TWENTY YEARS OF COTTON NITROGEN MANAGEMENT AND CYCLING TRIALS IN THE SOUTHWEST: WHAT HAVE WE LEARNED?

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ABSTRACT

Over 20 site-years of nitrogen fertilizer management and cycling trials have been conducted in Lubbock Texas and Maricopa Arizona from 1998 to 2019. Furrow, overhead sprinkler (OSI), subsurface drip irrigation (SDI) were used. Soil profile nitrate (0-36 inches in Texas and 0-72 inches in Arizona) was sampled and tested for in all trials. Nitrogen-15 labeled fertilizer was used for two years in Texas and for two years in Arizona. Canopy reflectance was measured with active optical sensors in every trial throughout the season. A pre-plant soil NO_3 test (0-24 inches in Texas, 0-36 inches in Arizona)-based N recommendation algorithm was successfully developed. A complementary approach of guiding in-season N applications with a vegetation index relative to a well-fertilized soil test-based plot saved N without hurting yields in both sites. The old 1984 recommendations for petiole NO_3 deficiency levels were lowered by 1000 ppm in Arizona after analyzing eight recent site-years of data. New lessons were learned on the fate of fertilizer N in irrigated cotton in Texas and Arizona. Nitrate leaching can be significant in furrow irrigation but is negligible in OSI and SDI. Recovery efficiency by cotton was about 20, 40, and 90 % of applied/fertigated N fertilizer for furrow, OSI, and SDI respectively. Internal N use efficiency for all yield levels, irrigation modes, and both sites was a remarkably consistent 40 lb N per bale. Net N mineralization was estimated by N uptake in zero-N plots minus credits for soil NO_3. Mineralization varied greatly, but was lowest with SDI where the wetting zone is small, and greatest with OSI where it was often as high as 50 lb N/ac. Testing irrigation water for NO_3 concentrations is an important N credit. Winter cover cropping with a small grain and strip- or zero-till cotton was tested extensively and is encouraged. This information all feeds into the pre-plant soil NO_3 test-based N recommendation which also requires a yield goal. Nitrous oxide (greenhouse gas 300 x more potent than CO_2) emissions were about 1 % of added N in furrow and OSI, but the N_2O emission factor was near zero with SDI and fertigation.

BACKGROUND

Following water, N is the largest constraint to cotton production in the western USA (Morrow and Krieg, 1990). Improving the N recommendations for irrigated cotton in both regions is a very critical task. In Arizona means basin, flood, and furrow irrigation are still the pre-dominant irrigation methods. Nitrogen fertilizer recovery, however, is usually less than 50 % in furrow-irrigated cotton in the West (Navarro et al. 1997; Booker et al., 2007). Current N management research and recommendations in the Western US are lacking for irrigated cotton, especially for newer cotton cultivars, and under conservation tillage. In the Western US, bi-weekly petiole NO_3 sampling and analysis is still a common approach to monitor in-season cotton plant N status. Petiole sampling is laborious and turn-around is several days. Canopy reflectance, on the other hand is a rapid newer technology to assess in-season cotton N status (Chua et al., 2003; Bronson et al, 2003).

W TEXAS 1998-2010

The 0-24-inch pre-plant soil profile NO_3 test was studied and tested at length in W. Texas during this period with a 2.5 bale/ac yield goal. The simple N fertilizer recommendation algorithm entailed:

N fertilizer (lb N/ac) = Lint yield goal (bale/ac)*50 lb N/bale – 0-24-inch soil NO_3 (lb N/ac) – inches estimated irrigation (inches)*ppm NO_3-N irrigation water*0.23.

In 2007-2009 (Bronson et al. 2011), 1.5* soil test N rates were also employed. In nearly all N fertilizer management trials in W. Texas a canopy reflectance-based N management treatment was tested as well. In this approach N rates were initially set at 50 % of the soil test treatment. Weekly canopy reflectance measurements were made with active optical sensors at 1 m above the plants in the soil test plots (passive sensor used in Chua et al., 2003). If the vegetation index calculated from the reflectance data in the reflectance plot was significantly less than that of the soil test plot, then the N rate in the reflectance plot was increased to match that of the soil test plot. This is a "save N without hurting yield" approach. This approach was successful in Lubbock in 2000 and 2001 with surface drip and SDI (Chua et al, 2003), 2005 and 2005 with SDI (Yabaji et al. 2009), and from 2007-2009 (Bronson et al. 2011) under SDI.

ARIZONA 2010-2018

In Arizona the N recommendation algorithm was modified slightly to use a 0-36-inch pre-plant soil NO_3 test and a 4.0 bale/ac yield goal. This is because of greater water inputs (nearly all irrigation), a longer growing season and greater yields that characterize the low desert Arizona cotton production compared to the high elevation, deficit irrigation (declining Ogallala aquifer irrigation water source) West Texas. The soil test NO_3 approach was successful with furrow irrigation in 2012 and 2013, with OSI in 2014 and 2015 (We also included a 1.3*soil test N rate, Bronson et al., 2017), and with SDI from 2016-2019 (Bronson et al., 2019). There was a small lint yield (94 lb/ac) reduction with the reduced N rates of reflectance management in 2015 and a seed yield (but not lint) in 2018.

Eight site-years of petiole NO_3 data taken from first square to peak bloom was evaluated from Maricopa and Safford, under OSI and SDI in Maricopa and furrow irrigation in Safford (Bronson et al., (2021). Results indicate that the deficiency levels based on Pennington and Tucker (1984) can be reduced 1000 ppm without hurting yields. Surprisingly petiole NO_3 in SDI cotton was very low most of the season (Bronson et al. 2020). It is possible that since water and N use efficiency is so high in SDI, the NO_3 reductase enzyme may be operating at a very rapid level, so that petiole NO_3 rarely builds up.

SITES IN BOTH STATES

Figure 1 A shows the lint yield response to N fertilizer rate on the 800 plots across both sites. Nitrogen response, N rates and lint yields were greater in the long-growing Arizona than W. Texas. In Arizona it appeared that the soil test N recommendations were over-predictions of the optimal N application rates. This is probably because the algorithm neglected to account for the contribution of net N mineralization from each plot. Recovery efficiency or the percentage of added N recovered by the cotton plants at first open boll generally increased from furrow to overhead sprinkler to subsurface drip irrigation. Recovery efficiency in Arizona was greater than in W. Texas. Leaching of NO_3 was probably the main N loss pathway with furrow irrigation. Recovery efficiency was > 90 % with subsurface drip irrigation in Arizona and emissions of the potent greenhouse gas N_2O were very low. Emission factors, or percent of added N emitted as N_2O were greatest in sprinkler irrigation in Arizona at about 1 % (Bronson et al. 2018) and similar to other crops like corn (Halvorson et al., 2014).

Recovery efficiency in Lubbock and Maricopa in ^{15}N studies showed similar recovery to the difference methods in SDI in Maricopa where there were 24 fertigation events (Bronson et al., 2019). In Lubbock, with three N applications, recovery efficiency by difference tended to be greater than with ^{15}N-labeled urea (Chua et al, 2003), giving more opportunity for immobilization of N in the organic matter.

Figure 1 B shows total N uptake vs. lint yield for both sites. A linear-plateau regression of has an R^2 of 0.60. The joint point of the linear-plateau regression is at 135 lb N ac^{-1} total N uptake. The 95 % confidence limits for the joint point was 130 and 140 lb N ac^{-1}. The plateau lint yield is 1623 lb ac^{-1} (Fig. 1 B). Dividing 1623 by 135 gives an optimal internal N used efficiency of 12.0 lb lint lb N $uptake^{-1}$. Using the 95 % confidence limits of the joint point we calculate an optimal internal N use efficiency range of 11.6 – 12.5 lb lint lb N $uptake^{-1}$. This very close to the 12.5 kg lint kg N $uptake^{-1}$ reported by Rochester for cotton in Australia (2011). Considering that a bale of cotton is 480 lb, the linear-plateau model estimated that the optimal N internal N use efficiency is 40 ± 1 lb N in the plant /bale for both regions. Internal N use efficiencies of 50 lb N/bale or more clearly represent luxury N uptake. This updated information can feed into the soil test NO_3-based N recommendations for cotton. Given that recovery efficiencies of added N fertilizer in cotton is < 100 %, we suggest retaining the 50 lb N/bale agronomic efficiency (product of recovery and internal N use efficiency) in the N recommendations detailed above.

KNOWLEDGE GAPS GOING FORWARD

Reliable methods to predict N mineralization are a most important research gap. Work is also need in Arizona (currently underway in Texas) on improving soil health, infiltration and soil organic matter with conservation tillage-cum-winter small grain cover cropping. Nearly all the described N management research in both states was with conservation tillage-cum-cover cropping, but it was not long-term and it did not compare conventional tillage. The canopy reflectance research described here used tractor-mounted sensors and so there is a need for drone-based remote sensing for cotton N management in both W. Texas and in Arizona. More research is needed for SDI cotton on petiole NO_3.

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Figure 1. 2000-2018, W. Texas and Arizona cotton N studies. A. Lint yields vs. N fertilizer rate, B. Lint yields vs. total N uptake.