

**RIGHT SOURCE**

Matches fertilizer type to crop needs.

**RIGHT RATE**

Matches amount of fertilizer to crop needs.

**RIGHT TIME**

Makes nutrients available when crops need them.

**RIGHT PLACE**

Keeps nutrients where crops can use them.

This article is part of a series from The Fertilizer Institute highlighting some of the latest 4R research.

4R nitrogen fertilizer management

in cotton production

Nitrogen supply for cotton is critical for vegetative growth, development of fruiting sites, and yield. Considerations for the 4Rs in nitrogen management in cotton are quite different from those for corn due to differences in the growth and nitrogen uptake patterns of the plant and the soils and climates in which cotton is commonly grown. Earn 0.5 CEUs in Nutrient Management by reading this article and taking the quiz at www.certifiedcropadviser.org/education/classroom/classes/684.

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Cotton is grown across the south of the United States with some fields requiring irrigation and some managed with natural moisture. In 2017, 12.6 million acres of cotton were planted across 20 states (National Cotton Council of America, 2019). Nitrogen supply for cotton is critical for vegetative growth, development of fruiting sites, and yield. The partitioning and pattern of nitrogen taken up by cotton is influenced by the plant's genetics, environmental conditions, and the availability of nitrogen in the soil-water solution. One genetic influence is that cotton has an indeterminate growth pattern unlike other crops like corn that have a determinate growth pattern.

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With indeterminate growth, plants continue to grow until they are killed by external factors; with determinate growth, plants develop reproductive structures and die based on complete formation of the genetically pre-determined structure.

Cotton takes up 30% of the total nitrogen needed for production between emergence and the first white bloom, which occurs 60 days after emergence. The remaining 70% of nitrogen need is taken up between the first white bloom and just after peak bloom or between 60 and 80 days after emergence. The higher nitrogen demand later in the growth cycle of the plant makes in-season applications of nitrogen critical to the rapid growth and fruiting development occurring in a short time period. Nitrogen fertilizer rate and plant development need to be balanced

since overfertilizing with nitrogen leads to increased vegetative growth and reduced production of fruiting sites, resulting in lower yields (Lemon et al., 2009; Main et al., 2013). Research across 20 cotton-growing sites reported that nitrogen application rate affected plant height and number of nodes (Main et al., 2013). Specifically, increased nitrogen rates resulted in more plant height and more nodes but also resulted in delayed crop maturity (Main et al., 2013). In addition to the potential problems with excess vegetative growth and decreased yields, high nitrogen applications also lead to nitrogen loss through nitrification as nitrate (NO_3^-) in leachate or denitrification as nitrous oxide (N_2O) in air emission.

Source, rate, time, place

In addition to the nitrogen uptake pattern of cotton, the nitrogen source, rate, time, and placement decisions are affected by soil type and water management characteristics of the site. Cotton will take up and respond to ammonium and NO_3^- from any source including soil, water, fertilizer, or atmospheric deposition (Main et al., 2013). Accounting for all fertilizer, soil, and water nitrogen additions is key to good cotton nitrogen management. The need to apply nitrogen at or before planting depends on preplant soil test nitrate-N levels (Doerge et al., 1991). Applying nitrogen before or at seeding when soil nitrate-N levels are higher can result in nitrogen losses due to the cotton plant's low nitrogen demand during the early growth stages. In drier areas, where soils have lower organic matter and less rainfall occurs, a critical part of the 4R strategy is deep soil testing for nitrates to determine nitrogen rates for pre-season or at-seeding applications. Soil testing for nitrate prior to planting should be performed to a depth of 24 inches to accurately credit available soil nitrogen before determining fertilization rates.

When preplant soil test nitrate-N levels indicate preplant nitrogen is needed, an ammoniacal fertilizer form is recommended to reduce leaching losses (Doerge et al., 1991). If applications are completed prior to seeding, granular fertilizers should be placed with two to three inches of soil between the fertilizer and the seed. Applications of anhydrous ammonia should be kept 6 to 9 inches below the soil surface and out of the seed zone (Doerge et



Above: The higher nitrogen demand later in the growth cycle of the plant makes in-season applications of nitrogen critical to the rapid growth and fruiting development occurring in a short time period. Photo by Bill Barksdale/AGE Fotostock America.

Right: Petiole testing is key to determining in-season nitrogen needs and the nitrogen fertilizer source to apply. Source: NC State Extension (go.ncsu.edu/readext?416851).



al., 1991). Research comparing nitrogen rates determined with and without accounting for soil NO_3^- found a more accurate relationship of lint yield to available nitrogen when soil NO_3^- was considered for nitrogen rate determination (Main et al., 2013). Accounting for the NO_3^- in the soil profile helped explain the decreasing yield response at higher nitrogen rates, showing the value of pre-plant soil nitrate testing to improve the return on applied nitrogen.

As the cotton plant matures, the demand for nitrogen increases and in-season nitrogen applications are recommended. Petiole testing is key to determining in-season nitrogen needs and the nitrogen fertilizer source to apply. When petiole levels are below 4,000 ppm at the pinhead square, or when the pre-bloom flower bud has developed at the initiation of a fruiting branch, application of a nitrate or urea source of nitrogen is recommended for more rapid absorption by the cotton plant (Doerge et al.,

1991). When petiole nitrate concentrations are higher, ammonium sources of fertilizer can be used; however, if anhydrous ammonia is the source used in season, be sure to consider the potential for plant injury from ammonia toxicity, especially when used in very sandy soils (Doerge et al., 1991). In many cotton-growing areas, irrigation and fertigation are used for in-season nitrogen applications. When nitrogen applications are made through fertigation or with a liquid sprayer, urea ammonium nitrate (UAN; 32–0–0) is generally applied (Lemon et al., 2009).

Managing nitrogen to reduce nitrous oxide loss

The source, rate, time, and placement of nitrogen application in cotton production affects crop growth, yield, and quality, and it influences the potential and magnitude of nitrogen loss. Loss of nitrogen as nitrous oxide (N_2O) is a concern in irrigated cotton management systems. In areas where irrigation is used in cotton production, irrigation is achieved through surface, overhead sprinkler, or sub-surface drip irrigation. A six-year study in Arizona compared nitrogen application through different irrigation systems and with different products and rates of nitrogen fertilizer (Bronson et al., 2018). The N_2O -N flux was not measured in the same years and was not statistically compared among the irrigation types. The nitrogen application rate and source of nitrogen fertilizer applied were tested in each system and compared within those systems. The effects of nitrogen source (UAN versus UAN with Agrotain Plus) and nitrogen recommendation method (soil test based versus reflectance based) were highly variable within irrigation management systems and between the years tested for each system (Bronson et al., 2018). Seasonal N_2O flux (g N_2O -N per ha for the number of growing days in the season) was highest when nitrogen was applied through the sprinkler-irrigated system and lowest when applied in the subsurface drip-irrigated system (Bronson et al., 2018). In the subsurface drip-irrigated system, the nitrogen applications were split into 24 individual applications, and this method of application likely contributed to the lower measure of N_2O emissions (Bronson et al., 2018).

Variable-rate nitrogen application in cotton

Variable-rate (VR) application of nitrogen is a growing trend in many cropping systems and was recently evaluated on 21 farm fields in Louisiana, Mississippi, Missouri, and Tennessee in cotton production using optical-sensing measurements (Stefanini et al., 2018). For each location, the following were compared: a uniform application of nitrogen across the field, VR based only on optical sensing, and VR based on optical sensing and historical yield, soil imagery, or aerial imagery. Across the 21 sites, there

was no difference in nitrogen applied or nitrogen use efficiency (NUE = lint yield divided by nitrogen application rate) among the uniform and VR applications; however, yield and NUE differed by location, soil type, and weather regardless of nitrogen application method. For example, soils with relatively more organic matter, coarser soil textures, or deeper soil profiles had decreased nitrogen application rates that resulted in higher NUE regardless of nitrogen application method (Stefanini et al., 2018). Site-specific considerations are critical with any 4R management system and need to be evaluated for both environmental and economic impacts.

Conclusions

Considerations for the 4Rs in nitrogen management in cotton are quite different from those for corn due to differences in the growth and nitrogen uptake patterns of the plant and the soils and climates in which cotton is commonly grown. In cotton, it is critical to not overapply nitrogen, which will encourage increased vegetative growth and decrease lint yield. Additionally, not accounting for soil test nitrate-N can lead to overapplications and losses. 🌱

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