differences due to the application of starter fertilizers occurred only at Midville and Plains in 1997. Also, significant differences in fiber properties occurred only at Plains in 1998. Economic analyses were conducted across all years and locations, and caution should be observed in interpreting these results. Although most yield differences were statistically insignificant, it is worth noting that net returns were higher than in the untreated check in 23 of the 30 comparisons (5 treatments $\times$ 2 yr $\times$ 3 locations = 30 comparisons).

The cost of employing starter fertilizer as a cultural practice is not prohibitive. The cost of the starter fertilizer materials used in this study ranged from $17 to $40 ha^{-1}. The investment in additional equipment needed is relatively minor ($2030 in the example assumed in this study); therefore, economies of scale or the lack thereof should not be a constraint (annual costs were only $2.52 ha^{-1} for 162 ha).

This study was not designed to determine if starter fertilizers ameliorate the effects of cool weather during germination and stand establishment. However, it is interesting to note that the only significant yield increases that occurred in this study were when the crop was exposed to cool weather for an extended period of time immediately after planting. Additional research is needed to properly address this question.

ACKNOWLEDGMENTS

The authors wish to thank Ben Mullinix for assistance with statistical analyses and Walt Harvey and Dudley Cook for technical support. The authors also wish to thank the Georgia Agricultural Commodity Commission for Cotton and Cotton Incorporated for financial support.

REFERENCES

Brown, S.M., M. Bader, R. Baird, G. Harris, P. Roberts, D. Shurley, and J. Stephens. 1997. 1997 cotton production guide. Publ. CSS 97-01. Univ. of Georgia, College of Agric. and Environ. Sci., Coop. Ext. Serv., Athens, GA.

Burmester, C.H., M. Patterson, and D.W. Reeves. 1993. Cover system and starter fertilizer placement for no-till cotton. p. 1292–1294. *In* D.J. Herber and D.A. Richter (ed.) Proc. Beltwide Cotton Prod. Res. Conf., New Orleans, LA. 10–14 January 1993. National Cotton Council of America, Memphis, TN.

Funderburg, E.R. 1988. Effect of starter fertilizer on cotton yields in Mississippi. p. 496–498. *In* J.M. Brown and T.C. Nelson (ed.) Proc. Beltwide Cotton Prod. Res. Conf., New Orleans, LA. 3–8 Jan. 1988. National Cotton Council of America, Memphis, TN.

Funderburg, E.R. 1993. Effect of starter fertilizer on cotton growth and other characteristics. p. 1291. *In* D.J. Herber and D.A. Richter (ed.) Proc. Beltwide Cotton Prod. Res. Conf., New Orleans, LA. 10–14 January 1993. National Cotton Council of America, Memphis, TN.

Gascho, G.J., P.L. Raymer, and F.J. Sikora. 1997. Phosphorous source and rate for canola in the southern coastal plain. J. Prod. Agric. 10:130–135.

Givan, W. and D. Shurley. 1999. Crop Enterprise Cost Analysis- South Georgia 1999. AGECON 94-010-S-Revised. Dep. of Agric. and Appl. Econ., Univ. of Georgia, Athens.

Givan, W., and G. Westberry. 1998. 1998 farm machinery custom rates. AGECON 91-001R-Revised. Dep. of Agric. and Appl. Econ., Univ. of Georgia, Athens.

Guthrie, D.S. 1991. Cotton response to starter fertilizer placement and planting dates. Agron. J. 83:836–839.

Hodges, S.C., and S. Baker. 1990. Effect of starter composition and placement on cotton in Georgia. p. 483–484. *In* J.M. Brown and D.A. Richter (ed.) Proc. Beltwide Cotton Prod. Res. Conf., Las Vegas, NV. 9–14 January 1990. National Cotton Council of America, Memphis, TN.

Hutchinson, R.L., and D.D. Howard. 1997. Response of no-tillage and conventional-tillage cotton to starter fertilization on loess soils. J. Plant Nutr. 20:975–986.

Littell, R.C., G.A. Milliken, W.W. Stroup, and R.D. Wolfinger. 1996. SAS system for mixed models. SAS Inst., Cary, NC.

Maples, R.J., and J.L. Keogh. 1973. Phosphorous fertilization experiments with cotton on Delta soils of Arkansas. Ark. Agric. Exp. Stn. Bull. 781. Fayetteville, AR.

Mullins, G.L., and C.H. Burmester. 1997. Starter fertilizer and the method and rate of potassium fertilizer effects on cotton grown on soils with and without winter grazing by cattle. Commun. Soil Sci. Plant Anal. 28:739–746.

Plank, C.O. 1979. Plant analysis handbook for Georgia. Georgia Coop. Ext. Serv., Univ. of Georgia, Athens.

Reich, R.C., E.J. Kamprath, and L.A. Nelson. 1981. Soil and management factors correlated with soybean yields in the southeastern U.S. Coastal Plain. Agron. J. 73:90–95.

Rickerl, D.H., W.B. Gordon, J.T. Touchton, and E.A. Curl. 1987. The effect of starter fertilizers on cotton production in legume residues. Commun. Soil Sci. Plant Anal. 18:1281–1302.

Steel, R.G.D., and J.H. Torrie. 1980. Principles and procedures of statistics: A biometrical approach. 2nd ed. McGraw-Hill, New York.

Stewart, A.M., and K.L. Edmisten. 1997. Effect of planting date, starter fertilizer, and fungicide interaction on cotton. J. Plant Nutr. 20:1225–1230.

Stewart, A.M., and K.L. Edmisten. 1998. Cotton response to placement and rate of starter fertilizer. J. Plant Nutr. 21:967–973.

Touchton, J.T. 1990. Starters boost early season performance. Solutions. January, p. 30–31.

Touchton, J.T., D.H. Rickerl, C.H. Burmester, and D.W. Reeves. 1986. Starter fertilizer combinations and placement for conventional and no-tillage cotton. J. Fert. Issues 3:91–98.