ADVANCING NITROGEN AND IRRIGATION MANAGEMENT FOR ROW CROPS AND BIOFUEL CROPS IN THE WESTERN US

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ABSTRACT

Nitrogen, irrigation and N by irrigation studies from West Texas and central Arizona are discussed. In the first study with surface drip, deficit irrigation, N fertilizer rate response was observed with cotton (*Gossypium hirsutum* L.) in 50 and 75 % ET replacement, but not with dryland or 25 % ET. Irrigation level response was evident with LEPA in two of three years in Lamesa Texas, but not in a wet, third year. Variable-rate N showed a more consistent response than blanket-rate N in that study. In a surface-irrigation management study in AZ, NDVI-based crop coefficients (Kcb), which allowed 65 % soil water depletion to a small percentage of the field, resulted in the highest cotton yield, and FAO-based Kcb achieved the lowest yields. In an N management cotton study in AZ, fertigation of urea ammonium nitrate (UAN) was just as uniform and as effective as knifing-in UAN. Recovery efficiency of N in furrow surface irrigation in AZ was similar to that of Texas. The optimum N fertilizer rate for lesquerella (*Lesquerella fendleri* L.) in central AZ was 200 lb N/ac for both medium and high irrigation levels. In summary, efficient water management results in greater N recovery efficiency in row and biofuel crops and reduced N losses.

INTRODUCTION

Water and N are the first and second limiting factors in crop production in the arid and semiarid Western U.S (Morrow and King, 1990). Surface irrigation techniques such as flooding level basins, or furrow irrigation between raised beds is still the most common irrigation method in the US. and worldwide. The more efficient center-pivot and subsurface drip irrigation systems are growing in use, especially drip irrigation (Colaizzi et al., 2009). Nitrogen fertilizer management differs greatly among irrigation methods, with the efficient fertigation option available in pivots and drip systems. Bronson et al. (2008) reported that in cotton in West Texas, N recovery efficiency varied from 15 to 70 % with furrow and subsurface drip irrigation, respectively. Nitrogen requirements vary greatly with cereal crops requiring more than cotton. Interest is growing in irrigated biofuel feedstock in the West (Tamang et al., 2011), and the high energy cost of N fertilizer needs consideration. In this paper we will review several recent N, water, and N by water crop and biofuel feedstock studies in semi-arid West Texas and arid central Arizona.

METHODS

The first study presented is Bronson et al. (2001) which was a 3-year cotton ('Paymaster HS26') study in Lubbock, TX with an five N fertilizer rates (0, 25, 50, 75, and 100 lb N/ac and four rates of surface drip irrigation (0, 25, 50, and 100 % ET replacement). Nitrogen and irrigation treatments were replicated three times. Pre-plant soil NO_3 was determined to 36 inches each year.

The next study discussed is a large-scale (35 acres) N fertilizer management cotton by irrigation level study under low energy precision (LEPA) center-pivot irrigation in Lamesa, TX from 2001 to 2003 (Bronson et al. 2006). The N treatments were zero-N, blanket-N and variable rate N. Variable rate N applications were based on interpolating 0-24 inch soil NO_3 sampled on grids. Three un-replicated levels of deficit irrigation were applied. Nitrogen treatments were replicated three times. Cotton cultivar was 'Paymaster 2326 RR' in 2002 and 2003 and 'FiberMax 989 RR' in 2004. Pre-plant soil NO_3 was determined to 36 inches each year.

The third study presented examines four irrigation management strategies, replicated four times in surface irrigated (raised beds in a level basin) cotton in Maricopa in 2009 and in 2011 under uniform N management. The 12-acre field consisted of 16 irrigation plots/borders (each 550 feet long), oriented north-south, each with 12, 40-inch spaced rows. 'Delta Pine 164 B2 RF' was planted in April in both years. Two of the treatments (denoted as VI_A and VI_B) utilized aerial and ground-based spatial information of crop evapotranspiration (ETc), soil water holding characteristics, and infiltrated water to separately monitor the crop and soil water status for each zone. A third irrigation scheduling treatment (denoted as FAO) employed zonal information on soil water holding and irrigation but did not use spatial estimates for ETc. The fourth irrigation treatment (denoted as MAC) adopted the irrigation schedule used by the farm supervisor at the Maricopa Agricultural Center. For the VI_A and FAO treatments, irrigations were given when the total available water (TAW) of the crop root zone had been depleted by 45%, as averaged for all zones within the treatment. The criterion used to determine irrigation timing for the VI_B treatment was when 5% of the zones in the treatment had been depleted to 65% of the TAW.

The fourth study presented is Bronson et al., (2013) describes an N fertilizer management cotton ('DP 1044 RR B2') study with uniform surface (beds in level basin) irrigation in Maricopa AZ during the 2012 growing season. Knifing-in of urea ammonium nitrate (UAN) was compared to fertigation of UAN and fertigation of ammonium sulfate. Plots were 8, 40-inch rows by 550 feet, and N treatments were replicated three times.

A fifth, study (unpublished) is an N fertilizer rate by irrigation level experiment with lesquerella (*Lesquerella fendleri* L.), cultivar 'Gail' in the 2011-2012 winter growing season of Maricopa, AZ. Six N fertilizer rates (0, 50, 100, 150, 200, and 300 lb N/ac) using solid urea in five splits were applied between pre-plant and eight weeks after first bloom. The two surface irrigation levels were 877 and 1173 mm. Plot size was 7 by 13 m, and each treatment was replicated four times.

RESULTS AND DISCUSSION

Cotton lint yields responded quadratically to surface drip irrigation levels in 1996 and 1997, and linearly in the drought year of 1998 in Lubbock, TX study (data not shown, Bronson et al., 2001). Quadratic regressions indicated that optimal irrigation level for yield ranged from 71 to 97 % ET. Nitrogen fertilizer response was observed in the second and third year, but only at the 50 and 75 % ET irrigation levels (Fig. 1). This indicates the importance of linking N management with irrigation planning.

Lint yield showed a linear response to LEPA irrigation level in Lamesa, TX, in 2002 and 2003, but there was no statistical irrigation response in the wet year of 2004 (Bronson et al., 2006). Nitrogen fertilizer resulted in increased yields in all years, but the response was less than that of irrigation in 2002 and 2003. Variable-N management had more consistent N response than blanket-N. Unlike the surface drip irrigation study, there was no N by water interaction in lint yields.

Table 1 shows lint yields for the two-year irrigation management study in Maricopa, AZ in 2009 and 2011. In both years, the greatest yields were achieved with the NDVI-based Kcb, which allowed 65 % soil water depletion to a small portion of the field and the regional irrigation practice " MAC". The lowest yield and total water applied in both years was with the FAO Kcb crop coefficients. Water use efficiency was greatest with NDVI, 65 % depletion, in 2009, but was similar among all treatments in 2011.

Nitrogen fertilizer response in cotton lint yields was similar among all N management treatments in the first year of a Maricopa, AZ study in 2012 (Table 2). It is notable that the common western US practice of fertigating UAN into surface irrigated furrows was as effective as knifing-in the side of the bed. Transects of soil profile (12 points across 550 feet) showed similar soil NO_3 concentrations in the 0-12 inch surface layer and with similar uniformity (CV = 47% for both fertigation and knifing soil NO_3 transects) (data not shown). Recovery efficiency of N was similar to furrow-irrigated studies in Texas (maximum 30%) as was the internal N use efficiency (40 lb N/bale) (Yabaji et al., 2009).

Nitrogen fertilizer and irrigation response was noted in the first year of surface irrigated lesquerella study in Maricopa, AZ 2011-2012 (Table 2). Recovery efficiency of N fertilizer ranged from 31 to 47 % and was not affected by irrigation level. Avoiding pre-plant N applications may boost N recovery efficiency, as water inputs are high after planting and the early growth was very slow. At 150 lb urea-N/ac, recovery efficiency was maximum, but optimal N rate for seed yield was 200 lb urea-N/ac at both water levels. The highest lesquerella seed yield of 1960 lb/ac was despite very short plants (i.e. < 10 inches).

SUMMARY

Irrigation amounts in arid Arizona are much greater than in semi-arid West Texas. In the occasional rainy season of West Texas, no irrigation response in observed. Yield levels of cotton vary considerably between these two regions, but the high lint yields (i.e. 1800 to 2000 lb/ac) are similar. Nitrogen recovery was similar between surface irrigated cotton in the West Texas and central Arizona at a maximum of 30 %. Recovery efficiency of greater than 50 % is very doable with several split applications and with efficient irrigation.

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Fig. 1. Lint yield response to N fertilizer by irrigation level, Lubbock, TX, 1998 (adapted from Bronson et al., 2001).

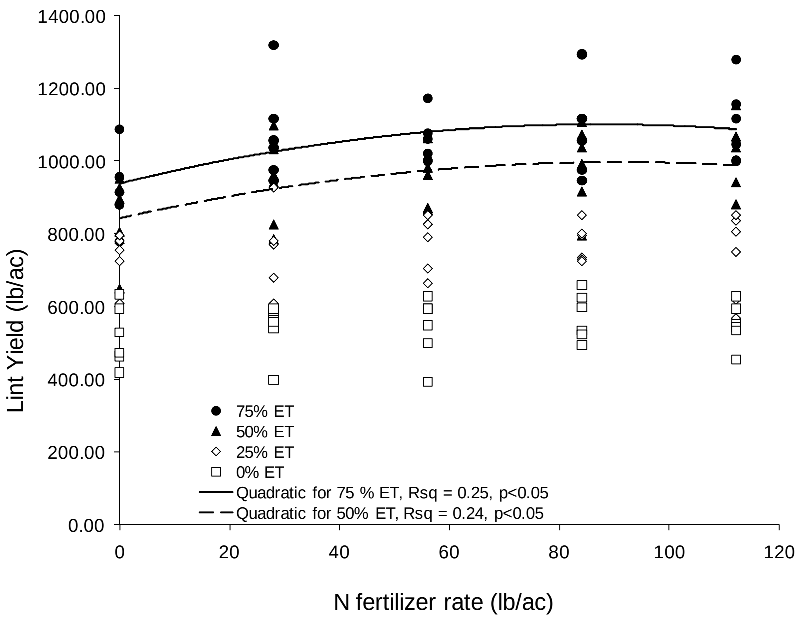

Table 1. Cotton lint yields as affected by water management strategies, Maricopa, AZ, 2009 and 2012

Water Management	Irrigation applied	Lint Yields	Water use efficiency
	mm	lb/ac	mm/lb
2009			
NDVI-based Kcb, 45 % depletion	820	1694 b	2.1
NDVI-based Kcb, 65% depletion	802	1825 c	2.3
FAO-based Kcb	754	1526 a	2.0
Maricopa Ag Center	861	1839 c	2.1
2011			
NDVI-based Kcb, 45 % depletion	812	1464 b	1.8
NDVI-based Kcb, 65% depletion	853	1534 c	1.8
FAO-based Kcb	768	1397 a	1.8
Maricopa Ag Center	851	1547 c	1.8

Table 2. Lint yield, recovery, agronomic and internal N use efficiency, as affected by N management in surface-irrigated cotton, Maricopa, AZ 2012 (adapted from Bronson et al., 2013).

Nitrogen treatment	Fertilization mode	Fertilizer source	Fertilizer rate	Lint yield	N Recov. efficiency	Agron. N use efficiency	Internal N use efficiency
			lb N/ac	lb/ac	%	lb lint/lb N fert.	lb N/bale
Zero-N			0	1450 b	-	-	37.5 ab
Soil test-based N†	Knife	Urea amm. nitrate	132	1718 a	25 a	2.0 a	40.5 a
Soil test-based N†	Fertigate	Urea amm. nitrate	132	1610 a	23 a	1.2 a	43.3 a
Soil test-based N†	Fertigate	Amm. Sulfate	132	1594 a	30 a	1.1 a	45.5 a
Reflectance-based N‡	Knife	Urea amm. nitrate	66	1714 a	8 a	4.0 a	32.3 b
Reflectance-based N§	Fertigate	Urea amm. nitrate	66	1671 a	15 a	3.3 a	35.3 b

Table 3. Seed yields and nitrogen uptake of lesquerella as affected by irrigation level and N fertilizer rate, Maricopa, AZ, 2012

	Medium irrigation			High irrigation		
N fertilizer rate	Seed yield	N uptake	N Recov. efficiency	Seed yield	N uptake	N Recov. efficiency
lb N/ac	lb/ac	lb N/ac	%	lb/ac	lb N/ac	%
0	306	37	-	365	36	-
50	730	53	32	795	58	44
100	902	76	39	1317	80	44
150	1193	107	47	1590	103	45
200	1532	118	41	1960	121	43
300	1345	131	31	1772	150	38