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Nitrogen fertilizer sources and tillage effects on cotton growth, yield, and fiber quality in a coastal plain soil☆

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ABSTRACT

Interest in urea-ammonium sulfate (UAS) as a N fertilizer is increasing due, in part, to increased restrictions on ammonium nitrate. This has resulted in UAS being marketed as an alternative fertilizer source; however, UAS has not been widely tested. A cotton (*Gossypium hirsutum* L.) field study was conducted in Central Alabama from 2009 to 2011 on a Coastal Plain soil (Marvyn loamy sand; fine-loamy, kaolinitic, thermic Typic Kanhapludult) comparing UAS to two common granular fertilizers [urea, ammonia sulfate (AS)] under both conservation and conventional tillage systems. The overall objective was to determine the influence of UAS on cotton growth parameters, yield, and fiber quality. Cotton was fertilized with 101 kg N ha^{-1} urea, AS, or UAS 5–6 wk after planting each year. Plant growth characteristics were evaluated 3–4 wk before defoliation, and cotton yield and fiber quality were determined on the machine-harvested lint. Tillage had little influence on plant growth, while UAS and/or AS tended to produce the largest number of bolls and largest aboveground, root, and total biomass in 2009 and 2011. Lint yield was also influenced by fertilizer source in 2009 and 2011, with UAS and AS producing significantly higher yields than urea. Both tillage and fertilizer source had minimal influence on cotton fiber quality. Results suggest that UAS produces similar or greater yields than urea and is comparable to AS. However, more research is needed to determine the long-term influence of UAS on soil acidity and N loss compared to urea and AS.

1. Introduction

Optimizing crop productivity is important to the sustainable supply of food, feed, fuel, and fiber for a growing human population. Nitrogen (N) is often the most limiting nutrient in agricultural systems; thus, supplying the soil with N for crop production is imperative to achieve maximum yields. During the past century, the use of synthetic N sources has surpassed the use of organic sources (manures and legume rotations) in agricultural systems throughout most of the world. Consequently, inorganic N inputs have become an indispensable commodity. Current annual world fertilizer use accounts for more than 180 million tonnes ($N+ P_2O_5+ K_2O$), with N being the most demanded nutrient at approximately 110 million tonnes (Heffer and Prud'homme, 2015). Stewart and Roberts (2012) estimated that 40–60% of the world's food production can be attributed to inorganic fertilizer use. All things considered, inorganic fertilizer N use is critical to securing sustainable crop production.

Traditionally, ammonium nitrate (AN; 34-0-0) has been one of the dominant N fertilizer sources used in row crops and forage production because it was easy to transport, store, and apply. In recent years, stringent regulations have been placed on the transport, storage and sale of AN due to concerns by the US Department of Homeland Security (U.S. Department of Homeland Security, 2013). As a result of potential liabilities, some manufacturers have stopped or limited AN production and dealers are hesitant to stock large quantities (Pearce et al., 2006). This resulted in AN use (as a percentage of total fertilizer use) decreasing from 15% in 1960 to 2% in 2011 (USDA-Economic Research Service, 2012).

As a result of restrictions on AN, fertilizer dealers have begun touting the use of urea-ammonium sulfate (UAS) as an alternative nutrient source. Urea-ammonium sulfate is essentially a 50:50 mix of urea (46-0-0) and ammonium sulfate (AS; 21-0-0-24), resulting in a product containing ~34% N. Globally, urea is the most widely used fertilizer and accounts for over 50% of all N applied (Gilbert

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Abbreviations: AS, ammonium sulfate; HVI, high volume instrumentation; NUE, nutrient use efficiency; UAS, urea-ammonium sulfate.

☆ Mention of trade names or commercial products in this article is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture.

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et al., 2006) due to its low cost, high N content and solubility, and ease of handling; urea usage has increased from 2% in 1960 to 22% in 2011 (USDA-Economic Research Service, 2012). Historically, AS has been sold as a specialty fertilizer for crops preferring acid soil conditions. Given that AS is only 21% N compared to that of AN (34%) or urea (46%), the cost is relatively high per kg of N content. Ammonium sulfate also has the potential to increase soil acidification (Stumpe and Vlek, 1991).

With all N fertilizers, N use efficiency (NUE) is estimated at 30–50% in most agricultural soils (Newbould, 1989; Raun and Johnson, 1999; Delgado, 2002; Abbasi and Tahir, 2012), leaving the excess subject to runoff, leaching, and volatilization. These N losses pose risks to the environment and to human health (Spalding and Exner, 1993). Ammoniacal fertilizers (e.g., AN, AS, and urea) are the most susceptible to ammonia (NH_3) volatilization which is one of the main pathways for N loss from fertilizer application (Ma et al., 2010; Jantalia et al., 2012). Research has shown that 10–60% of topdressed fertilizer N can be lost through NH_3 volatilization (Ellington, 1986; Hargrove, 1988). Nitrogen loss from fertilizer application can depend on the form of N applied, soil type, and the environment at the time of application. Previous research has shown that NH_3 loss is greatest with urea and least with AS (Gasser 1964; Hargrove et al., 1977; Ellington, 1986; Sommer and Jensen, 1994); NH_3 loss from UAS has not been thoroughly studied.

Tillage practices are an integral part of a crop production system. In the last 20 years, conservation tillage has become common practice to improve water availability, fuel energy savings, erosion control, and government erosion compliance regulations. Nitrogen fertilizer management can be greatly affected by tillage. Plant residue decomposition can be slowed when tillage is limited which can increase short-term N immobilization (Gilliam and Hoyt, 1987; Wood and Edwards, 1992). Conservation tillage systems may also increase leaching losses (Tyler and Thomas, 1977) and promote denitrification (Gilliam and Hoyt, 1987). Soil N dynamics are also impacted by the effects of tillage on soil moisture and temperature (Nadelhoffer et al., 1991; Torbert and Wood, 1992). As a result, fertilizer N rates have increased in some production systems by as much as 25% to prevent yield limitations (Randall and Bandel, 1991). Thus, the interaction between tillage and N source is important from a crop production perspective (Balkcom and Burmester, 2015). Few experiments have examined interactions between differing tillage systems and N fertilizer sources.

The sustainability of any crop production system is dependent on supplying adequate amounts of N for uptake. Nitrogen can be supplied through a variety of sources; however, these can vary with regard to environmental impacts. For example, several researchers have reported that urea is more susceptible to N losses as NH_3, while others have reported that AS may decrease soil pH. Given that UAS is being sold as substitute for AN, research is needed to determine its effect on crop yield. Furthermore, the influence of UAS and its integration with tillage on crop production is not well understood. Thus, the objective of this study was to evaluate the influence of three fertilizer sources (urea, AS, and UAS), under conventional vs. conservation tillage, to determine their influence on cotton growth, lint yield, and fiber quality.

2. Materials and methods

2.1. Site description

A field experiment was conducted from 2009 to 2011 at the Alabama Agricultural Experiment Station's E.V. Smith Research Center – Field Crops Unit (32°25′19″N, 85°53′, 7″W) near Shorter, Alabama, USA. The soil was a Coastal Plain Marvyn loamy sand (fine-loamy, kaolinitic, themic Typic Kanhapludult), which consists of deep, well-drained, moderately permeable soils formed from loamy marine sediment. Soil textural analysis was 81%, 4%, and 5% for sand, silt, and clay, respectively with a 6.4 pH, 6.3 g kg^{-1} soil organic matter (SOM) concentration, and an extractable P concentration of 18 mg kg^{-1}, K concentration of 19 mg kg^{-1}, and S concentration of 4.7 mg kg^{-1}. Mean annual precipitation is approximately 1350 mm, with an annual temperature of 18 °C, resulting in a humid subtropical climate (Current Results, 2015).

2.2. Experimental design and treatments

The study consisted of two tillage treatments (conventional vs. conservation tillage) and three N fertilizer treatments (urea, ammonium sulfate, and urea-ammonium sulfate) in a 2 × 3 factorial arrangement using a randomized complete block design with four replicate blocks. Cereal rye (*Secale cereale* L.) was planted in November of each year at a rate of 100 kg ha^{-1} using a conservation tillage grain drill as a winter cover. In the conventional tillage treatment, the rye was mowed and disked in April of each year. In conservation tillage plots, the rye was killed with glyphosphate (*N*-phosphosnomethyl glycine) at a rate of 1.15 kg ai ha^{-1} and rolling 7–10 d before sowing cotton seed (*Gossypium hirsutum* L.). Conventional tillage plots received a second disking and rototilling in May of each year prior to sowing cotton. Conservation tillage consisted of in-row subsoiling which was conducted using a lead coulter followed by a strip-till shank and closing wheels. Each plot consisted of four planted rows spaced 1.01 m apart in 31 m^2 (4.08 m by 7.62 m) plots. Each plot within blocks was separated with a 1.01 m buffer (non-fertilized cotton row); a 7.6 m alley separated blocks. Cotton seed were sown at a rate of 17 seeds m^{-1}. Deltapine 454 BT Stack was planted on 12 June, 2009; Phytogen 375 was planted on 13 May, 2010; and Deltapine 0949 BT 2 Roundup Flex was planted on 17 May 2011. Nitrogen treatments were urea (46% N), ammonium sulfate (AS; 21% N), and urea-ammonium sulfate (UAS; 34% N) surface broadcast by hand at 101 kg total N ha^{-1} 5–6 weeks after sowing, around first square. Supplemental irrigation was applied each year as needed using an overhead linear-movement sprinkler irrigation system. A total of 35.6 mm was applied in 2009 (June – 15.24 mm; July – 20.34 mm), 40.6 mm in 2010 (June – 12.7 mm; August – 27.9 mm), and 71.1 mm in 2011 (May – 25.4 mm; June – 45.7 mm). Pesticides were applied to cotton as needed based on Alabama Cooperative Extension System's recommendations. Cotton was chemically defoliated and a boll opener applied when 60–70% of the bolls were opened. After harvesting each year, cotton stalks were shredded with a rotary mower.

2.3. Pre-yield harvest

Detailed cotton growth measurements were determined 3–4 weeks prior to chemical defoliation. In each plot, a 1.5 m plastic pipe was thrown adjacent to each of the outer two rows and all plants along the pipe length were cut at the ground line with pruning shears. All bolls were removed by hand and placed into cloth bags by plot. All plants were bagged by plot and placed in walk-in cold rooms (4 °C) until detailed measurements were made. Height and ground line diameter (using high precision digital calipers) of each plant was measured. After bolls were counted, bolls and the remaining aboveground plant parts (leaf + stems) were placed in separate paper bags and dried to a constant weight at 55 °C in a forced-air drying oven.

Two randomly selected plants in each outer row were used for vertical root-pulling resistance (Böhm 1979; Prior et al., 1995). A manual winch (Model No. 527, Fulton, Milwaukee, WI) mounted on a portable metal tripod with a cable gripping tool (Model No. 72285K8, Klein Tools, Chicago, IL) attached to the cotton stalk was used to break the roots from soil. A scale (Model No.