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Full Length Research Paper

Evaluation of slow-release nitrogen and potassium fertilizers for cotton production

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Current nitrogen (N) and potassium (K) fertilization involves the use of conventional fertilizer materials with little information on the use of slow release materials. The objectives of this research were to evaluate new programmed slow -release N and K fertilizers for cotton production. Field experiments were conducted in 1997 and 1998 in Tennessee and Arkansas in the USA. The applied nutrient rates were a percentage of the total recommended rates for each state. In 1997, the applied percentages were 100, 80, and 60%; an additional 40% rate was evaluated in 1998. The recommended rate of either N or K was applied as conventional fertilizers controls. These varying rates of programmed-release materials were applied in direct contact with the seed at planting while the conventional fertilizers were broadcast before planting. Cotton yields were not reduced when the N rate was reduced to 60% recommended rate and applied as Meister programmed slow- release N. Yields were reduced when N applications were further reduced to 40% the recommended rate in 1998. Similarly, in-furrow applications of the slow-release K at 60% of the recommended rate did not affect yields for both states. Our results indicate that programmed-release; soil-applied fertilizers can potentially provide a one-time fertilizer application at planting with no detrimental effect on seedling germination, growth or yield. Furthermore, nutrient efficiency for applying the slow-release materials was increased by maintaining high yields at reduced fertilizer rates.

Key words: cotton, nitrogen, potassium, Meister programmed release fertilizer, slow-release fertilizer, lint yield.

INTRODUCTION

Within the cotton (*Gossypium hirsutum L.*) producing areas research has been conducted evaluating nitrogen (N), phosphorus (P), and potassium (K) application rates, application methods, and application timing for maximizing yields (Mullins and Burmester, 1991; Bassett et al., 1970). Recent research objectives have shifted to evaluate methods for reducing nutrient applications while maintaining yields, improving nutrient use efficiency, and reducing nutrient losses. A primary result of this research has been the development and promotion of no- tillage and reduced production input practices. Nutrient efficiency can be improved by production practices that include delaying nutrient applications until sufficient plant root development, or utilizing slow-release fertilizers, and foliar feeding.

Delaying soil nutrient applications until the root system has sufficiently developed for nutrient uptake reduces potential erosion and leaching nutrient losses (McConnell et al., 2000). However, delayed nutrient application may require changes in management practices and require specialized application equipment as opposed to broadcasting equipment. Nitrogen fertilization materials in particular may require specialized injection equipment. Furthermore, because of possible loss mechanisms, N is the primary nutrient that the crop has the greatest need for after crop establishment (Gerik et al., 1999).

Recent advances in slow-release nutrient technology indicate that coating urea with a polyolefin containing a surfactant allows predictable N release with increased soil temperature (Gandeza et al., 1991). Shoji and Gandeza (1992) categorized coatings of slow-release materi-

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rials into three groups: sulfur-coated, thermosetting resin coated, and thermoplastic resin-coated materials. They pointed out that the polyolefin thermoplastic resin-coated materials have the most accurate controlled release of nutrients. The release is controlled by temperature having a release rate showing a Q_{10} of 2. They reported the Meister Programmed- Release (MPR) materials (Anonymous, 1990) have an accurate controlled-nutrient release. The release is controlled by soil temperature when soil moisture conditions are adequate for root growth but the release is unaffected by soil factors including pH, texture, oxidation-reduction potential, and soil solution nutrient concentrations. Gandeza et al. (1991) reported that the temperature dependency of moisture permeating the resin coating was achieved by the addition of an inorganic fine powder such as talc, silica, and metal oxides. They indicated that the length of nutrient release period is controlled by varying the talc resin ratio in the coating process. The MPR materials have been categorized by the number of days for 80% nutrient release through the coating at 20^{o}C. Several fertilizer materials are available with the number of days of the N release ranging from 70 to 400 (Anonymous, 1990). For these materials to be effectively used for efficient crop production, knowledge of the nutrient uptake by the plant and the prevailing soil temperatures are required to match the release of material with crop development within a specific location.

Shoji et al. (1991) reported that the gradual release of N from MPR-N increased fertilizer efficiency for corn production and should reduce environmental concerns. Advantages other than improved nutrient efficiency includes the possibility of fertilizer applications well before planting during the colder winter or spring months since temperatures normally encountered during these months would restrict N release from the polyolefin-coated material. Gandeza et al. (1991) concluded that at low temperatures (5^{o}C), dissolution of urea from the coating follows a zero-order reaction where the rate of application does not affect the rate of reaction. Research is needed to evaluate both application rates and application methods for selected crop production within an area. Due to the expensive nature of the material, the crops selected should have a high cash return. Guertal (2000) concluded that utilization of MPRN may be a viable option for small-scale vegetable growers that are not using drip application systems.

Information regarding slow-release K materials for cotton production is lacking compared to information available on N materials. The authors were unable to find any references describing research evaluating slow or controlled K nutrient release for cotton production. Potassium fertilization is important for cotton production. Even though the cost of the materials was considered to be excessive relative to commercial K fertilizer, it is of agronomic interest to determine the effect of a controlled release K material for cotton production.

Research was established to evaluate polyolefin resin-coated urea (Meister T15) and polyolefin resin-coated K chloride (Meister T20) for no- till non-irrigated cotton in Tennessee, USA, while similar research was established evaluating the material for conventionally tilled irrigated cotton in Arkansas, USA. Objectives of this research at both locations were to (1) evaluate Meister Programmed-Release N and Meister Programmed-Release K fertilizers for cotton production; and to (2) evaluate the effects of reduced N and K application rates on yield.

MATERIALS AND METHODS

Field experiments were conducted in 1997 and 1998 evaluating a Meister programmed release N fertilizer T15 and Meister programmed release K fertilizer T20 in Tennessee and Arkansas, USDA. The research was conducted on Collins silt loam (course-silty, mixed, active, acid, thermic, Aquic Udifluvents) at the West Tennessee Experiment Station, Jackson, TN, and on a Hebert silt loam (fine-silty, mixed, thermic, Aeric Ochraqualfs) at the Southeast Branch Experiment Station, Rohwer, AR. Both soils tested high and medium in extractable P and K levels, respectively, as evaluated by the respective University Soil Testing Laboratories.

Agronomic information concerning each research location is reported in Table 1. The research areas were seeded at a rate to provide 13 to 16 plants per meter of row at a row spacing of 0.9 m. The production systems used in the research were no-till with no irrigation in Tennessee and conventional-till with irrigation in Arkansas. Recommended N rates for cotton production varied between the two states; the rates of the MPR materials in the treatments were a percentage of these recommended rates (Anonymous, 2000; Chapman, 1998). In 1997, the treatments included 100, 80, and 60% of the recommended rates. Actual treatment rates applied at each location are reported in Table 2. In 1998, a lower treatment rate (40%) of both MPR N and K materials were added along with a lower rate (60%) of the recommended K which was applied as K chloride. The MPR materials were applied in-furrow in direct contact with the seed at planting while the conventional fertilizers (ammonium nitrate and KCl) were broadcast before planting. A Gandy Orbit-Air 6210 dry fertilizer applicator fitted with a Zero-Max control box (Gandy Co., Owatonna, MN) for precise application of the materials. The applicator was configured between the tractor and a four row planter, with the materials applied in- furrow using a colter and dry fertilizer knife manufactured by Yetter (Yetter Farm Equipment, Colchester, IL). The Gandy Orbit-Air was a two row applicator and the materials were applied in contact with seed of the two middle plot rows. Fertilizers were surface applied to the two outside plot rows immediately following planting.

The N research area was fertilized by broadcasting triple superphosphate (20% P) at a rate to supply 15 kg P ha^{-1}, and K chloride (50% K) was broadcast at 56 kg K ha^{-1} before planting (Table 1). The K research area was fertilized by broadcasting ammonium nitrate (34% N) at the recommended rate for both states and triple superphosphate was broadcast at 15 kg P ha^{-1} before planting. A recommended cotton cultivar was planted each year at both locations (Table 1). Weed control, insect control measures, defoliants, etc. recommended for cotton production in each state were used in the research (Shelby, 1996; Bonner, 1995).

A recommended defoliant was applied when 60% of the bolls were open at both locations. In Tennessee, lint yields were determined by mechanically picking the two center plot rows twice each year. Cotton was first picked approximately two weeks after defoliation with a second picking approximately three weeks later. Percent lint was determined by combining sub-samples of seed- cotton from individual treatments across replications (less than 4.5 kg)

Table 1. Agronomic data for slow-release fertilizer studies in Tennessee (TN) and Arkansas (AR), USA in 1997 and 1998.

	TN (Collins silt loam)		**AR (Hebert silt loam)**	
	N Study	**K study**	**N study**	**K study**
Planting data				
1997	16 May	16 May	6 May	6 May
1998	2 May	2 May	7 May	7 May
Cultivar				
1997	DPL 50	DPL 50	Suregrow 125	Suregrow 125
1998	DPL 5409	DPL 5409	Suregrow 125	Suregrow 125
Plot width (m)	4.1	4.1	4.1	4.1
Plot length (m)	12.2	12.2	15.2	15.2
N fertilization (kg ha^{-1})	—†	90	—†	123
P fertilization (kg ha^{-1})	15	15	15	15
K fertilization (kg ha^{-1})	56	—†	56	—†

† Applied as differential treatments listed in Table 2

Table 2. Nitrogen and potassium application rates evaluated at the two locations of Tennessee and Arkansas, USA.

Source	**Rate†**	**Tennessee**		**Arkansas**	
		N	K	N	K
	%	**kg ha^{-1}**			
Ammonium Nitrate‡	100	90	56	123	56
Ammonium Nitrate	60	54	34	74	34
Meister¶	100	90	56	123	56
Meister	80	72	45	99	45
Meister	60	54	33	74	33
Meister	40	36	22	49	22

† Percentage of recommended rate.
‡ Ammonium Nitrate as controls.
¶ Meister programmed-release materials

and ginned on a 20-saw gin with dual lint cleaners. Lint yields were calculated by multiplying the lint fraction by seed cotton weights. In Arkansas, prior to harvesting plots, a random 50-boll sample was handpicked from each plot to determine boll weight and lint fraction (gin turnout). Lint sub- samples were sent to Louisiana State University for fiber quality tests using High Volume Instrument (HVI) systems. In the Arkansas test, the center two rows of each plot were machine harvested at approximately 60% open boll to determine final yield.

The experimental design at both locations was a randomized complete block with treatments replicated five times in Tennessee and six times in Arkansas. Statistical analyses of lint yields were performed utilizing mixed model SAS procedures (SAS Ins., 1999). The mixed model procedure provided Type III F statistical values but not mean square values for each element within the analyses or the error terms for mean separation. Therefore, mean separation

Table 3. Effect of Meister slow-release nitrogen on cotton lint yields produced in Tennessee (TN) on a Collins silt loam and in Arkansas (AR) on a Hebert silt loam.

N source	Rate†	Applic‡ Method	1997		1998	
			TN	AR	TN	AR
	%		kg lint ha^{-1}			
Meister	100	I-F	1097a¶	1749a	1082a	1625a
Meister	80	I-F	1080a	1896a	1113a	1698a
Meister	60	I-F	1050a	1876a	1101a	1587ab
Meister	40	I-F	---§	---§	964b	1499b
Ammonium Nitrate	100	B	1034a	1826a	1097a	1454b

† Percent of the recommended nitrogen rate for each state.
‡ Application methods; I-F = in furrow application; B = Broadcast.
¶ Within a yield column, means followed by the same letter are not significantly different at $P = 0.05$.
§ Treatment not included.

was evaluated through a series of protected pair-wise contrasts among all treatments (Saxton, 1998). Mean differences with probabilities greater than P = 0.05 were categorized as non-significant.

RESULTS AND DISCUSSION

Nitrogen study

Lint yields from MPR-N were not affected by any treatment (N source or placement) at either location in 1997 (Table 3). In Tennessee, lint yields ranged from 1034 to 1097 kg ha^{-1} while in Arkansas lint yields were considerably higher ranging from 1749 to 1896 kg ha^{-1}. These results indicated that in-furrow applications of MPR-N did not reduce yields at either location regardless of application rate. The results of the present study also showed that the N fertilization rate could be decreased while maintaining high yields by applying the MPR-N fertilizer. Reducing the rate to 60% of the recommended N rate, a reduction of 32 kg N ha^{-1} in Tennessee and 49 kg N ha^{-1} in Arkansas, represents a significant decrease in N application with no yield reduction. The magnitude of this N reduction has tremendous implications for crop production from improved nutrient use efficiency and reducing potential environmental concerns (Bremner, 1995). Nitrogen use efficiency was increased compared with the conventional N source when equivalent yields were produced at a lower N rate using MPR-N (Table 3).

In 1998, yields produced at both locations were reduced when the MPR-N material was applied to supply 40% the recommended N rate (Table 3). In Tennessee, lint yields were increased from 964 to 1101 kg ha^{-1} as the MPR-N was increased from 40 to 60% (36 to 54 kg N ha^{-1}) of the recommended N rate. In Arkansas, applying the 40% MPR-N (49 kg N ha^{-1}) rate significantly reduced yields compared with the 80% (99 kg N ha^{-1}) rate while yields from the 60% (74 kg N ha^{-1}) rate was intermediate between the two rates. Yields resulting from broadcasting ammonium nitrate were lower than applying either 80 or 100% the recommended rate using MPR-N.

Boll weights were evaluated for cotton produced in Arkansas and with no significant differences among treatments (data not presented). Also, HVI tests were conducted and there were no significant differences in gin turnout, micronaire, fiber length, fiber length uniformity, and strength (data not reported).

The temperature controlled release characteristic (Anonymous, 1990) suggests the possibility of banding the material 5 to 10 cm below the surface several weeks ahead of planting (winter or early spring) eliminating the need to apply N at or following planting. Soil temperatures during the late winter or early spring should be sufficiently low to restrict N release, because the N release from MPR-N fertilizer is virtually zero when soil temperatures are 10°C (personal communication, Jim Thomas of Helena Chemicals), which is typical for soils of the Mississippi River Delta during winter or early spring. Banding of this material would eliminate any problems encountered when cotton is planted either in or close to an anhydrous ammonia application zone.

Potassium study

Lint yields for the MPR fertilizer K study were affected by the treatments applied at both locations (Table 4). The 1997 Tennessee data showed that in-furrow applications 56 kg K ha^{-1} (100%K) as MPR-K reduced yields compared with broadcasting K chloride at 56 kg K ha^{-1}. Yields were reduced by the in-furrow slow-release applications

Table 4. Effect of slow-release potassium on cotton lint yields produced in Tennessee (TN) on a Collins silt loam and in Arkansas (AR) on a Hebert silt loam.

Source	Rate†	App.‡	1997		1998	
		Method	TN	AR	TN	AR
	%		kg lint ha^{-1}			
KCl	100	B	1172ab¶	1840a	1182c	1449a
KCl	60	B	---§	---§	1246b	1549a
Meister	100	I-F	1055d	1662b	1341a	1620a
Meister	80	I-F	1100cd	1709ab	1219bc	1692a
Meister	60	I-F	1133bc	1826a	1179c	1581a
Meister	40	I-F	---§	---§	1237bc	1493a

† Percent of the recommended potassium rate for each state.
‡ Application methods; I-F = in furrow application; B = broadcast.
¶ Within a yield column, means followed by the same letter are not significantly different at P = 0.05.
§ Treatment not included.

of 100% K, i.e., 56 kg K ha^{-1} (1055 kg lint ha^{-1}) as compared to applying the same material at a rate equivalent to 60% of the recommended rate (1133 kg lint ha^{-1}). A similar relation was observed in Arkansas, yields were reduced by in-furrow applications of 56 kg K ha^{-1} using MPR K compared with reducing the application to 60% the recommended rate. Yields at both locations were not reduced by reducing the K rate to 60% recommended K rate when in-furrow applied as MPR-K compared with broadcasting K chloride at 56 kg K ha^{-1} (100%K rate). The data suggest that high K concentration within the planting zone may have had a detrimental effect on yields. The mechanism of this yield reduction is not understood. Personal observations (by Howard) suggest that high K fertilization may delay crop maturity and thus restrict yields during certain years. Plant populations were not decreased and cannot be considered as a sour-ce for yield reduction.

In 1998, the yield response to in-furrow applications of MPR- K differed from the 1997 treatment effects (Table 4). In Tennessee, the highest yielding treatment was an in- furrow application of 100% recommended K rate (56 kg K ha^{-1}) as MPR- K with lower yields resulting from in-furrow application of the lower rates of MPR-K. This was a reversal of the 1998 results. Also, in 1997 broadcasting K chloride resulted in higher yields compared with in-furrow applications of K at 100 or 80% of the recommended rates as the MPR-K. In 1998, in-furrow applications of MPR-K at 100% the recommended K rate (56 kg K ha^{-1}) in Tennessee resulted in higher yields compared with broadcasting K chloride. The 1998 Arkansas yields were unaffected by treatment. Therefore, in-furrow applications of the MPR-K may in certain years have a detrimental effect on cotton yields.

The effects of K treatments on boll weights were evaluated in 1997 on cotton produced on the Hebert silt loam in Arkansas and there were no significant differences due to treatment. The weights ranged from 4.61 to 5.04 g/boll (data not presented). Also, HVI tests were conducted and there were no significant differences in micronaire, fiber length, fiber length uniformity, and strength (data not reported). However, gin turnout was significantly decreased as the rate of the MPR material was reduced from 100 to 60%. Fiber elongation was lower for the control fertilizer (KCl) and compared with the the MPK material.

Yield differences between the two locations may be due to tillage and moisture. Previous research conducted in Tennessee suggests cotton response to K fertilization may be affected by tillage (Howard et al., 1999). A second factor is that the Arkansas research was irrigated promoting higher yields. Data from both locations show that additional research is needed to fully evaluate the MPR- K for cotton production. Evaluation of the treatment effect on both leaf and petiole K concentrations of material collected at first flower and seven days later showed that treatments did not have a significant effect and therefore the data are not presented.

Conclusions

Nitrogen release from the programmed slow-release N fertilizer was sufficiently low that in-furrow applications did not affect cotton seedling germination, plant popula-tions and yields at two locations. The use of the material allowed high lint yields when fertilized at a lower N rate thus improving nutrient use efficiency. Utilization of MPR-N fertilizer would allow cotton production in areas improve nutrient efficiency and restrict potential environmental concerns. However, additional research is needed to evaluate proper placement. The utilization of the MPR-K fertilizer was not as effective for promoting high cotton yields as observed for the MPR-N. Lint yield response to the MPR-K fertilizer showed contrasting effects between the two experimental years suggesting the need for further research. A primary concern with usage of the MPR materials is their cost. These costs range from five to seven times higher than conventional fertilizers making their usage questionable for current cotton production. Injecting these materials only increases the overall production costs.

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