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WEED SCIENCE

Starter Fertilizer Effects On Cotton Development And Weed Interference

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ABSTRACT

Application of postemergence-directed herbicides in cotton (*Gossypium hirsutum* L.) requires a height differential between the crop and weeds. Weeds may respond more to starter fertilizer than cotton, and the enhanced weed growth could adversely affect the height differential, herbicide effectiveness, and reduce lint yields. A field experiment was conducted to determine the effect of type and placement of starter fertilizer and timing of postemergence-directed herbicide applications on growth of cotton, sicklepod (*Senna obtusifolia* L. Irwin and Barneby), and pitted morningglory (*Ipomoea lacunosa* L.) and cotton yield. Starter fertilizer treatments included urea-ammonium nitrate (UAN) and ammonium polyphosphate (AMP) applied either in a 10-cm band over the surface of the crop row or 5 cm below and 5 cm to the side of the crop row. Methazole plus MSMA at 0.8 plus 2.2 kg a.i. ha^{-1} were applied early or late postemergence-directed to cotton 9 to 10 or 15 to 18 cm tall, respectively. When early season conditions were dry, optimal cotton yields were obtained with AMP starter fertilizer and early herbicide application. When early season soil moisture was adequate, weed control and cotton yield were generally better with late herbicide application, and starter fertilizer did not affect cotton yield. Cotton maintained sufficient height differential over weeds to allow directed herbicide application, even when starter fertilizer increased sicklepod growth. These results indicate that the benefit of starter fertilizer and timing of directed herbicide application to optimize cotton yield is dependent on soil moisture conditions following planting.

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Cotton response to starter fertilizer has been variable in the southeastern United States (Funderburg, 1988; Morris et al., 1989; Touchton et al., 1986). Starter fertilizer often increases early growth of cotton, but yield increases occur less frequently. In Georgia, the height, weight, nitrogen content, and number of leaves on cotton seedlings were altered by different nitrogen-containing starter fertilizers (Ashley et al., 1974). Time of first bloom and number of blooms also were affected, but there were no differences in yield among nitrogen sources. Starter fertilizer increased yield in no-till cotton 2 of 3 years and yield in conventional cotton 1 of 3 years in Alabama (Touchton et al., 1986). Mitchell and Burmester (1989) evaluated several starter fertilizers at 12 locations that increased nutrient concentrations of young cotton plants but failed to increase cotton yields. In Mississippi, banded applications of liquid 10-34-0 starter fertilizer at 168 kg ha^{-1} increased lint yield an average of 104 kg ha^{-1} in 13 of 18 field trials conducted on several soil types during a 3-year period (Funderburg, 1988). A positive response to starter fertilizer occurred on only 1 of 10 sites across four soil series over a 2-year period in Arkansas (Morris et al., 1989).

Concentrated placement of starter fertilizer near the crop row is necessary to elicit yield increases. Placing starter fertilizer 5 cm below and 5 cm to the side of the crop row at planting increased cotton yield compared with broadcasting the fertilizer (Howard and Hoskinson, 1990; Guthrie, 1991). Narrow, surface applications of starter fertilizer generally produce results similar to 5x5 placement. Application of starter fertilizer in an 8-cm band over the crop row or in 5x5 placement increased lint yields compared with broadcast fertilizer application, but applications in a 40-cm band over the crop row did not increase lint yield (Hodges and Baker, 1990).

Some researchers (Walker et al., 1984; Funderburg, 1988) who observed yield increases from starter fertilizer containing nitrogen and phosphorus suggested the increases were due to phosphorus, but the possibility that nitrogen contributed to positive crop responses cannot be overlooked. When nitrogen and nitrogen plus phosphorus were evaluated in the same experiment, the response was similar (Hodges and Baker, 1990; Howard and Hoskinson, 1990).

Starter fertilizers containing phosphorus can be beneficial to cotton growth and development when cool conditions at planting reduce phosphorus mineralization. Increased lint yields from banded phosphorus were increased when cool weather prevailed for several weeks after planting (Maples and Keough, 1973). Bednarz et al. (2000) examined starter fertilizer sources on several coastal plains soils in southern Georgia over 2 yr and determined that the most appropriate cotton starter fertilizer was dependent on soil type.

Increased fertilizer levels associated with starter fertilizer applications presumably enhance the early season growth rate of cotton (Ashley et al., 1974). It is perhaps more likely that weeds present in or near the crop row, where control is generally more difficult to achieve, may respond more rapidly and to a greater extent than the cotton. The increased fertility level may enhance cotton and weed growth, but the most aggressive species would be expected to dominate (Anderson, 1977).

Several researchers have documented the greater ability of weeds to absorb and use nutrients compared with crop species (Appleby et al., 1976; Gray et al., 1953; Hoveland et al., 1976; Vengris et al., 1955). Uptake of nitrogen, phosphorus, and potassium decreased by 42, 37, and 53%, respectively, by corn (*Zea mays* L.) when weeds were present compared with uptake in a weed-free environment (Vengris et al., 1955). This occurred even with relatively high rates of fertilization. In contrast, the presence of corn did not affect nutrient uptake by weeds. Early cotton growth was reduced by 20% when phosphorus levels were very low (8 kg ha^{-1}) and low (22 kg ha^{-1}) compared with growth when the phosphorus level was high (90 kg ha^{-1}) (Hoveland et al., 1976). The average growth reduction of several broadleaf weeds was 73% at very low levels compared with high phosphorus levels. These results indicate that when weeds are present low rates of starter fertilizer applied close to the row may be adequate for the crop and help reduce weed interference.

The early season growth rate of cotton seedlings is slow and may reduce the competitiveness of cotton with weed seedlings (Bridges et al., 2002; Buchanan and Burns, 1971). Also, since weeds generally absorb nutrients faster and in larger quantities than crops, and in many cases derive greater benefit (Alkamper, 1976), use of starter fertilizers may provide an additional advantage for weeds.

Growers planting non-transgenic cotton often rely on herbicides that must be directed beneath the crop canopy to minimize contact with the crop. An insufficient height differential between cotton and weed seedlings would preclude effective use of postemergence-directed herbicides. Research has not been published on the response of weeds to starter fertilizer and their interaction with cotton. This research was conducted to examine the effects of starter fertilizer and time of postemergence-directed herbicide application on cotton, pitted morningglory, and sicklepod development. An important objective was to determine whether the use of starter fertilizer affects optimal timing of postemergence-directed herbicide application to achieve effective weed control. Our hypothesis was that starter fertilizer would enhance weed growth to a greater extent than cotton growth. Therefore, postemergence-directed herbicides would be less effective, and cotton lint yields would be reduced because of weed interference. Sicklepod and pitted morningglory were selected for the study because they consistently rank as two of the most common and troublesome weed species encountered in cotton in Alabama, Florida, Georgia, North Carolina, and South Carolina (Elmore, 1989). Competition from sicklepod and morningglory reduced cotton yield up to 40 and 75%, respectively, at densities as low as eight weeds per 7.3 m of row (Buchanan and Burns, 1971).

MATERIALS AND METHODS

The experiment was conducted at the Pee Dee Research and Education Center, Florence, SC, on a Rains loamy sand (fine-loamy, siliceous, semiactive, thermic, Typic Paleaquults) in 1990 and a Norfolk loamy sand (fine-loamy, siliceous, thermic, Typic Kandiudults) in 1991. Monthly rainfall totals during the growing season for each year and the 30-year averages are presented in Table 1. Soil pH and Mehlich-extractable phosphorus and potassium from soil tests were 5.0, 120 kg ha^{-1}, and 160 kg ha^{-1}, respectively, for the Rains soil and 6.1, 74 kg ha^{-1}, and 128 kg ha^{-1}, respectively, for the Norfolk soil. Based on soil test recommendations (Anonymous, 1982), dolomitic limestone was broadcast prior to planting

Table 1. Monthly rainfall totals during the cotton growing season for 1990, 1991, and the 30-year average at the Pee Dee Research and Education Center, Florence, SC

	Rainfall (cm)		
Month	**1990**	**1991**	**30-year average**
May	**8.2**	**7.7**	**9.4**
June	**2.5**	**8.7**	**12.4**
July	**13.5**	**15.2**	**14.3**
August	**17.0**	**14.6**	**13.9**
September	**2.5**	**4.2**	**10.5**
October	**26.0**	**2.2**	**6.8**

at 2.24 Mg ha^{-1} in 1990, and potassium was applied each year at 56 kg ha^{-1} as sulfate-of-potash-magnesia (0-0-22). Phosphorus was not recommended either year. Cotton cultivar Coker 320 (Coker Seed Company, Hartsfield, SC) was seeded 15 May 1990 and 17 May 1991 to achieve a stand of 10 to 12 plants m^{-1} of row. Plots consisted of four rows spaced 1 m apart and 9.1 m long. Plots were arranged in a split-plot design with four replications. Whole plot and sub-plot treatment factors were four levels of weed management and five levels of starter fertilizer, respectively. Sicklepod and pitted morningglory seed were broadcast together over all plots, except the weed-free plot, prior to final seedbed preparation each year to achieve densities of 65 and 20 plants m^{-2}, respectively. Trifluralin (Treflan 4 EC, Dow Agrosciences, Indianapolis, IN) was preplant-incorporated at 0.8 kg a.i. ha^{-1} to control annual grasses.

Weed management systems included the following: none; methazole (Probe, Sandoz Agro, Des Plains, IL) plus MSMA (Bueno 6, KMG Chemicals, Houston, TX) at 0.8 plus 2.2 kg ha^{-1} applied early postemergence-directed when cotton seedlings were 9 to 10 cm tall; methazole plus MSMA at the same rates applied late postemergence-directed when cotton was 15 to 18 cm tall; and weed-free (hand-weeded every 2 wks). Herbicides were applied in a 51-cm band over the cotton row with a tractor-mounted, sliding-shoe applicator operated at 7.2 km h^{-1}. The spray volume was 187 L ha^{-1}, and pressure was maintained with compressed air at 180 kPa. Plots were cultivated twice to control weeds in the row middles.

Starter fertilizer treatments applied at planting consisted of the four factorial combinations of two types, urea-ammonium nitrate (UAN) and ammonium polyphosphate (AMP), and two placements, a 10 cm-band over the surface of the crop row and 5 cm below and 5 cm to the side of the crop row, plus a control without starter fertilizer. UAN starter fertilizer was applied as 30 and 10% solutions in 1990 and 1991, respectively, and provided 17 kg nitrogen ha^{-1}. AMP starter fertilizer provided 17 kg nitrogen ha^{-1} plus 46 kg P_2O_5 ha^{-1}. Side-dressed nitrogen was surface-applied as ammonium nitrate on 13 June each year and placed 10 cm from the row. The side-dressed nitrogen provided 62 kg nitrogen ha^{-1} in plots receiving starter fertilizer and 78 kg nitrogen ha^{-1} in plots without starter fertilizer.

Cotton and weed plant heights were measured from the soil to the junction of the petiole and blade of the last fully expanded leaf immediately prior to the early and late postemergence-directed herbicide applications, which corresponded to 21 and 31 d after planting (DAP), respectively. Five plants of each species were randomly selected from a 10-cm band directly above each of the two middle rows for measurement. Seedlings in these bands would have access to the starter fertilizer early in the growing season and would be most difficult to control with postemergence-directed herbicides due to their close proximity to the crop row. For weed biomass determinations, weeds were hand-harvested from a randomly selected 41 cm wide by 122 cm long band over each of the two middle rows of each plot 7 and 10 d after the early and late postemergence-directed herbicide applications (28 and 42 DAP), respectively, and dried at 65ºC for 2 wk before determining the combined biomass for the two weed species.

Crop injury and a composite weed control rating for the two species were visually estimated 14 and 21 d after the early and late postemergence-directed herbicide applications (35 and 53 DAP), respectively, using a scale of 0 to 100, where 0 = no crop injury or weed control and 100 = complete crop loss or weed control (Frans et al., 1986). Cotton yields were obtained by harvesting the two center rows of each plot with a spindle picker. All seed cotton samples were cleaned at least once with an incline cleaner on a 20-saw cotton gin. Seed cotton from the no herbicide treatments in 1991 was cleaned twice. The seed cotton was ginned, and fiber properties were determined by the Cotton Division of the USDA Agricultural Marketing Service in Clemson, SC with motion-control, high-volume instrumentation (Sasser, 1981).

Combined analyses of results for the 2 yr revealed considerable treatment by year interactions, so treatment effects were examined for each year when significant. Interaction and main effects of weed management systems and starter fertilizers were evaluated using $P = 0.05$. When interactions were detected, starter fertilizer effects were separately examined for each weed management system using single degree of freedom contrasts that assessed the interaction and main effects of starter fertilizer types and placements using $P = 0.05$. If the two factors responded independently and the main effect for weed management systems and/or starter fertilizers was significant, marginal means were evaluated using single degree of freedom contrasts. A logarithmic transformation was performed on weed dry weights prior to analysis due to heterogeneity of variance. Data analysis was performed using SAS version 8.2 (SAS Institute, Cary, NC).

RESULTS AND DISCUSSION

Plant height. The interaction between starter fertilizers and years was not significant for any plant heights 21 or 31 DAP (Table 2), but differences among starter fertilizers were detected for cotton height 21 DAP and sicklepod height 21 and 31 DAP. The interaction for type and placement of starter fertilizer was significant for cotton height 21 DAP. Over the row placement of AMP starter fertilizer increased cotton height compared with 5x5 placement, while cotton height with UAN starter fertilizer was similar to no starter fertilizer regardless of placement (Table 3). This indicates that additional phosphorus can stimulate early season cotton growth on loamy sand soils, but over the row placement may optimize availability to cotton roots.

Enhancement of early season cotton growth could contribute to more effective application of postemergence-directed herbicides if the height differential between cotton and weeds is increased. Starter fertilizer increased sicklepod height at 21 DAP, but there were no differences among types or placements (Tables 2 and 3). AMP starter fertilizer increased sicklepod height at 31 DAP compared with UAN starter fertilizer regardless of placement. Starter fertilizer had no effect on pitted morningglory height. Although sicklepod growth was enhanced by starter fertilizer, cotton plants maintained sufficient height advantage over weeds to permit application of postemergence-directed herbicide sprays.

Table 2. Analysis of variance for plant heights 21 and 31 days after planting (DAP) immediately prior to early and late postemergence-direct herbicide applications, respectively, with linear contrasts among starter fertilizers from trials conducted in 1990 and 1991

Source of variation[y]	Mean square for plant height[z]					
	21 DAP			31 DAP		
	Cotton	Sicklepod	Pitted morningglory	Cotton	Sicklepod	Pitted morningglory
Year	**33.86***	**6.81***	**10.20***	**253.01***	**197.58***	**824.46***
Starter fertilizer	**1.01***	**0.72***	**0.07**	**1.62**	**4.90***	**3.87**
Starter vs. none	**0.90***	**1.85***			**2.40**	
Type (UAN vs. AMP)	**1.12***	**0.32**			**12.75***	
Placement (OTB vs. 5x5)	**1.28***	**0.66**			**4.06**	
Type x placement	**1.05***	**0.03**			**0.41**	
Starter fertilizer x year	**0.51**	**0.03**	**0.06**	**1.37**	**2.33**	**3.13**

[y] UAN = urea-ammonium nitrate; AMP = ammonium polyphosphate; OTB = a 10-cm band over the crop row; 5x5 = a band 5 cm below and 5 cm to side of the crop row.

[z] * indicates effects that are significantly different at $P \leq 0.05$.

Table 3. Effect of starter fertilizer treatments on cotton and sicklepod height 21 and 31 days after planting (DAP) and weed biomass 28 and 42 DAP from trials conducted in 1990 and 1991[x]

Starter fertilizer and placement[y]		Cotton height (cm)		Sicklepod height (cm)		Weed biomass [$\log_{10}$(g m^{-2})] [z]		
						1990	1991	
		21 DAP	31 DAP	21 DAP	31 DAP	28 DAP		42 DAP
None		9.2	17.2	4.3	9.7	0.17	1.12	1.19
UAN	OTB	9.3	17.1	5.0	10.2	0.18	0.97	1.13
UAN	5x5	9.3	17.0	4.6	9.2	0.21	1.00	1.12
AMP	OTB	10.1	18.1	5.1	11.2	0.26	1.20	1.32
AMP	5x5	9.3	17.3	4.9	10.7	0.04	1.19	1.32
Standard error of the mean		0.17	0.58	0.16	0.50	0.044		0.040

[x] Results pooled over years unless otherwise noted.

[y] UAN = urea-ammonium nitrate; AMP = ammonium polyphosphate; OTB = a 10-cm band over the crop row; 5x5 = a band 5 cm below and 5 cm to side of the crop row.

[z] Biomass for sicklepod and pitted morningglory combined.

Table 4. Analysis of variance with linear contrasts among weed management systems for weed biomass 28 and 42 days after planting (DAP), weed control ratings 35 and 53 DAP and yield of lint cotton from starter fertilizer trials conducted in 1990 and 1991

Source of variation[w]	Mean squares[x]				
	Weed biomass[y]		Weed control[z]		Lint cotton
	28 DAP	42 DAP	35 DAP	53 DAP	
Year	16.85*	6.17*	9.1	832.0	16
Weed management (M)	3.29*	16.55*	177.0*	288.8	11,461,002*
M x Year	0.81*	4.57*	5008.6*	2080.8*	190,299
1990: Herbicide vs. none	0.42*	15.84*			
1990: Early vs. late		10.18*	3534.4*	409.6	
1991: Herbicide vs. none	3.69*	15.05*			
1991: Early vs. late		1.18*	1651.2*	1960.0*	
Starter fertilizer (F)	0.06	0.23*	7.3	25.7	12,533
F x Year	0.08*	0.05	16.8	22.7	39,298
F x M	0.04	0.04	11.9	25.9	34,247
F x M x Year	0.03	0.06	9.7	9.2	60,292*

[w] Herbicide was methazole + MSMA applied at 0.8 + 2.2 kg a.i. ha^{-1}; early = applied postemergence-directed to cotton 9 to 10 cm tall; late = applied postemergence-directed to cotton 15 to 18 cm tall.

[x] * indicates effects that are significant different at $P \leq 0.05$.

[y] Combined biomass for sicklepod and morningglory was logarithmically transformed prior to analysis.

[z] Weed control for sicklepod and morningglory combined.

Weed biomass. An interaction between weed management systems and years was significant for weed biomass 28 and 42 DAP (Table 4). Early season weed biomass production was greater in 1991 than 1990 due to differences in June rainfall totals (Table 1). At 28 DAP, the early postemergence-directed herbicide treatment reduced weed biomass compared with the non-treated each year, but the magnitude of the reduction was different for the 2 yr (Tables 4 and 5). At 42 DAP, both herbicide management systems had less weed biomass than the non-treated each year. The early postemergence-directed herbicide treatment was more effective at reducing weed growth than the late postemergence-directed in 1990, while the late postemergence-directed herbicide treatment controlled weed growth better in 1991.

Differences in performance of the weed management systems for the 2 yr can probably be attributed to variation in early season soil moisture that affects weed emergence and growth. In 1990, rainfall for the first 4 wk following planting totaled 6.5 cm, while only 0.6 cm occurred during the next 2 wk. In 1991, only 2.1 cm of rain was received for the first 4 wk, while 7.4 cm of rain fell during the next 2 wk. The single flush of weeds following planting in 1990 was controlled more effectively by the early postemergence-directed than the late postemergence-directed herbicide treatment since the plants were smaller at the early application. In 1991, a second flush of weeds followed 6.2 cm of rain that occurred after the early postemergence-directed application, so the late postemergence-directed herbicide treatment provided the most effective weed control that year.

Effects of starter fertilizer on weed biomass 28 DAP was different for the 2 yr (Table 4). The interaction between type and placement of starter fertilizer was significant in 1990 (Table 6). Weed biomass at 28 DAP was similar for the two placements with UAN starter, but weed biomass was considerably less for 5x5 than over the row placement with AMP starter (Table 3). There does not seem to be a plausible explanation for this result as weed seed were uni-

Table 5. Effect of weed management systems on weed biomass 28 and 42 days after planting (DAP) and weed control 35 and 53 DAP from cotton starter fertilizer trials conducted in 1990 and 1991

Year	Weed management[y]	Weed biomass [$\log_{10}(g\ m^{-2})$] [z]		Weed control (%)[z]	
		28 DAP	42 DAP	35 DAP	53 DAP
1990	Early herbicides	0.07	0.12	97	96
	Late herbicides		1.13	78	90
	Untreated	0.28	1.72		
1991	Early herbicides	0.79	1.26	82	80
	Late herbicides		0.92	94	94
	Untreated	1.40	2.15		
Standard error of mean		0.028	0.043	1.0	0.8

[y] Herbicide was methazole + MSMA applied at 0.8 + 2.2 kg a.i. ha^{-1}; early = applied postemergence-directed to cotton 9 to 10 cm tall; late = applied postemergence-directed to cotton 15 to 18 cm tall.

[z] Biomass and weed control for sicklepod and pitted morningglory combined.

Table 6. Linear contrasts among starter fertilizers for weed biomass at 28 and 42 days after planting (DAP) and lint cotton yield from trials conducted in 1990 and 1991

Linear contrast[w]	Mean squares[x]						
	Weed biomass[y]			Lint cotton			
	1990	1991		1990		1991	
	28 DAP		42 DAP	Early herbicide[z]	Late herbicide	Early herbicide	Late herbicide
Starter vs. none	< 0.01	< 0.01	0.02	253,125*	4	9,116	599
Type (UAN vs. AMP)	0.01	0.35*	0.91*	93,942*	121,801*	349,281*	770
Placement (OTB vs. 5x5)	0.07	< 0.01	< 0.01	12,321	12,432	120,409*	9,361
Type x placement	0.12*	< 0.01	< 0.01	22,350	441	32,580	58,443

[w] UAN = urea-ammonium; AMP = ammonium polyphosphate nitrate; OTB = a 10-cm band over the crop row; 5x5 = a band 5 cm below and 5 cm to side of the crop row.

[x] * indicates effects that are significant different at $P \leq 0.05$.

[y] Combined weed biomass was logarithmically transformed prior to analysis; results were pooled over years at 42 days.

[z] Herbicide was methazole + MSMA applied at 0.8 + 2.2 kg a.i. ha^{-1}; early = applied postemergence-directed to cotton 9 to 10 cm tall. late = applied postemergence-directed to cotton 15 to 18 cm tall.

formly broadcast prior to final seedbed preparation each year. The starter fertilizer by year interaction for weed biomass 42 DAP was not significant (Table 4), but AMP starter fertilizer produced higher weed biomass than UAN starter (Tables 3 and 6). Thus, starter fertilizer with phosphorus generally enhanced weed growth compared with starter fertilizer with only nitrogen or no starter.

Crop injury and weed control. No evidence of crop injury from either starter fertilizer or herbicide applications was observed (data not shown). There was a weed management system by year interaction for weed control 35 and 53 DAP (Table 4) as soil moisture conditions following planting differed for the 2 yr (Table 1). Control ratings were higher for the early herbicide treatment than the late treatment 35 and 53 DAP in 1990 (Table 5), but both weed management systems controlled weeds at least 90% by 53 DAP. Control ratings were higher for the late herbicide treatment (94%) than the early (approximately 81%) at each observation date in 1991. Thus, subjective control ratings were generally consistent with the objective weed biomass results. Weed control ratings were not affected by starter fertilizer treatments (Table 4), and the interaction of starter fertilizer with years or weed management systems was not significant.

Similar control of these species was obtained by Crowley et al. (1987) in an extensive study conducted across the eastern Cotton Belt to evaluate the response of various broadleaf weeds by size to postemergence-directed applications of methazole at rates of 0.28 to 0.84 kg ha^{-1} plus MSMA at 1.85 kg ha^{-1}. Control of all species was ≥80% using 0.56 kg ha^{-1} of methazole when weed height was 5 cm or less and 0.84 kg ha^{-1} when weed height was 5 to 7.6 cm. For heights greater than 7.6 cm, control of broadleaf weeds using 0.84 kg ha^{-1} of methazole was variable, and morningglory species (*Ipomoea* spp.), prickly sida (*Sida spinosa* L.), and spotted spurge (*Euphorbia maculata* L.) were the most difficult to control.

Lint cotton yield. The three-factor interaction between starter fertilizer, weed management system, and year was significant for lint cotton yield (Table 4). Cotton yield in non-treated plots was reduced by 81 and 80% in 1990 and 1991, respectively, compared with weed-free cotton (Table 7). In 1990, when dry conditions prevailed following planting, early herbicide application resulted in greater cotton yield than late application ($P = 0.046$) and comparable yield to the weed-free ($P = 0.48$) because of more effective weed control that resulted in less weed competition (Table 5). Cotton produced higher yields in 1990 with AMP starter fertilizer than with UAN starter for early and late herbicide treatments (Tables 6 and 7). Early season conditions in 1990 were apparently conducive to cotton benefiting from the phosphorus provided by the AMP starter fertilizer.

In 1991, when near normal rainfall occurred following planting (Table 1), an interaction between starter fertilizer and weed management system was

Table 7. Effect of starter fertilizer treatments on lint cotton yields with different weed management systems from trials conducted in 1990 and 1991

Starter fertilizer and placement[y]		Lint yields (kg ha^{-1})[z]							
		1990				1991			
		Weed-free	Early herbicide	Late herbicide	Untreated	Weed-free	Early herbicide	Late herbicide	Untreated
None		1510	1180	1220	320	1480	1160	1350	300
UAN	OTB	1570	1370	1160	280	1520	1320	1390	280
UAN	5x5	1360	1390	1110	270	1430	1410	1320	320
AMP	OTB	1340	1600	1340	220	1530	940	1280	360
AMP	5x5	1450	1470	1280	300	1410	1200	1450	250
Standard error of the mean		77							

[y] UAN = urea-ammonium; AMP = ammonium polyphosphate nitrate; OTB = a 10-cm band over the crop row; 5x5 = a band 5 cm below and 5 cm to side of the crop row.

[z] Herbicide was methazole + MSMA applied at 0.8 + 2.2 kg a.i. ha^{-1}; early = applied postemergence-directed to cotton 9 to 10 cm tall; late = applied postemergence-directed to cotton 15 to 18 cm tall; weed-free was handed-weeded every 2 wk.

significant for cotton yield. Starter fertilizer effects were detected with early but not with late herbicide treatment (Tables 6 and 7). When the early herbicide treatment was applied without starter fertilizer or in combination with AMP starter, yields were lower than weed-free cotton ($P = 0.028$ and 0.002, respectively). The combination of UAN starter and early herbicide treatment achieved yields comparable to weed-free cotton ($P = 0.34$). When the late herbicide treatment was applied without starter fertilizer, yields were comparable to weed-free cotton ($P = 0.35$), and the addition of starter did not affect yield ($P = 0.88$). Weed biomass data (Tables 4 and 5) help explain these results. The higher weed biomass for early than late herbicide treatment in 1991 reflects weed emergence and uncontrolled growth following a big rainfall (6.2 cm) that occurred after the early herbicide application. The increased weed competition reduced cotton yield when no starter fertilizer was used with the early treatment. Application of UAN starter with the early herbicide treatment enabled cotton to successfully compete with the emerged weeds and maintain optimal yield levels. Higher weed biomass and lower cotton yield was observed for AMP than UAN starter when the early herbicide treatment was used (Tables 3 and 6). The phosphorus provided by AMP starter fertilizer enhanced weed growth, and the increased competition reduced cotton yield.

Cotton yields for over the row and 5x5 starter fertilizer placements were very similar in this study (Tables 6 and 7). The only difference occurred in 1991 when the 5x5 placement of AMP starter yielded more than the over the row placement ($P = 0.035$). Hodges and Baker (1990) noted that 5x5 placement provided more consistent yield increases than surface-banded applications. Other researchers also reported increased lint cotton yields from side-banded starter fertilizer applications (Guthrie, 1991; Hodges and Baker, 1990; Stewart and Edmisten, 1998; Touchton et al., 1986).

Fiber properties. Even though treatments affected lint cotton yield, no important differences in fiber properties were noted. Mean values of lint percentage, micronaire, fiber length, fiber length uniformity, and fiber strength averaged across treatments and years were 43.4%, 4.2, 29 mm, 84%, and 251 kN m kg^{-1}, respectively (data not shown). Bauer et al. (1993) also reported limited effects of starter fertilizer applications on fiber properties.

CONCLUSIONS

When early season conditions were dry, optimal cotton yields were obtained with AMP starter fertilizer and early herbicide application. Thus, if conditions permit effective weed control early in the growing season, cotton can benefit from additional phosphorus provided by starter fertilizer and achieve lint yield comparable to weed-free conditions. When soil moisture was adequate in early season, weed control and cotton yield were generally better with late herbicide application, and starter fertilizer did not affect cotton yield. Cotton maintained sufficient height differential over weeds to allow directed herbicide application even when starter fertilizer increased sicklepod growth. Results suggest the benefit of starter fertilizer and timing of directed herbicide application to optimize cotton yield may depend upon soil moisture conditions following planting. Further research is needed to better elucidate the impact of environmental and other conditions on starter fertilizer effects in cotton.

REFERENCES

Alkamper, J. 1976. Influences of weed infestation on effect of fertilizer dressings. Pflanzenschutz-Nachrichten 29:191-235.

Anderson, W.P. 1977. Weed Science: Principles. West Publishing Co., St. Paul, MN.

Anonymous. 1982. Lime and fertilizer recommendations based on soil-test results. Cir. 476. Clemson Univ. Coop. Ext. Serv., Clemson, SC.

Appleby, A.P., P.D. Olson, and D.R. Colbert. 1976. Winter wheat yield reduction from interference by Italian ryegrass. Agron. J. 68:463-466.

Ashley, D.A., J.E. Elsner, O.L. Brooks, and C.E. Perry. 1974. Factors affecting early growth of cotton and subsequent effects on plant development. Agron. J. 66:20-23.

Bauer, P.J., J.J. Camberato, and S.H. Roach. 1993. Cotton yield and fiber quality response to green manures and nitrogen. Agron. J. 85:1019-1023.

Bednarz, C.W., G.H. Harris, and W.D. Shurley. 2000. Agronomic and economic analyses of cotton starter fertilizers. Agron. J. 92:766-771.

Bridges, D.C., T.L. Grey, and B.J. Brecke. 2002. Pyrithiobac and bromoxynil combinations with MSMA for improved weed control in bromoxynil-resistant cotton [Online]. J. Cotton Sci. 6:91-96. Available at http://journal.cotton.org/2002/issue01/pdf/art10.pdf

Buchanan, G.A. and E.R. Burns. 1971. Weed competition in cotton: I. Sicklepod and morningglory. Weed Sci. 19:576-579.

Crowley, R.H., J.H. Jordan, Jr., D.H. Williamson, and R.H. Neill. 1987. Response of different size broadleaf weeds to various methazole rates. p. 94. *In* 40th Proc. South. Weed Sci. Soc., Orlando, FL. 12-14 Jan. 1987. Southern Weed Sci. Soc., Champaign, IL.

Elmore, C.D. 1989. Weed survey- southern states broadleaf crops subsection. p. 408-420. *In* 42nd Proc. South. Weed Sci. Soc., Nashville, TN. 16-18 Jan. 1989. Southern Weed Sci. Soc., Champaign, IL.

Frans, R. E., R. Talbert, D. Marx, and H. Crowley. 1986. Experimental design and techniques for measuring and analyzing plant responses to weed control practices. p. 29-46. *In* N. D. Camper (ed.) Research Methods in Weed Science. Southern Weed Sci. Soc., Champaign, IL.

Funderburg, E.R. 1988. Effect of starter fertilizer on cotton yields in Mississippi. p. 496. *In* Proc. Beltwide Cotton Prod. Res. Conf., New Orleans, LA. 3-8 Jan. 1988. Natl. Cotton Counc. Am., Memphis, TN.

Gray, B., M. Drake, and W.G. Colby. 1953. Potassium competition in grass-legume associations as a function of root cation exchange capacity. Soil Sci. Soc. Am. J. 17:235-239.

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* Proc. Beltwide Cotton Prod. Res. Conf., Las Vegas, NV. 9-14 Jan. 1990. Natl. Cotton Counc. Am., Memphis, TN.

Hoveland, C.S., G.A. Buchanan, and M.C. Harris. 1976. Response of weeds to soil phosphorous and potassium. Weed Sci. 24:194-201.

Howard, D.D., and M.D. Hoskinson. 1990. Effect of starter nutrient combinations and N rate on no-tillage cotton. J. Fert. Issues 7:6-9.

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

Mitchell, C.C., and C.H. Burmester. 1989. Starter fertilizer tests on cotton in 1988. Farm Demonstration Report S-1-88, Auburn University, Auburn, AL.

Morris, G.L., R. Maples, H.J. Mascagni, J. Welch, R. Thompson, and R.G. Wells. 1989. Results from starter fertilizer applied for cotton. p. 480. *In* Proc. Beltwide Cotton Prod. Res. Conf., Nashville, TN. 2-7 Jan. 1989. Natl. Cotton Counc. Am., Memphis, TN.

Sasser, P.E. 1981. The basics of high volume instruments for fiber testing. pp. 191-193. *In* Proc. Beltwide Cotton Conf., New Orleans, LA. 4-8 Jan. 1981. Natl. Cotton Council Am., Memphis, TN.

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

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.

Vengris, J., W.G. Colby, and M. Drake. 1955. Plant nutrient competition between weeds and corn. Agron. J. 47:213-216.

Walker, M.E., T.C. Keisling, H.L. Balay, and G.A. Slappey. 1984. Comparison of starter fertilizer materials and their placement with broadcast fertilizer for corn. J. Fert. Issues 1:44-49.