IMPROVING NITROGEN FERTILIZER MANAGEMENT FOR SURFACE-IRRIGATED COTTON IN ARIZONA

Kevin F. Bronson
Jarai Mon
Doug Hunsaker
Eduardo Bautista
Kelly Thorp
Andrew French
Jeff White
US Arid Land Agric. Res. Center
USDA-ARS
Maricopa, AZ
Pedro Andrade-Sanchez
Maricopa Agric. Center
University of Arizona
Maricopa, AZ

Abstract

In a first year of study, we compared fertigation of N fertilizer with knifing in surface-irrigated cotton in central Arizona. We also compared soil-test based N management with reflectance-based and ammonium sulfate vs. urea ammonium nitrate. Nitrogen fertilizer response was observed, but not was different among the N treatments. Nitrogen recovery efficiency was low (max 30%), similar to Texas data. The internal N use efficiency was greater than expected (40 lb N/bale). Emissions of N_2O were very low economically (maximum 0.2 % loss of N fertilizer), but were still elevated (2 – 4X) compared to the zero-N plots. Inorganic soil N transects indicated that fertigation was as uniform as knifing N fertilizer. Amber NDVI showed N deficiency in zero-N plots before red NDVI.

Introduction

Land and canal infrastructure means that level-basin surface irrigation in raised beds in the predominant irrigation system for cotton production in central Arizona. High yields (ie. statewide averages 1500 lb lint/ac) are achieved with typical 40 or more inches of in-season surface irrigation. Nitrogen requirements of the plant are assumed to be high for these high yields. Nitrogen fertilizer is usually managed with early season ground applications followed by "fertigations" i.e. dribbling 32-0-0 UAN into the canal. With typical surface irrigations in the range of 4-5 inches, there is potential for deep leaching N fertilizer when it is fertigated. Additionally, there is concern about the uniformity of N fertigations in surface irrigation systems. There is little research however, that compares ground applications of N fertilizer with fertigations in these systems. The pre-plant soil profile NO_3 test has been shown to be valuable to cotton N management in West Texas (Bronson et al., 2001; Bronson et al., 2007; Bronson et al., 2009), but this has not been tested in Arizona. Similarly, canopy reflectance has been tested in West Texas as a valuable aid to the soil test for in-season N management (Yabaji et al., 2009), but this approach has not been tested in Arizona. The objectives of this study are to:

1. Compare urea ammonium nitrate (UAN) fertigation with knife applications of UAN for a farm-scale surface-irrigated field, furrowed for cotton.
2. Compare urea ammonium nitrate (UAN) fertigation with ammonium sulfate fertigation for a farm-scale surface-irrigated field, furrowed for cotton.
3. Compare soil test-based N fertilizer management with canopy reflectance-based N management in surface-irrigated cotton.
4. Construct N balances for surface-irrigated cotton, i.e. quantify total N uptake, recovery N use efficiency, NO_3 leaching, and denitrification losses.

Materials and Methods:

In April 2012, pre-plant soil sampling to 180 cm for NO_3 was done with four samples per plot. Cotton cultivar 'DP 1044 B2RF' was planted in late April, 2012 in plots that were 8, 1-m rows wide by 160 m. Nitrogen treatments were:

Table1.

Nitrogen treatment	Fertilization mode	Fertilizer source	Fertilizer rate (lb N/ac)	Notes
1. Zero-N			0	
2. Soil test-based N†	Knife	Urea amm. nitrate	132	2 splits: 1st square, 1st bloom†
3. Soil test-based N†	Fertigate	Urea amm. nitrate	132	2 irrigations: 1st square, 1st bloom†
4. Soil test-based N†	Fertigate	Amm. Sulfate	132	2 irrigations: 1st square, 1st bloom†
5. Reflectance-based N‡	Knife	Urea amm. nitrate	66	2 splits: 1st square, 1st bloom†
6. Reflectance-based N§	Fertigate	Urea amm. nitrate	66	2 irrigations: 1st square, 1st bloom†

† Based on lint yield goal of 3.5 bale/ac, and a 175 lb N/ac N requirement, minus 0 - 24 in. soil NO_3-N and estimated irrigation input of 20 lbN/ac (estimated 40 inch irrigation of 2 ppm NO_3-N water).
‡ First split equals 50 % treatment no. 2, second split based on NDVI relative to treatment no. 2.
§ First fertigation 50 % treatment no. 3, second fertigation based on NDVI relative to treatment no. 3.
The experimental design was a completely randomized block, with three replicates.
Transects of soil profile (0 – 180 cm in 30 cm increments) NO_3-N was determined after the first fertilization/fertigation events on four, unreplicated plot-treatments, i.e. treatments 1, 2, 3, and 4. Transects consisted of 12 samples at 12 m intervals.

Surface flux of N_2O was measured weekly for 10 weeks during the season using vented chambers and gas chromatography. Biomass and total N uptake was determined from plant samples on 2 m of row at first open boll. Nitrogen recovery efficiency, physiological N use efficiency and agronomic use efficiency was calculated. Lint and mature seed yields were machine harvested. Mature cotton seed N was determined from grab samples at the four DGPS points per plot and the percentage of seed N to total N uptake calculated.

Transect soil NO_3 data was subject to repeated measured ANOVA, repeated by depth and by latitude. Pre-plant soil profile NO_3, N_2O emission, NDVI, plant biomass, plant N uptake, lint, and seed yield was analyzed with a mixed model using SAS. Replicate was considered random, and N treatment was be considered fixed.

Results and Discussion

Pre-plant soil NO_3 was low in this study, with only 23 lb NO_3-N/ac in the 0-36 inch profile. Nitrogen fertilizer applied was 132 lb N/ac on the soil test-based N management treatments and 66 lb N/ac on the reflectance- based treatments. Rates were not increased on the reflectance plots because NDVI never differed between those plots and the soil test-based N plots. Lint and seed yields were similar among all of the N-fertilized treatments, but significantly greater than the zero-N plots (Table 1). Lint yield averaged 1660 lb/ac in the N-fertilized plots , equal to the 3.5 ba/ac yield goal. Total N uptake at first open boll was positively related to N fertilizer rate but, not N source. Zero-N uptake was a remarkable 116 lb N/ac (Table 2). When subtract from this value 23 lb N/ac of soil profile NO_3-N and 16 lb N/ac of calculated irrigation water NO_3 (40 inches of 2 ppm NO_3-N), we arrive at an estimate of net N mineralization of 77 lb N/ac. Recovery efficiency of N fertilizer was not affected by N treatment and ranged from 8 to 30 (Table 2). This is similar to values for furrow-irrigated cotton in West Texas (Bronson et al., 2008).

Table 2. Lint yield, seed yield, agronomic and internal N use efficiency, as affected by N management in surface-irrigated cotton, Maricopa, AZ 2012

Nitrogen treatment	Fertilization mode	Fertilizer source	Fertilizer rate	Lint yield	Seed yield	Agron. N use efficiency	Internal N use efficiency
			lb N/ac	lb/ac	lb N/ac	lb lint/lb N fert.	lb N/bale
Zero-N			0	1450 b	2166 b		37.5 ab
Soil test-based N†	Knife	Urea amm. nitrate	132	1718 a	2604 a	2.0 a	40.5 a
Soil test-based N†	Fertigate	Urea amm. nitrate	132	1610 a	2439 a	1.2 a	43.3 a
Soil test-based N†	Fertigate	Amm. Sulfate	132	1594 a	2396 a	1.1 a	45.5 a
Reflectance-based N‡	Knife	Urea amm. nitrate	66	1714 a	2552 a	4.0 a	32.3 b
Reflectance-based N§	Fertigate	Urea amm. nitrate	66	1671 a	2449 a	3.3 a	35.3 b

Table 3. First open boll biomass, N uptake and recovery efficiency, as affected by N management in surface-irrigated cotton, Maricopa, AZ 2012

Nitrogen treatment	Fertilization mode	Fertilizer source	Fertilizer rate	Biomass	N uptake	Recovery efficiency	Seasonal N_2O flux
			lb N/ac	lb/ac	lb N/ac	%	g N_2O-N/ac/96 d
Zero-N			0	6558 b	116 b		46 b
Soil test-based N†	Knife	Urea amm. nitrate	132	7026 ab	149 a	25 a	98 ab
Soil test-based N†	Fertigate	Urea amm. nitrate	132	7474 a	147 a	23 a	178 a
Soil test-based N†	Fertigate	Amm. Sulfate	132	7981 a	155 a	30 a	154 a
Reflectance-based N‡	Knife	Urea amm. nitrate	66	6103 b	121 b	8 a	
Reflectance-based N§	Fertigate	Urea amm. nitrate	66	6970 ab	126 b	15 a	

Internal N use efficiency averaged 39 lb N/bale (Table 2), with the lowest values on the 66 lb N/ac N rate. These values are similar to previous reports in West Texas of 40 lb N/bale (Bronson, 2008) and much different than the 100 lb N/bale in previous Arizona work (Navarro et al,, 1997).

Twelve-point transects to 72 inches were soil sampled eight days after the first fertigation. Soil NH_4 levels were low (data not shown), but NO_3 levels were high in the subsoil (Fig. 1). Low soil NH_4 was not expected, but is probably explained by rapid NH_4 oxidation to NO_3. Error bars (not shown) were similar among all treatments, indicating that fertigation was about as uniform as knifing. Nitrate was less in the top profile for knife vs. fertigation, probably because the soil sampling was in the furrow and the knifing was in the side of the bed.

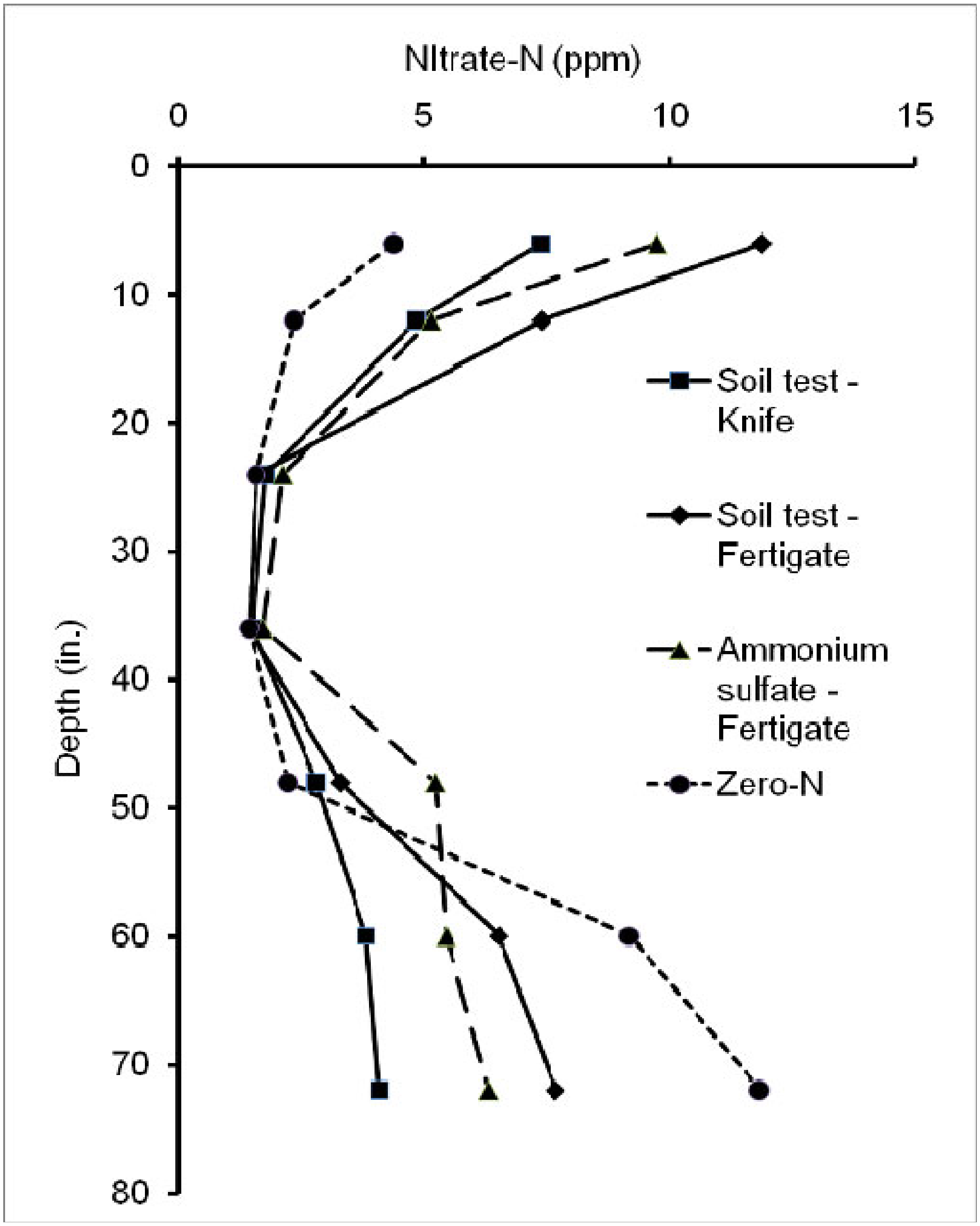

Fig. 1. Extractable nitrate-N as affected by N treatment, mid bloom cotton, Maricopa, AZ 2012 (averages of 12 transect points).

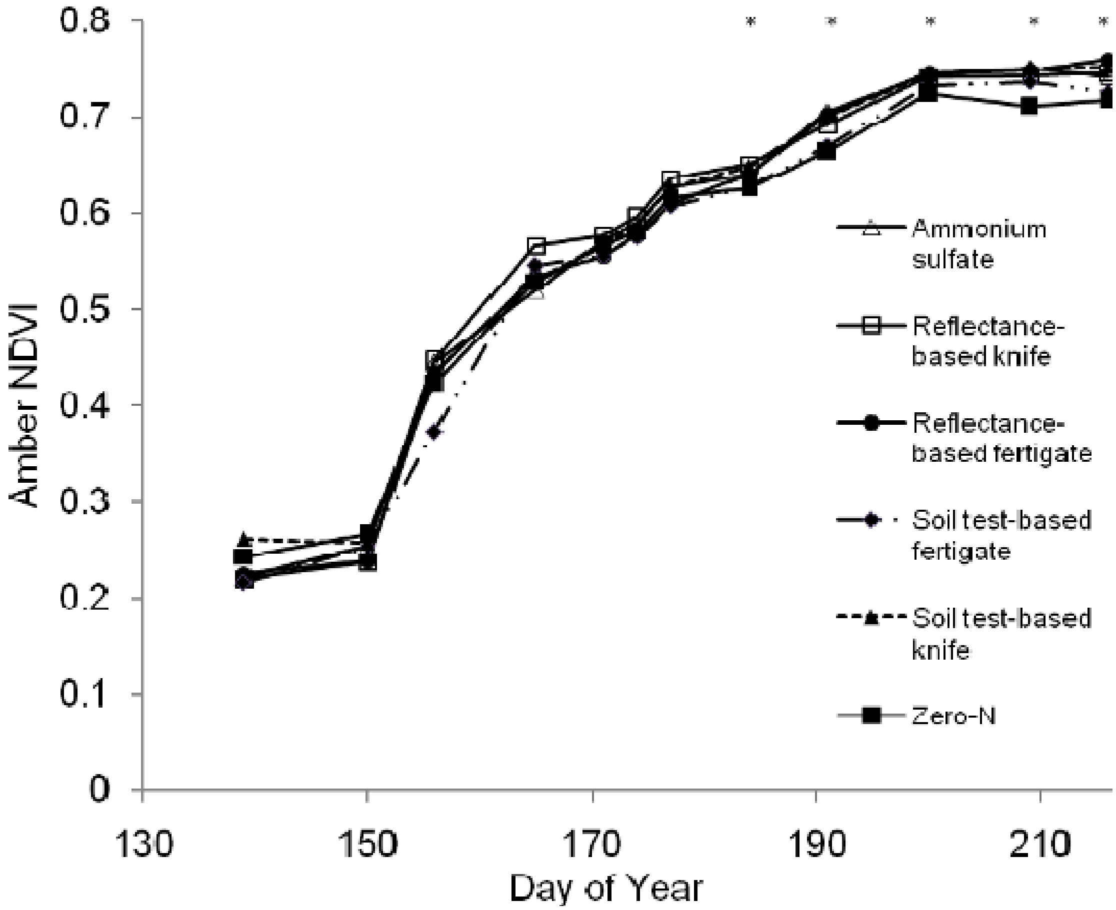

Fig. 2. Seasonal amber NDVI in cotton as affected by N treatment, Maricopa, AZ 2012

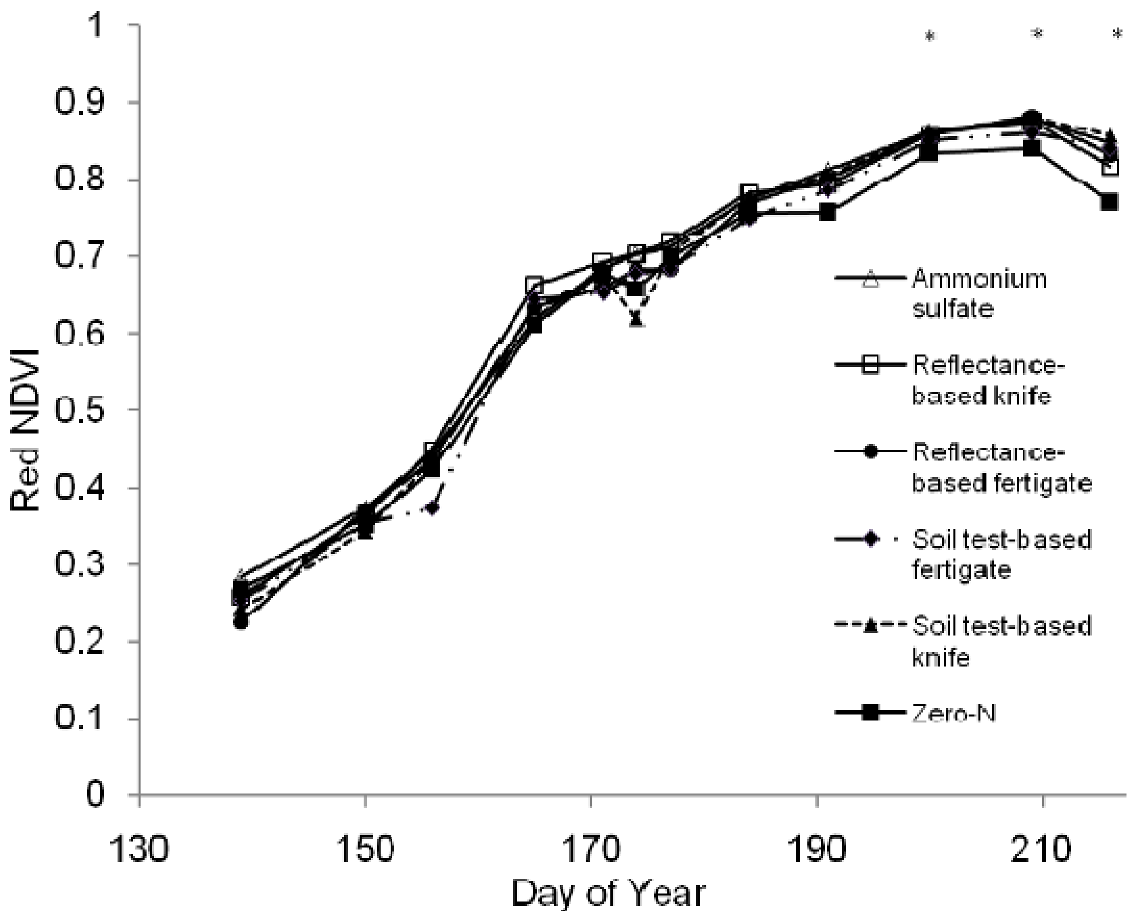

Fig. 3. Seasonal red NDVI in cotton as affected by N treatment, Maricopa, AZ 2012

As mentioned above, the vegetative indices did not show differences among N treatments, so Fig. 3 and 4 show the individual indices by date, average across treatment. Amber NDVI was significantly less in the zero-N plots vs N-fertilized plots at 185th day of the year. Red NDVI did not show the zero-N plots until 200 day of the year.

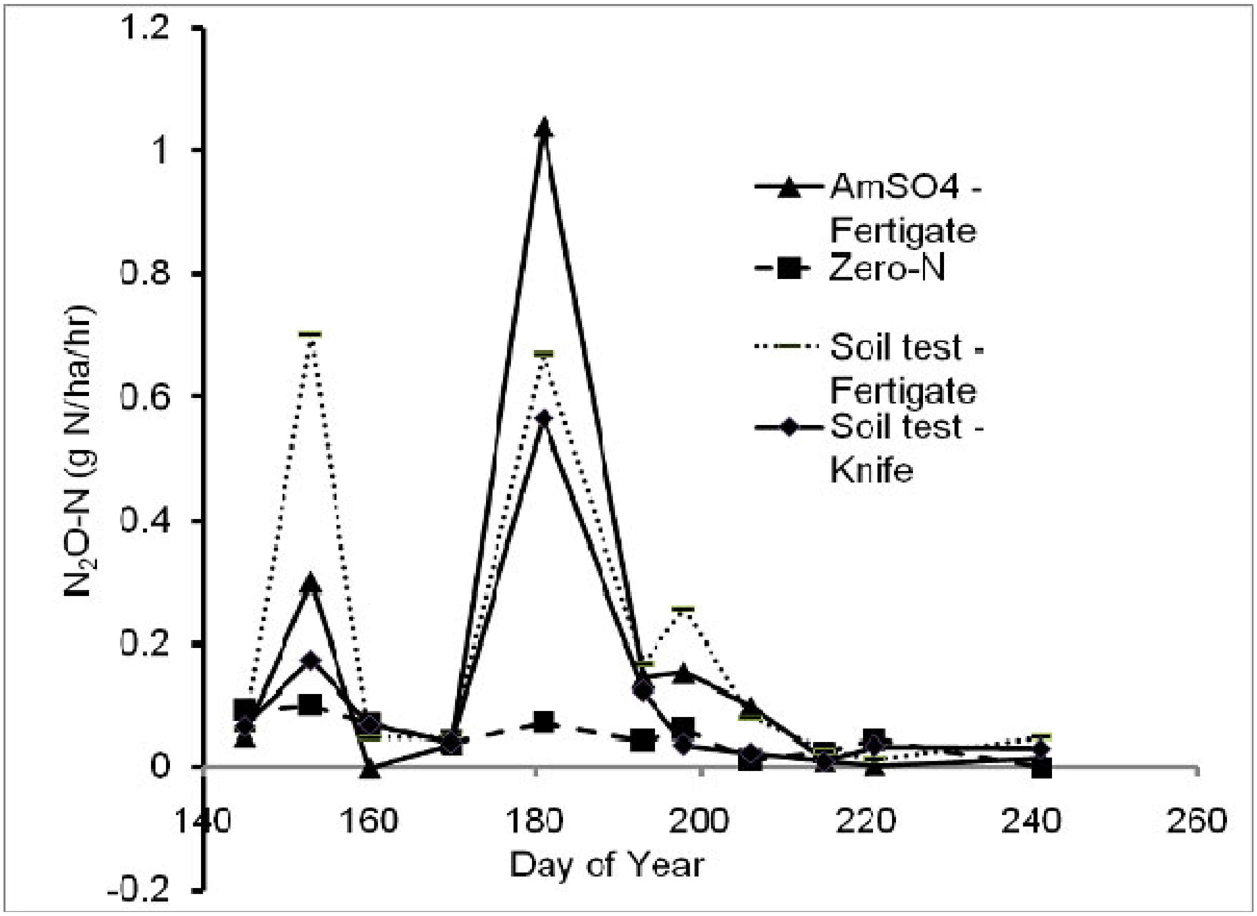

Fig. 4. Seasonal nitrous oxide emissions in cotton as affected by N treatment, Maricopa, AZ 2012

Nitrous oxide emissions were low in all N treatments during the 95-day measurement period following fertilization and fertigation (Table 3 and Fig. 4). The soil-test based fertigation treatment lost only 0.2 % of fertigated N fertilizer as N_2O, which is in the range of N_2O losses from drip-irrigated cotton in Texas (Yabaji et al, 2009).

Table 4. Nitrous oxide emission as affected by N source, and fertigation vs. knifing, Maricopa, AZ, 2012.

Nitrogen treatment	Fertilization mode	Fertilizer source	Fertilizer rate	Seasonal N_2O flux
			lb N/ac	g N_2O-N/ac/96 d
Zero-N			0	46 b
Soil test-based N†	Knife	Urea amm. nitrate	132	98 ab
Soil test-based N†	Fertigate	Urea amm. nitrate	132	178 a
Soil test-based N†	Fertigate	Amm. Sulfate	132	154 a

References

Bronson, K.F. 2008. Nitrogen Use Efficiency Varies with Irrigation System. Better Crops with Plant Food. 92 (4): 20-22.

Booker, J.D., K.F. Bronson, C.L. Trostle, J.W. Keeling, and A. Malapati. 2007. Nitrogen and phosphorus fertilizer and residual response in cotton-sorghum and cotton-cotton sequences. Agron. J. 99:607-613.

Bronson, K.F., A. Malapati, J.D. Booker, B.R. Scanlon, W. H. Hudnall, and A.M. Schubert. 2009. Residual soil nitrate in irrigated Southern High Plains cotton fields and Ogallala groundwater nitrate. J. Soil Water Conserv. 64: 98-104.

Bronson, K.F., A.B. Onken, J.W. Keeling, J.D. Booker, and H.A. Torbert. 2001. Nitrogen response in cotton as affected by tillage system and irrigation level. Soil Sci. Soc. Am. J. 65: 1153-1163.

Yabaji, Rajkumari, J.W. Nusz, K. F. Bronson, A. Malapati, J. D. Booker, R.L. Nichols, and T. L. Thompson. 2009. Nitrogen management for subsurface drip irrigated cotton: Ammonium thiosufalte, timing, and canopy reflectance. Soil Sci. Soc. Am. J. 73:589-597.