Fertilizer Research and Education Program

Final Report

A. Project Information

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B. Abstract

A three-year study was conducted to evaluate cotton yield responses to nitrogen fertilization under subsurface drip and furrow irrigation at one site (Univ. CA West Side REC), and crop nitrogen (N) uptake and removal in the N fertilizer response study and in Pima variety trial sites at 4 grower field sites in different counties of the San Joaquin Valley. The N removal with harvest is largely from harvest of the seed, with a smaller amount removed with the gin trash produced during the ginning process to separate seed from lint. The evaluations at the University of CA ANR West Side Research Center (WSREC) include two Pima varieties compared with two Upland varieties at early boll maturation and harvest time N removal in a field study under subsurface drip and furrow irrigation at four N application levels (50, 75, 100, and 125% of estimated N fertilizer needs, adjusted for planting time soil residual nitrate-N in the upper 2 feet of soil profile). A zero applied fertilizer treatment was included in the study as a baseline treatment in terms of uptake and yield response. To provide data on N removal across a range of yield potentials and soil conditions, we also collected yield data and N removal data in three or more Pima cotton varieties (variable by year) as part of the Pima variety trials conducted in grower fields at three to four locations (Merced County, Kern County, Fresno and/or Kings County). At these grower sites, there were no N fertilizer application variables, but rather the evaluations were done under typical grower fertilizer practices at these sites. Lint yields during the three years at the West Side REC site ranged from low to moderately high, versus moderate to moderately high in on-farm trial locations. At the Univ. CA West Side REC field trial site, beginning soil residual nitrate-N levels in the upper two feet of soil at planting were relatively low, resulting in significantly lower yields in the 0 and 50% estimated N requirement treatments.

Nitrogen removed with the harvested Pima cotton crop has been quantified in this study across multiple years, ranging from about 44 to 52 lbs N per ton of seedcotton yield, averaging about 49 lbs N removed with the seed per ton of seedcotton. When lint plus seed are harvested from the field and processed at a cotton gin, extraneous leaf, stem and boll fragments (called gin trash) remain after seed and lint are separated out. Nitrogen removed as gin trash ranged from approximately 4 lbs of N per ton of seedcotton (lint plus seed) to almost 15 lbs N per ton, with an average of 7 lbs N per ton of seedcotton in gin trash. These evaluations included grower fields sites and different soil types and a wide range of yield levels, so this information should assist growers and consultants to better estimate minimum crop nitrogen needs for a range of yield potentials. While recognizing the important impacts of pest pressure on seedcotton yield potential in any year, the fertilizer N rate study portion of the project determined that both Pima and Upland cultivars had similar yield responses to applied fertilizer N rates.

C. Introduction - Project background

San Joaquin Valley cotton growers aim for high yields in order to be able to cover production costs and pay for increasing costs of inputs such as irrigation water, fertilizer and crop protection chemicals. This high yield goal can serve as a significant incentive to apply high rates of fertilizer N to increase their chances of achieving desired yields

and profit potential. However, applications of nitrogen (N) to cropland in the form of fertilizers or manure have received increased attention due to groundwater nitrate studies by United States Geologic Survey and UC Davis researchers (Harter et al (2012). Regulatory decisions made since that time by State Water Board and other agencies raise the likelihood of a range of efforts to require more tightly managed use of fertilizer and manure-based N sources. These N management programs in various stages of development and implementation across the state also serve to point out some knowledge gaps we have regarding crop N responses, and uptake and removal under a range of production conditions. Pima cotton is one relatively large acreage crop for which there is quite limited data on N responses, uptake and removal with harvest.

As part of University of CA Cooperative Extension field research efforts in irrigation projects, we have been collecting some limited information as a side project on above-ground plant nutrient uptake measurements in both Upland and Pima types of cotton. All of this work has been done over a number of years at the University of CA West Side Research and Extension Center (WSREC). The nitrogen component of these studies was only a minor subset of the work on the overall projects, so much of this work was done with limited replications and only at one site and has not been published to date. There is some limited work on Pima cotton N uptake. Values shown in some prior reports described on the CDFA FREP website shows some limited studies (7 observations total) for Pima types of cotton (Fritschi, et al, 2004), with an average value of N removal of 33.1 lbs N/ton of lint plus seed, suggesting that removal in Pima is much lower than the average value of 43.7 lbs N/ton of lint plus seed that was referenced for Acala and non-Acala Upland types of cotton. The limited uptake data from small plot irrigation studies on Pima cotton (unpublished to date) conducted at the UC West Side REC in recent years were determined using small area harvests in field research plots, with plants partitioned in different components, weighed, and then subsampled to determine N content. In those studies, the average values for N removal with harvest for Pima types of cotton were actually quite similar to those in some more limited studies we have done using Upland varieties and have not shown lower values for Pima cotton.

D. Objectives

1: For Pima cotton in the San Joaquin Valley at the Univ. CA West Side REC, evaluate for high-yield potential cultivars the impacts of N application amount, variety and irrigation method (subsurface drip versus furrow) on total plant N uptake and harvest removal, including a comparison with a widely planted Upland variety.

2: Utilize 3 grower farm sites with moderate to high yield potential, using multiple Pima varieties and representing different soil types to determine total above-ground plant N uptake at early open-boll timing, and N removal with harvest (measured as N content of seed, lint, gin trash, measured separately) to better understand Pima N requirements.

3: As information is developed in the study, present information to appropriate grower groups, consultants and industry to give opportunities for feedback and to refine concepts of workable changes in N management approaches.

E. Methods

Experimental Sites:

Two types of field studies were conducted in this three-year study, including:

1. University of CA West Side REC - small plot studies on N uptake as a function of N application amount and variety under subsurface and drip irrigation, including two Pima varieties versus two Upland cotton varieties for comparison. For each year of the rate study at the WSREC, a different study site was selected and established at the West Side REC in a field that had been in small grains the prior year to provide a reduced / lower initial soil nitrate profile. Since the sites changed each year to avoid carryover nitrogen effects, new subsurface drip tape was installed for SDI studies each year.
2. Grower field site studies in three San Joaquin Valley counties (Merced, Kern and Fresno or Kings) focused on determining total plant N uptake and N removal with seed and gin trash in multiple Pima cotton varieties with some potential for differences in gin turnout percentage.

Most grower sites were in soils described as clay loams or loams in terms of texture, since few sandy loam grower sites are still in cotton production. All grower site locations were furrow or level-basin irrigation. All grower sites each year (Kern County, Kings County, Fresno County, Merced County sites) were planted in March or April each year. Early season soil samples were collected from the upper four feet of soil profile (collected at times varying from one week prior to planting to 2-3 weeks post planting but prior to any irrigations) and analyzed for NO3-N. The Pima cotton varieties grown at these on-farm sites were relatively similar in growth habit, plant vigor and size, but have some differences in seed size (about 15% range in seed size), and some modest varietal differences in timing for harvest maturity were evident (about 7 days maximum). At the larger Grower Sites, we used existing, planned sites for our UC Cooperative Extension Pima variety trials for these trials, and typically those trials have 6 or more different commercial variety entries. We identified different Pima varieties to use for the N uptake and removal studies, and those same 3 to 4 varieties were used for evaluations at all grower test sites. Some of the varieties included changed during the course of the three-year study due to changes in commercial seed availability. At grower and REC sites, yields were determined using spindle-type pickers, and subsamples were collected from the picker during the harvest operations for later ginning to separate seed from trash and lint as part of the protocol.

At the West Side REC site, N removal and uptake, growth and yield responses of 2 Pima and 2 Upland varieties were sampled for evaluations at five N application levels, representing 0, 50, 75, 100 and 125% of estimated N requirements, adjusted for soil residual nitrate N in the upper 2 feet of the soil profile at planting timing. For the purposes of these studies, based on prior field experiments at the West Side REC, we established 185 lbs N/ac as the target fertilizer application at the 100% level treatment

to supply what we considered adequate N for a 2000 lbs lint/acre yield. The actual N fertilizer applications shown in Table 2 were calculated based on the % value for each purposes of these studies, based on prior field experiments at the West Side REC, we established 185 lbs N/ac as the target fertilizer application at the 100% level treatment to supply what we considered adequate N for a 2000 lbs lint/acre yield. The actual N fertilizer applications shown in Table 2 were calculated based on the % value for each treatment multiplied by 185 lbs N/acre minus the average early-season soil residual nitrate in the upper 2 feet of soil (Table 1). Estimated fertilizer needs were adjusted for early season residual soil nitrate, with the target amount based on a realistic yield goal for the site. The timing of N applications for the subsurface drip treatments started at the 7-8 leaf growth stage, with proportional application rates stepped up as plants grow (based on prior West Side REC studies with drip), with the goal of completing N applications (applied as water-injected liquid urea) by approximately peak bloom growth stage (late July or early August). Furrow irrigated plots received N applications in two injections of knifed-in liquid UAN (2019 and 2020) about 8-10 inches away from the seed row and about 4 to 6 inches deep, with the injections split between one made about 3 weeks post-planting and another at lay-by. Similar timing was used in 2021, but fertilizer applications were as a granular urea application in the bottom of furrows.

Early Season Soil Sampling. At initiation of the projects at West Side REC, we used a Giddings soil sampler to collect samples to a depth of eight feet below grade to identify initial residual soil nitrate. Residual NO3-N values determined for the upper two feet of the profile were used to adjust fertilizer application rates in the N rate study (values shown in Table 1). End-of-season (harvest timing) evaluations of soil nitrate levels to eight feet depth were only done at the West Side REC site in all nitrogen treatments, but only for one Pima variety in the test under both irrigation regimes (furrow and subsurface drip). At the grower farm sites, we hand augered to a depth of 4 feet for initial residual soil nitrate (values shown Table 9 in Appendix). Soil samples were collected at or prior to planting in the upper two feet of the soil profile in three locations on the tail end of each field used in this part of the study, and three locations on the head end of the field (each about to one-fourth of the field length in from the field edge). The three locations per side of the field were composited, and the samples mixed, dried and analyzed for soil nitrate N. Soil nitrate levels were considered to be moderately-low to moderate in most grower sites, considering that prior crops at these sites included small grains, cotton, garbanzos and processing tomatoes across different sites.

Plant Tissue Sampling. Plant sampling for peak above-ground N uptake was done approximately at 30% open boll stage. Biomass sample estimates were made at the same time in all plots as an area harvest (about 5 feet of row length), with 5 plants selected from these areas for separation into stems, leaf/petiole and burs/seed components and then analyzed to determine tissue N concentrations for uptake estimates. Seeds are the primary location for most N in cotton bolls, and this has been found in CA and AZ location studies in both Upland and Pima. All plots at grower sites and West Side REC site were harvested using a spindle type commercial picker, so we

used large samples (approximately 3 to 6 lbs each) collected at intervals from the same field plots where seedcotton weights were measured to Plants were grown on 40-inch row spacing at the University of CA West Side REC in a Panoche clay loam soil to run the cotton nitrogen response study using two Pima cultivars (Phy-881RF, DP348RF) and two Upland cultivars (Phy764 WRF, DP 1845 B2RF). Irrigations with both furrow and subsurface drip systems were scheduled to avoid significant water stress during the primary fruit development and boll filling periods each year. A locally derived crop coefficient and CIMIS weather station data were used to estimate crop ETc to schedule irrigations. Irrigations were in amounts and frequency to avoid damaging water deficits, and considering soil water storage capacity, applied irrigations should not have generated significant deep percolation past the 5-to-6-foot depth in the soil profile. Periodic crop water stress monitoring using an infrared thermometer and the CWSI (crop water stress index) type of analyses verified CWSI levels of a maximum of <0.25 prior to furrow irrigations.

Matching experiments were set up to apply N fertilizer amounts to achieve the same total N application amounts under subsurface drip (SDI) and furrow irrigation (F). In SDI plots, drip tape with 0.27 gph emitters spaced 12 inches apart were installed at a depth of 8-10 inches below the bed centers, with the system operated 2 times/week during lower evapotranspiration (ET) time of the year, and 3 times/week during higher ET periods. N fertilizer applications in the SDI plots were initiated at the 7-9 node stage in the cotton plants (about the first week of June), and weekly applications of nitrogen (urea) were injected to match estimated plant uptake during rapid growth phases, with the final applications to be made during the 2nd or 3rd week of August. Nitrogen fertilizer applications in the furrow irrigated plots were split in timing and amount, with the first half applied just prior to planting, and the second half applied just prior to the irrigation applied about 5-6 weeks later.

F. and G. – Data / Results and Discussion

Pre-plant residual soil nitrate levels in the upper two feet of soil are shown in Table 1, and fertilizer nitrogen treatment and application amounts are shown in Table 2.

Table 1. Pre-plant residual soil NO3-N – West Side REC study, 2019, 2020 and 2021 as a function of irrigation treatment and field replication.

Nitrogen Study Area	Pre-Plant Residual Soil NO_3-N in Upper 2 feet of soil (lbs N as NO_3-N/acre)		
	Field Rep #1	Field Rep #2	Field Rep #3
Subsurface Drip Area			
2019	37	45	31
2020	26	37	29
2021	39	37	33
2019 average = 37.7 2020 average = 30.7 2021 average = 36.3			
Furrow Irrigation Area			
2019	44	34	49
2020	33	28	35
2021	43	33	41
2019 average = 42.3 2020 average = 32.0 2021 average = 39.0			

Table 2. Applied nitrogen amounts in furrow and subsurface drip (SDI) irrigated nitrogen rate trials at the Univ. CA West Side REC in 2019, 2020 and 2021.

Irrigation Method And study year	Total applied fertilizer N (lbs/acre)				
	Trt N-0	Trt N-50	Trt N-75	Trt N-100	Trt N-125
Furrow (2019)	0	50	97	143	189
SDI (2019)	0	55	101	147	194
Furrow (2020)	0	61	106	153	200
SDI (2020)	0	62	107	154	201
Furrow (2021)	0	55	100	145	190
SDI (2021)	0	55	102	147	190

Seedcotton and lint yield responses for Pima and Upland varieties in nitrogen rate studies at WSREC are summarized in Tables 3 through 8. Response curves showing lint yield plotted against applied N fertilizer plus residual NO3-N in the upper two feet of the soil profile are shown in Figure 2 in the Appendix. Lint yield levels were quite different across years, with significantly higher yields in 2019 than in 2020 (moderate yields) or 2021 (lower yields). Reduced yield potential in 2020 and 2021 at the WSREC site was due to heavy lygus bug pressure and greater boll and square losses associated with pest pressure.

In all three years and under both drip and furrow irrigation, seedcotton and lint yields for Pima and Upland cotton cultivars in general peaked at the N-75 or N-100 treatment levels (Tables 3 through 8, Figure 2 in Appendix). With Pima cultivars, additional applied N at the N-100 level did not significantly affect yields in either cultivar under furrow irrigation in the 2020 or 2021 studies, with somewhat lower yield levels than 2019, but did increase yield of one cultivar in 2020 and one Upland cultivar in 2019. Higher N applications in N-125 treatment either reduced yields (furrow irrigation treatments) or did not have a significant impact on yield under SDI (although a non-significant trend toward lower yields at N-125 level also existed). Plant height and total leaf area (data not shown) were found in N-125 treatments compared with lower N application treatments, suggesting that additional vegetative growth in N-125 treatments was not beneficial to yields of reproductive tissue (bolls/seed/lint). In all cases, the two varieties of Pima responded similarly to rates of applied N. In the Uplands, the higher-yielding DP1845B3XF variety in some cases did not exhibit lower yields at the N-125 application level.

Table 3. Seed cotton yield and lint yield for Pima cotton varieties in Univ. CA West Side REC site N response study (clay loam soil) in 2019. Yield values followed by different letters were significantly different at the P<0.05 level using LSD analyses.

Type of cotton	Irrigation Method	Variety	Nitrogen Level	Seed cotton yield (lbs/acre)	Lint Yield (lbs/acre)
Pima	Furrow	Phy881RF	0	3347 b	1356 c
			50	3534 b	1415 bc
			75	4072 ab	1597 b
			100	4682 a	1894 a
			125	4649 a	1873 a
Pima	Furrow	DP348RF	0	3305 b	1297 c
			50	3140 b	1257 c
			75	4182 a	1684 ab
			100	4586 a	1837 a
			125	4595 a	1851 a
Pima	SDI	Phy881 RF	0	3561 b	1425 b
			50	4518 a	1785 a
			75	4667 a	1841 a
			100	4614 a	1853 a
			125	4640 a	1868 a
Pima	SDI	DP348RF	0	3576 b	1413 c
			50	4175 ab	1666 b
			75	4652 a	1850 a
			100	4470 a	1771 ab
			125	4770 a	1885 a

Table 4. Seed cotton yield, gin turnout, and lint yield for Upland cotton varieties in Univ. CA West Side REC site N response study (clay loam soil) in 2019. Yield values followed by different letters were significantly different at the P<0.05 level using LSD analyses.

Type of cotton	Irrigation Method	Variety	Nitrogen Level	Seed cotton yield (lbs/acre)	Lint Yield (lbs/acre)
Upland	Furrow	Phy764WRF	0	3826 b	1601 c
			50	4800 ab	2002 b
			75	5003 ab	2068 ab
			100	5428 a	2312 a
			125	5485 a	2272 a
Upland	Furrow	DP1845B3XF	0	3949 c	1673 c
			50	4568 b	1938 b
			75	6080 a	2551 a
			100	5675 a	2369 a
			125	5902 a	2481 a
Upland	SDI	Phy764WRF	0	3980 c	1683 c
			50	4524 b	1902 b
			75	6001 a	2491 a
			100	5742 a	2441 a
			125	5986 a	2541 a
Upland	SDI	DP1845B3XF	0	3960 c	1675 c
			50	4790 b	2004 b
			75	6417 a	2685 a
			100	5947 a	2519 a
			125	6111 a	2495 a

Table 5. Seed cotton yield, gin turnout, and lint yield for Pima cotton varieties in Univ. CA West Side REC site N response study (clay loam soil) in 2020. Yield values followed by different letters were significantly different at the P<0.05 level using LSD analyses.

Type of cotton	Irrigation Method	Variety	Nitrogen Level	Seed cotton yield (lbs/acre)	Lint Yield (lbs/acre)
Pima	Furrow	Phy881RF	0	2198 c	921 c
			50	3369 b	1385 b
			75	4325 a	1795 a
			100	4352 a	1754 a
			125	3668 b	1504 b
Pima	Furrow	DP348RF	0	2386 c	983 c
			50	3455 b	1392 b
			75	4222 a	1727 a
			100	4231 a	1730 a
			125	3484 b	1373 b
Pima	SDI	Phy881 RF	0	2496 b	1029 b
			50	3148 b	1306 b
			75	4023 a	1625 a
			100	4421 a	1812 a
			125	4015 a	1630 a
Pima	SDI	DP348RF	0	2205 c	886 c
			50	3375 b	1380 b
			75	4319 a	1810 a
			100	4652 a	1800 a
			125	3971 ab	1580 b

Table 6. Seed cotton yield, gin turnout, and lint yield for Upland cotton varieties in Univ. CA West Side REC site N response study (clay loam soil) in 2020. Yield values followed by different letters were significantly different at the P<0.05 level using LSD analyses.

Type of cotton	Irrigation Method	Variety	Nitrogen Level	Seed cotton yield (lbs/acre)	Lint Yield (lbs/acre)
Upland	Furrow	Phy764WRF	0	3599 b	1537 b
			50	4150 ab	1764 b
			75	4890 a	2088 a
			100	4669 a	1942 a
			125	4574 a	1898 a
Upland	Furrow	DP1845B3XF	0	3402 c	1493 c
			50	4344 b	1872 ab
			75	4908 a	2140 a
			100	4816 a	2037 a
			125	4244 b	1774 b
Upland	SDI	Phy764WRF	0	2589 c	1093 a
			50	3594 b	1528 b
			75	4708 a	1977 a
			100	5079 a	2087 a
			125	4856 a	2010 a
Upland	SDI	DP1845B3XF	0	2410 c	1065 c
			50	3805 b	1640 b
			75	5020 a	2234 a
			100	5098 a	2157 a
			125	4701 a	2003 a

Table 7. (a) Pooled varieties yield analysis (seed cotton yield, gin turnout, lint percent, and lint yield) for **Pima cotton** varieties included in the study at the Univ. CA West Side REC (clay loam soil) in 2021. Yield values followed by a different letter were significantly different at the $P<0.05$ level using LSD 0.05 analyses.

(a) POOLED VARIETIES ANALYSES – both Pima Varieties							
Type of Cotton	Nitrogen Trt	Irrig. Type	Seed Cotton (lbs/acre)	Gin Turnout (%)	Lint Percent (%)	Lint Yield (lbs/acre)	
Pima	N-0	Furrow	2582 c	40.7	41.6	1049 c	
	N-50		3010 bc	40.8	41.8	1230 b	
	N-75		4029 a	40.6	41.9	1634 a	
	N-100		3762 a	40.4	41.6	1518 a	
	N-125		3119 b	40.0	41.6	1248 b	
Pima	N-0	SDI	2047 c	40.9	41.7	839 c	
	N-50		2700 b	40.0	41.4	1079 c	
	N-75		3793 a	40.5	41.7	1534 a	
	N-100		3925 a	40.9	42.3	1602 a	
	N-125		3333 ab	41.0	42.0	1362 b	
(b) INDIVIDUAL VARIETIES DATA ANALYSES							
Type of Cotton	Nitrogen Trt	Irrig Type	Variety	Lint Yield (lbs/acre)	Irrig Type	Variety	Lint Yield (lbs/acre)
Pima	N-0	Furrow	Phy 881 RF	1032 d	SDI	Phy 881 RF	753 c
	N-0		DP 347 RF	1067 d		DP 347 RF	925 c
	N-50		Phy 881 RF	1139 cd		Phy 881 RF	1116 b
	N-50		DP 347 RF	1320 c		DP 347 RF	1043 b
	N-75		Phy 881 RF	1633 a		Phy 881 RF	1562 a
	N-75		DP 347 RF	1636 a		DP 347 RF	1505 a
	N-100		Phy 881 RF	1506 b		Phy 881 RF	1610 a
	N-100		DP 347 RF	1529 ab		DP 347 RF	1595 a
	N-125		Phy 881 RF	1245 c		Phy 881 RF	1425 ab
	N-125		DP 347 RF	1252 c		DP 347 RF	1299 b
N treatment affects were analyzed statistically with data pooled across varieties within each type of cotton (Pima versus Upland							

Table 8. (a) Pooled varieties yield analysis (seed cotton yield, gin turnout, lint percent, and lint yield) for **Upland cotton** varieties in the study at the Univ. CA West Side REC (clay loam soil) in 2021. Yield values followed by a different letter were significantly different at the $P<0.05$ level using LSD 0.05 analyses.

(a) POOLED VARIETIES ANALYSES – both Upland Varieties							
Type of Cotton	Nitrogen Trt	Irrig. Type	Seed Cotton (lbs/acre)	Gin Turnout (%)	Lint Percent (%)	Lint Yield (lbs/acre)	
Upland	N-0	Furrow	2557 d	43.4	44.3	1107 d	
	N-50		3110 c	43.4	44.4	1356 c	
	N-75		4234 a	43.1	43.7	1827 a	
	N-100		4236 a	42.8	43.7	1815 a	
	N-125		3856 b	42.8	43.4	1651 b	
Upland	N-0	SDI	2185 d	43.9	44.9	960 d	
	N-50		3729 c	43.9	44.8	1640 c	
	N-75		4638 a	42.6	43.5	1975 a	
	N-100		4460 ab	42.9	44.1	1914 ab	
	N-125		4155 b	42.5	43.6	1769 bc	
(b) INDIVIDUAL VARIETIES DATA ANALYSES							
Type of Cotton	Nitrogen Trt	Irrig Type	Variety	Lint Yield (lbs/acre)	Irrig Type	Variety	Lint Yield (lbs/acre)
Upland	N-0	Furrow	Phy 764 WRF	1069 c	SDI	Phy 764 WRF	875 c
	N-0		DP 1845 B3RF	1145 c		DP 1845 B3RF	1045 c
	N-50		Phy 764 WRF	1116 c		Phy 764 WRF	1451 b
	N-50		DP 1845 B3RF	1595 b		DP 1845 B3RF	1829 ab
	N-75		Phy 764 WRF	1725 ab		Phy 764 WRF	1849 ab
	N-75		DP 1845 B3RF	1929 a		DP 1845 B3RF	2101 a
	N-100		Phy 764 WRF	1741 ab		Phy 764 WRF	1831 ab
	N-100		DP 1845 B3RF	1889 a		DP 1845 B3RF	1997 a
	N-125		Phy 764 WRF	1580 b		Phy 764 WRF	1619 b
	N-125		DP 1845 B3RF	1722 ab		DP 1845 B3RF	1919 a
N treatment affects were analyzed statistically with data pooled across varieties within each type of cotton (Pima versus Upland). Individual variety yield responses across N treatments are shown to demonstrate similarity of responses to N treatments.							

Fiber Quality Impacts. Fiber quality key parameters (micronaire, length, strength, uniformity) were only evaluated in one Pima variety and one Upland variety in the N rate response study in the N-0, N-50 and N-100 nitrogen treatment levels, but as shown in the 2021 mean values for these parameters (Table 10 in Appendix), there were no trends toward impacts of nitrogen treatments on these important fiber quality parameters. Data from all three years of the WSREC N rate study (data not shown)

indicated that while yields can be strongly impacted by nitrogen treatments, plants in general were still able to produce high quality fiber at yield-limiting available N levels.

Petiole Nitrate. Petiole nitrate-N values are shown in Figure 1 in the Appendix for select N application treatments in 2020 at some key growth stages during the season for SDI-irrigated Pima (values shown are for Phy-881RF cultivar). The borderline deficient and higher limit values shown in Figure 1 were determined from prior nitrogen studies we have conducted at the same site (West Side REC). We also know from prior studies that petiole NO3-N values in Pima cultivars are typically about 60-70% of values observed in Upland cotton varieties grown with similar soil residual N and fertilizer N (see Petiole NO3-N guidelines developed using data from this and prior studies, Table 14). The values shown for the N-0 and N-50 treatments (which had significantly lower yields than the N-75 and N-100 treatment) were lower during most of the growing season during which we collected petiole NO3-N samples (mid-squaring to early open boll). The N-75 treatment was getting close to borderline deficient towards the end of the growing season at early open boll (Early OB) stage.

Petiole nitrate-N values for furrow irrigated plots were generally about 20 to 25% higher than in SDI plots in the period prior to peak bloom, and more variable but still 10 to 15% higher from peak bloom to early open boll (data not shown, but guidelines shown in Table 14). Based on past observations which have in general been consistent with furrow-irrigated cotton having higher petiole NO3-N than plants grown under SDI at similar growth stages, our assumption is that these differences are related to the larger pre-plant, front-end “loading” of nitrogen fertilizer typically used when furrow irrigating. In this study and in many grower fields, a much larger proportion of total N fertilizer for the season is applied pre-plant in furrow-irrigated fields, with a second (and sometimes third) application made as a split fertilizer application prior to layby in most cases. With SDI, most growers tend to apply smaller amounts injected into the irrigation water, ramping up the amounts applied as plant growth rates speed up mid-season.

Seed and Gin Trash N Removal at Grower Sites. At the grower sites, harvest samples were collected for grinding followed by N analyses at the UC Davis Analytical lab. Data shown in Tables 11 through 13 show values for: (a) seedcotton yields; (b) seed nitrogen concentrations at harvest; (c) N removal amounts in the form of seed lbs N per ton of seedcotton harvested; and (d) gin trash nitrogen concentrations. At the grower sites, nitrogen removed with the harvested seed from the Pima seedcotton crop has been quantified in this study across multiple years in different soil types and a range of yield levels. Across different sites and cultivars, average seed N % at harvest ranged from 3.77 to 4.23%, average 4.02% (2019), 3.7 to 4.42%, average 4.12% (2020), and 3.78 to 4.49%, average 4.07% (2021). Across different sites and cultivars, nitrogen removal (in the seed) with harvest ranged from 43.6 to 50.4 lbs N/Ton of seedcotton, average 47.7 (2019), 42.76 to 52.4 lbs N/Ton of seedcotton, average 48.9 (2020), and 46.9 to 53.4 lbs N/Ton of seedcotton, average 48.87 (2021). These values vary to some degree with

cultivar and site yield ranges, with somewhat lower N removal values shown for low yielding sites where water, N or other limitations also impacted seed N concentrations.

When lint plus seed are harvested and then processed at a cotton gin, extraneous leaf, stem and boll fragments (called gin trash) remain after separating seed and lint. Gin trash nitrogen concentrations ranged from 1.54% to 2.33% N, average 1.93% (2019), 1.49% to 2.36% N, average 1.94% (2020), and 1.61% to 2.37% N, average 2.01% (2021). When N concentrations were multiplied by quantities of gin trash from ginning operations, nitrogen removed as gin trash ranged from approximately 4 lbs N per ton of seedcotton (lint plus seed) to almost 15 lbs N per ton, with an average of 7 lbs N per ton of seedcotton in gin trash. This average N content would equal about 14 lbs of N/acre for a 4-bale lint/acre cotton crop (good yield with modern cotton cultivars). It is to be expected that the range of quantities of gin trash will be highly variable by location, physical operation of the harvester, crop condition at harvest, and efficacy of defoliation efforts.

Seed and Gin Trash N Removal at West Side REC field site. At the WSREC N rate response study site, harvest samples were collected for grinding followed by N analyses at the UC Davis Analytical lab. Data shown in Figures 3 and Figure 4 show the average seed nitrogen concentrations as a function of: (a) type of cotton (Upland versus Pima); (b) irrigation method (furrow versus SDI); (c) and nitrogen application amounts for all three years of the study. In reviewing the seed N concentration data, it was consistent that the most nitrogen-deficient treatments, N-0 and N-50 (which also had lower yields as shown in figures 2-3) had significantly lower seed nitrogen concentrations (in the 3.4 to 3/7% range) than the higher N application treatments, which were mostly in the 4 to 4.5% range. There were no significant, consistent differences in N concentrations between Upland versus Pima varieties.

Since in multiple years in both Upland and Pima varieties the yields were not significantly different at the N-75, N-100 and N-125 levels, the tendency for higher seed N% values in the highest two applied N treatments (N-100 and N-125) could indicate excess nitrogen uptake in the form of increased seed N percent. The same patterns described for seed N concentrations also apply to calculated N removal in seed (in lbs N/Ton of seedcotton), since those removal estimates are based on seed N concentration values times seed yields (see Figures 5 and 6 for 2019, 2020 and 2021).

Above-Ground Plant N Uptake. Above-ground whole plant samples were collected in plots of N-50, N-75 and N-100 treatments in all cultivars, plus N-0 and N-125 treatments in Phy-881 RF Pima at peak biomass timing (which was estimated to occur within a period of about 3-4 weeks prior to harvest). The total amount of N contained in above-ground plant parts (stem and branches, leaf, burs and seed ranged from about 105 lbs N/acre in the lowest yielding plots (less than 850 lbs lint/acre) in the no N application treatments (N-0) to a high of over 300 lbs N/acre in the N-125 treatment of Phy-881RF. Above-ground biomass weights (dry) measured 3-4 weeks prior to harvest ranged from a low of less than 6000 lbs/acre to many plots in the 8,000 to 11,000 lbs/acre range.

Since the ratio of seed+lint as a fraction of total biomass is highly variable with boll retention, it is not a surprise that the seed+lint portion ranges from as low as 35 percent to over 55 percent of the total above ground biomass. In this rate study, we had lint yields ranging from as low as 750 lbs lint/acre to over 2500 lbs lint/acre, with highly variable boll retention as well as plant size differences (reductions) with the most N-deficient treatments (N-0, N-50). This is the explanation for the large variation in plant N uptake totals prior to harvest. Perhaps a more useful range of total above-ground N uptake to focus on is for the peak-yielding N-75 and N-100 treatments, where above-ground plant N uptake ranges from about 175 to 220 lbs N/acre when yields were in the 1500 to 1700 lbs/acre range in relatively moderate-sized plants with better fruit set versus approximately 190 to 275 lbs/acre in larger plants with moderate to good fruit set and higher yields.

Planting Time versus Post-Harvest Soil NO3-N Changes – WSREC Rate Study.

Soil samples were collected from the upper 8 feet of the soil profile in three replications of the nitrogen rate plots of the Pima cultivar Phy-881RF in the WSREC location N rate response study all three years. Table 15 shows the change in soil NO3-N between the planting time sampling in the 0- to 4-foot-deep zone and 4- to 8-foot-deep zone and the post-harvest sampling. In this presentation of the data in Table 15, "-"numbers indicate a reduction in the amount of NO3-N in the soil (in lbs NO3-N/acre) from planting time to harvest, indicating a net reduction in soil NO3-N. Such a reduction could indicate plant uptake and use, or it could result from leaching or denitrification processes. With the irrigation methods and amounts used in this type of clay loam soil, we would assert that the observed changes in soil NO3-N between planting and harvest were largely plant utilization of soil N. There was a very large amount of variation between replications in the calculated changes in soil NO3-N during the planting to harvest period each year, as evidenced by the standard errors shown in Table 15. However, there were still some fairly consistent general observations that could be made based on this data: (a) that net reductions in soil NO3-N were much larger (indicating more plant uptake) in the lower applied N treatments (N-0 and N-50); and (b) there were more instances of net increases in soil NO3-N from planting to harvest in the higher applied N treatments, particularly the N-125 treatment. Along with the peaking of yield response curves at N-75 or N-100 in this study and the higher seed N concentrations in the N-125 treatments, this data is consistent with the observation that the N-125 (and in some cases the N-100) treatments are supplying N in excess of plant needs for the yields in this study.

H. Challenges

Challenge	Corrective Action and/or Project Change/lessons learned
Loss of UCCE Farm Advisor / Cooperators for Merced County farm site	When we initiated the project in 2019, for part of one season we had the assistance of Dr. Lynn Sosnoskie, Farm Advisor – Merced County prior to her departure for another job in New York. Late in 2020, we added a new UCCE Farm Advisor (Dr. Jose Diaz) in Merced County as part of the project, and he provided some early season assistance in 2021. However, he left UCCE in fall of 2021 to accept a different position in Arizona. Our crew was able to take on and complete all the project work at the Merced County site in his absence.
COVID-19 impacts on some of our Sample preparations, and in submittal of samples	During COVID impacted periods in 2020-2021 we had limited staff and did much of the sample preparation with few individuals at the West Side location. For field work, we had to travel in separate vehicles for separation reasons during COVID-19 situations, requiring additional fleet service vehicles or travel reimbursements for personal owned vehicle use for tasks such as sample collection, harvests, sample grinding, etc.
COVID-19 impacts on: (a) sample processing, drying and grinding operations; (b) operation of UCD Analytical lab	We have done irrigation water sample analysis, and some limited soil analyses ourselves on the project. Our crew must travel in separate vehicles for partial days for grinding and sample prep at the West Side REC, and this has been a slower and more expensive process in 2020 and 2021. During late 2021-2022 the UCD Analytical Lab was back in normal operation mode, albeit with longer wait times for sample processing due to limited staffing under COVID-19 restrictions.

I. Project Impacts

Data from project on N removal with seed harvest plus gin trash supplied to Dr. Daniel Geisseler for inclusion in crop N removal website of the CDFA-FREP program. This data provides an up-to-date comparison of N rate response and N removal data for modern Acala / Upland versus Pima cultivars as a more thorough analysis that includes UC research center sites for the rate study, plus grower farm sites for large scale field trials to provide yield data and seed from harvests across a range of soils and yield levels and production practices. Results of this study, with many more measurement locations and multiple current commercial varieties serve to verify that the N removal levels and fertilizer N rate responses in pima cotton are quite similar to those more broadly available for Upland cotton under irrigated conditions, and this data can be utilized by growers and consultants to improve confidence in fertilization decisions.

J. Outreach Summary

No field day type of activities was allowed by the University of CA at the UC West Side REC location where we had our primary N management study for this project during both the 2020 growing season and part of the 2021 season due to mandatory COVID-19 precautions. This situation made it somewhat challenging to meet in-field outreach

plans, but we provided information updates on the project in small group meetings as well as several larger meetings later in 2021 and 2022 as assessed the plant and soil nutrient data. The year 2021 and 2022 provided some opportunities for presentations to the cotton industry and grower/consultant meetings as detailed below. As we prepare data for journal publications, we will also plan to offer the cotton industry a summary of the project findings at the annual CA Cotton Ginners and Growers Association meetings if they have any interest.

Event Name (1)	CDFA FREP Nutrient Management Conference		
Presentation title	Pima Cotton Nitrogen Management, Update and Removal: Impacts of Variety, Subsurface Drip and Furrow Irrigation		
Location and date	October 27-28, 2021; San Luis Obispo, CA Presentation (in-person) – includes participants from California principally, some from Arizona, Nevada		
Attendee demographics (CCAs, PCAs, growers, consultants, researchers, etc.)	Consultants and Company representatives from wide range of companies and consulting firms, plus Regulatory Agency and other State Agency personnel, University researchers and cooperative extension personnel from participating states, growers and their PCA's and Managers		
CCA/Grower Continuing Education Units (CEUs) offered	**Yes – not sure how many were offered at this meeting**	**Number of participants**	Reports were for about 80 for this part of the sessions
Event Name (2)	Southwest Physiology Meeting		
Presentation title	Pima Cotton Management Update and Review: including water management, PGR use, Nutrients and Pre-Harvest		
Location and date	Feb 2, 2021, Webinar – includes participants from Texas, Oklahoma, New Mexico, Arizona and California		
Attendee demographics (CCAs, PCAs, growers, consultants, researchers, etc.)	Mostly University researchers and cooperative extension personnel from all participating states, but also includes some seed company and chemical company reps and consultants from these states		
CCA/Grower Continuing Education Units (CEUs) offered	**None offered** **Zoom link was:** https://dasnr.zoom.us/j/98818634599?pwd=RldGenplWXZ3K09xaGMwMHpGS2V6UT09	**Number of participants**	Reports were for about 65-70 for this part of the sessions

Event Name (3)	Presentation to CA Cotton Alliance and Cotton Growers Association group		
Presentation title	Cotton Nitrogen Management and Uptake / Removal – presentation on current research project		
Location and date	March 25, 2021 – West Side Research Center		
Attendee demographics	Growers, one chemical company rep		
CCA/Grower Continuing Education Units (CEUs) offered	None offered. ** This information was presented in recognition of the fact that I was presenting some preliminary data plus older data to Daniel Geisseler that he was using for a MARCH 2021 update of the Cotton Nitrogen Mgmt. web page that is part of the CDFA – FREP crop guidelines for cotton	Number of participants	There were 7 participants

Additional Products or Information Provided included:

a) website posting – UC cotton website
b) petiole nutrient recommendations for Pima versus Uplands
c) Fresno County Farm Bureau talk – crop management – saline conditions, crop fertility management issues with cotton
d) Southwest Physiology Conference – San Angelo, TX – cotton disease, N mgmt. issues
e) Reporting to CA Cotton Alliance and CA Cotton Growers Association Research groups – Harris Ranch, Merced County, Fresno County.
f) Field visit by FREP project staff – tour of hemp and cotton field nitrogen projects
g) Class visits by Dr. Ranjit Riar Agronomic crops class (CSU Fresno) – cotton and field crop management, including nitrogen project

L. Appendix - Additional information

Acknowledgements. The support of the CDFA FREP program is gratefully acknowledged, with funding provided for staff support, research center recharge costs for field trials, supplies for field trials, UC vehicle use and partial costs for sample preparation and analyses done through the UC Davis Analytical Laboratory. The FREP program representatives have been extremely patient in allowing the PI major extra time to process and analyze samples and prepare data summaries and wish to offer a thank you for these considerations.

The CA Cotton Ginners and Growers Association and CA Cotton Alliance provided major supplemental funding for expanded sample analyses on soil and plant samples, and we are thankful for that support. Salary and support for Principal Investigators were provided by the University of California. The rate response field trials were conducted at UC-ANR University of CA West Side Research & Extension Center (WSREC) and the on-farm field trials were conducted on private farms with access and equipment provided by growers. During the study period, the University of CA subsidized about 45-55% of the recharge cost (staff time, acre charges) for the project at the WSREC, located at 17353 W. Oakland Avenue, P.O. Box 158; Five Points, CA. Grower supporters who provided large field trial sites were Bryan Bone (Kern County); Scott Schmidt-Farming (Fresno Co.); Erik Hansen-Hansen Ranches (Kings County); Ted Sheely-AZCAL Farms (Kings & Fresno Co's); and Cannon Michael-Bowles Farms (Merced Co.). All the grower sites used in the FREP nitrogen trial work were absolutely essential to the project, and also served as Pima variety trials, and we are grateful to these farms for access to their land and support to the project. Those Pima variety trials were also supported by the CA Cotton Ginners and Growers Association and the CA Cotton Alliance.

Table 9. Pre-Plant or early post-planting Residual Soil NO_3-N in the upper four feet of the soil profile at grower farm sites (various locations, counties shown) in 2019, 2020, 2021 Pima on-farm nitrogen studies.

County and area for farm	Year	Pre-Plant Residual Soil NO_3-N in Upper Four Feet of Soil (lbs N as NO_3-N/acre)	
		High value for field	Low value for field
Kings Co. Corcoran area	2019	71	60
	2020	57	52
	2021	88	73
Fresno Co. Five Pts area	2019	79	58
Fresno Co.	2020	65	56
Huron area	2021	90	73
Kern Co.	2019	68	44
Buttonwillow area	2020	71	50
	2021	65	61
Fresno Co.	2019	80	62
WSREC	2020	52	41
Variety trial	2021	67	60
Merced Co.	2019	109	83
Los Banos area	2020	87	62
	2021	105	73

Table 10. Fiber Quality Component (HVI Fiber Quality – USDA Classing Office standards) mean values and (in parentheses after means, standard deviations) for one **Upland cotton** variety (Phy 764 WRF) and one **Pima cotton** variety (Phy 881 RF) as influenced by select nitrogen rate treatments in the study at the Univ. CA West Side REC (clay loam soil) in 2021.

HVI Fiber Quality Analyses (by USDA AMS Classing Office – Visalia, CA)							
Type of Cotton	Variety	Nitrogen Trt	Irrig Type	Micronaire	Fiber Length (inches)	Fiber Strength (g/Tex)	Fiber Uniformity Scale
Upland	Phy 764 WRF	N-0	Furrow	4.07 (0.12)	1.19 (0.02)	39.13 (0.81)	84.0 (0.26)
		N-50		4.10 (0.26)	1.18 (0.01)	39.17 (1.75)	83.9 (0.30)
		N-100		4.30 (0.14)	1.17 (0.01)	38.65 (0.07)	83.95 (0.2)
Upland	Phy 764 WRF	N-0	SDI	4.13 (0.25)	1.16 (0.02)	38.3 (2.36)	83.8 (0.31)
		N-50		3.87(0.12)	1.19 (0.02)	39.27 (1.25)	83.9 (1.23)
		N-100		4.10 (0.14)	1.19 (0.00)	39.35 (1.91)	84.3 (0.85)
Pima	Phy 881 RF	N-0	Furrow	4.27 (0.15)	1.46 (0.01)	49.5 (0.46)	87.43 (1.17)
		N-50		4.13 (0.15)	1.48 (0.03)	49.8 (0.35)	87.7 (0.30)
		N-100		4.27 (0.47)	1.49 (0.02)	48.77 (1.0)	88.1 (1.21)
Pima	Phy 881 RF	N-0	SDI	4.13 (0.12)	1.48 (0.03)	48.43 (1.55)	88.07 (1.08)
		N-50		4.17 (0.32)	1.48 (0.05)	49.20 (1.39)	88.57 (0.49)
		N-100		4.07 (0.12)	1.49 (0.02)	49.03 (0.95)	88.6 (0.60)

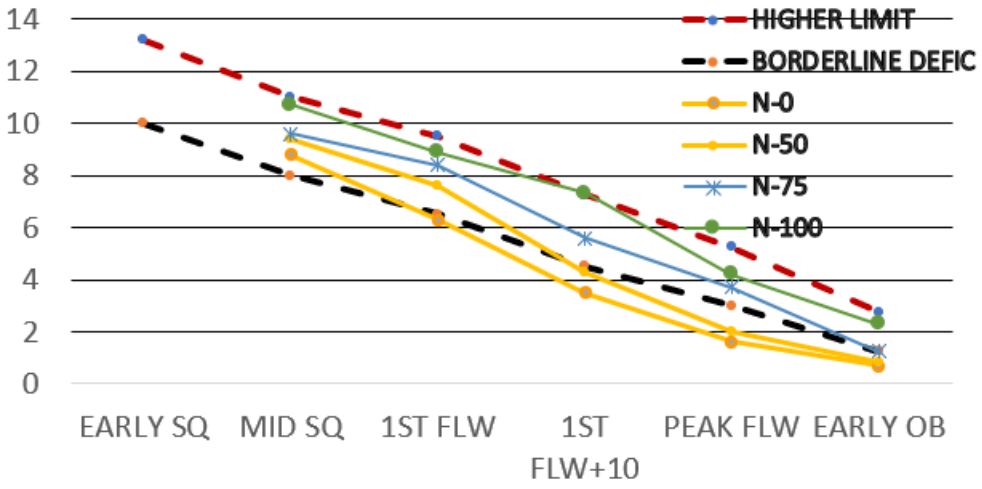

Figure 1. Mean petiole nitrate levels in subsurface drip-irrigated Pima cotton variety PHY-881RF at select growth stages (mid-squaring, 1st flower, 10 days after 1st flower, peak flowering, early open boll) in 2020 as a function of Nitrogen application treatments as defined in Table 2.

The figures shown on following pages are referenced in the main text by Figure number.

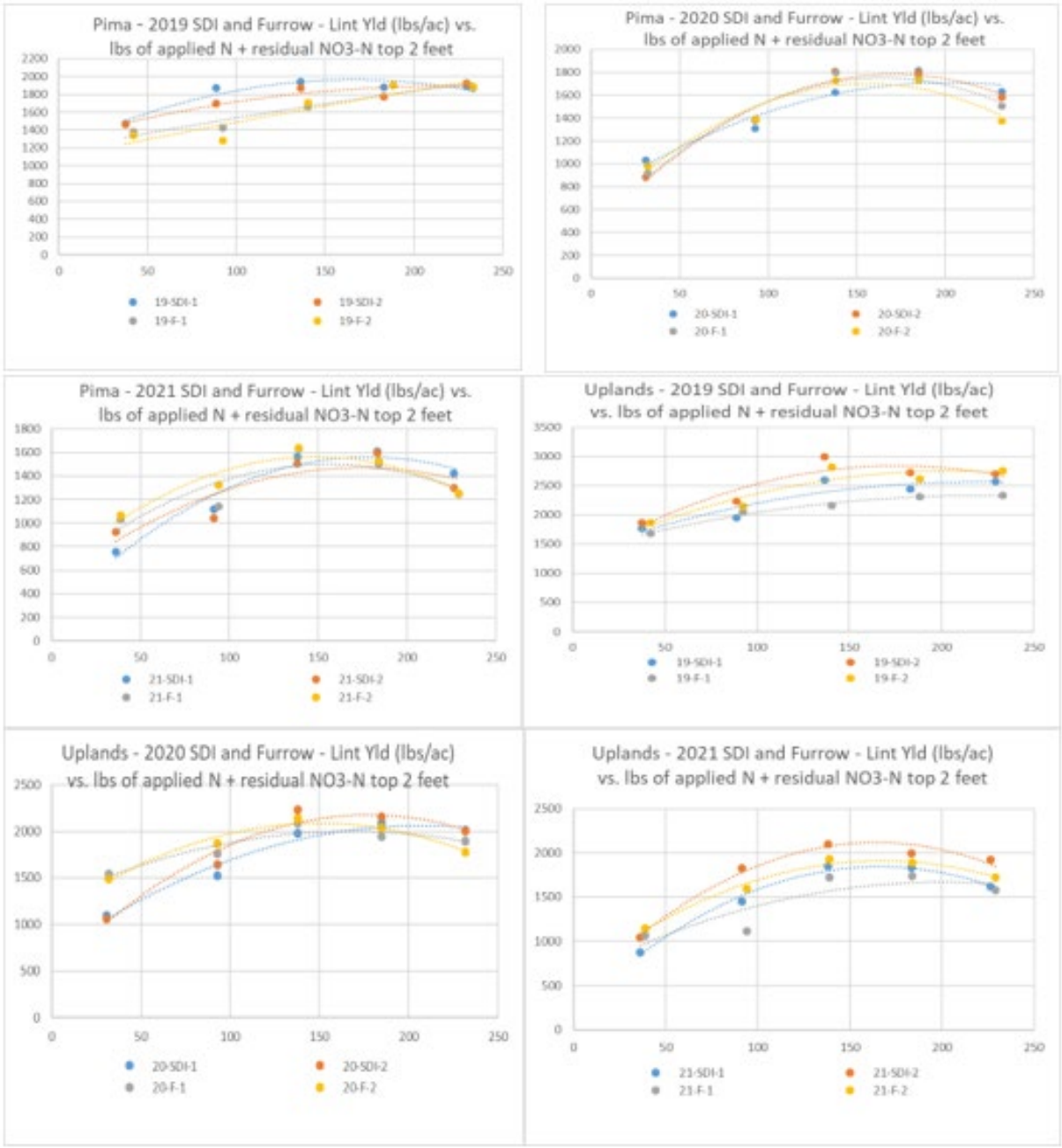

Figure 2. Lint yield responses of 2 Pima cultivars and 2 Upland cultivars as a function of applied fertilizer nitrogen plus residual soil NO_3-N in the upper two feet of soil at planting time. The yield responses are also shown in Tables 3 through 8 in the main text, and those tables provide information on statistical significance in treatment evaluations.

Table 11. 2019 grower and WSREC variety trial site average seedcotton yield, gin trash nitrogen concentration, seed nitrogen concentration, and nitrogen removal per ton of seedcotton. All varieties shown are Pimas. Values were determined based on samples collected during spindle picker machine harvest of replicated field trials, with yield weights measured using field scales and nitrogen concentrations determined on dried, ground (and delinted for the seed) samples at the UC Davis Analytical Laboratory.

County Site / Area	Pima Variety	Seedcotton (lint+seed) yield (lbs/ac)	Average seed nitrogen Conc. (%)	Nitrogen removal with harvest (lbs N per Ton seedcotton)	Gin trash nitrogen concentration (%)
Kern County (Buttonwillow)	DP 341 RF	2864	3.82	44.55	1.72
	DP 348 RF	2225	3.89	45.95	1.58
	Phy 881 RF	2881	3.77	43.60	1.69
Merced (Los Banos)	DP 341 RF	3132	4.14	49.52	2.06
	DP 348 RF	2900	4.23	50.44	2.15
	Phy 881 RF	2730	4.19	50.00	2.33
Kings (Corcoran)	DP 341 RF	4953	3.93	47.51	1.80
	DP 348 RF	5120	4.05	49.64	1.54
	Phy 881 RF	5164	4.18	50.30	1.76
Fresno (Five Points area)	DP 341 RF	5755	3.93	46.64	1.92
	DP 348 RF	5326	3.97	46.92	1.81
	Phy 881 RF	5345	4.03	47.12	2.05
Fresno (WSREC)	DP 341 RF	4417	4.07	48.1	2.09
	DP 348 RF	4020	4.11	48.15	1.93
	Phy 881 RF	4092	4.14	47.73	2.22
	DP 359 RF	3712	3.89	45.12	2.07
	HA 1432 Gowan	5940	3.96	48.49	2.15
Average (across all sites)		4114	4.02	47.65	1.93

Table 12. 2020 grower and WSREC variety trial site average seedcotton yield, gin trash nitrogen concentration, seed nitrogen concentration, and nitrogen removal per ton of seedcotton. All varieties shown are Pimas. Values were determined based on samples collected during spindle picker machine harvest of replicated field trials, with yield weights measured using field scales and nitrogen concentrations determined on dried, ground (and delinted for the seed) samples at the UC Davis Analytical Laboratory.

County Site / Area	Pima Variety	Seedcotton (lint+seed) yield (lbs/ac)	Average seed nitrogen Conc. (%)	Nitrogen removal with harvest (lbs N per Ton seedcotton)	Gin trash nitrogen concentration (%)
Kern County (Buttonwillow)	Phy 881RF	4227	4.20	50.15	1.67
	Phy 807RF	4653	3.88	44.74	1.75
	DP 341 RF	4323	3.98	48.11	1.49
	DP 359 RF	4287	4.02	47.09	1.88
	DP 347 RF	4088	3.97	45.59	1.93
Merced (Los Banos)	Phy 881RF	3073	4.25	51.77	1.76
	Phy 807RF	3402	4.07	48.31	2.09
	DP 341 RF	3566	4.12	49.86	1.90
	DP 359 RF	2832	4.13	49.22	2.12
	DP 347 RF	3134	4.18	47.06	2.06
Kings (Corcoran)	Phy 881RF	5996	4.23	50.68	1.81
	Phy 807RF	6106	4.37	52.38	1.70
	DP 341 RF	5641	4.07	49.16	1.92
	DP 359 RF	6275	4.09	49.30	1.83
	DP 347 RF	5745	4.13	48.02	1.77
Fresno (Huron)	Phy 881RF	4914	4.15	48.73	2.17
	Phy 807RF	5334	4.42	51.86	2.25
	DP 341 RF	4736	4.21	50.09	2.31
	DP 359 RF	5233	4.13	48.71	2.27
	DP 347 RF	5048	4.31	48.47	2.02
Fresno (WSREC)	Phy 881RF	4168	3.67	42.66	2.14
	Phy 807RF	4403	3.79	43.76	1.79
	DP 341 RF	4400	3.79	45.26	2.36
	DP 359 RF	3878	3.70	43.37	1.71
	DP 347 RF	4071	3.78	42.05	1.80
Average (across all sites)		5247	4.12	48.88	1.94

Table 13. 2021 grower and WSREC variety trial site average seedcotton yield, gin trash nitrogen concentration, seed nitrogen concentration, and nitrogen removal per ton of seedcotton. All varieties shown are Pimas. Values were determined based on samples collected during spindle picker machine harvest of replicated field trials, with yield weights measured using field scales and nitrogen concentrations determined on dried, ground (and delinted for the seed) samples at the UC Davis Analytical Laboratory.

County Site / Area	Pima Variety	Seedcotton (lint+seed) yield (lbs/ac)	Average seed nitrogen Conc. (%)	Nitrogen removal with harvest (lbs N per Ton seedcotton)	Gin trash nitrogen concentration (%)
Kern County (Buttonwillow)	Phy 881RF	5595	4.06	48.04	1.61
	Phy 807RF	6015	4.07	47.78	1.69
	DP 347 RF	5334	4.15	47.13	1.87
	DP 359 RF	5846	3.78	44.47	1.76
Merced (Los Banos)	Phy 881RF	3418	4.16	49.0	2.14
	Phy 807RF	3079	4.17	49.08	1.96
	DP 347 RF	3294	4.42	49.34	1.99
	DP 359 RF	3226	4.16	45.90	2.28
Kings (Corcoran)	Phy 881RF	4467	4.35	48.53	1.69
	Phy 807RF	4891	4.35	47.73	1.64
	DP 347 RF	4451	3.94	46.87	1.79
	DP 359 RF	5138	4.11	46.92	1.8
Fresno (Huron)	Phy 881RF	5620	4.11	50.56	2.17
	Phy 807RF	6202	4.34	50.97	2.29
	DP 347 RF	6109	4.18	49.47	1.93
	DP 359 RF	6505	3.89	53.42	2.35
Fresno (WSREC)	Phy 881RF	2313	4.49	50.29	2.17
	Phy 807RF	2307	4.37	50.54	2.29
	DP 347 RF	2472	4.3	52.15	2.32
	DP 359 RF	2119	4.17	49.16	2.37
Average (across all sites)		4435	4.07	48.87	2.01

Figure 3. Seed nitrogen concentration for Upland and Pima cotton in WSREC nitrogen rate trial in 2019 and 2020 as a function of nitrogen treatment (0,50,75,100,125), cultivar (Uplands: Phy764WRF, DP1845B3XF: Pimas: Phy 881RF, DP348RF) and irrigation treatment (F=furrow, SDI=subsurface drip). Seed collected during harvest, analyzed after ginning and delinting.

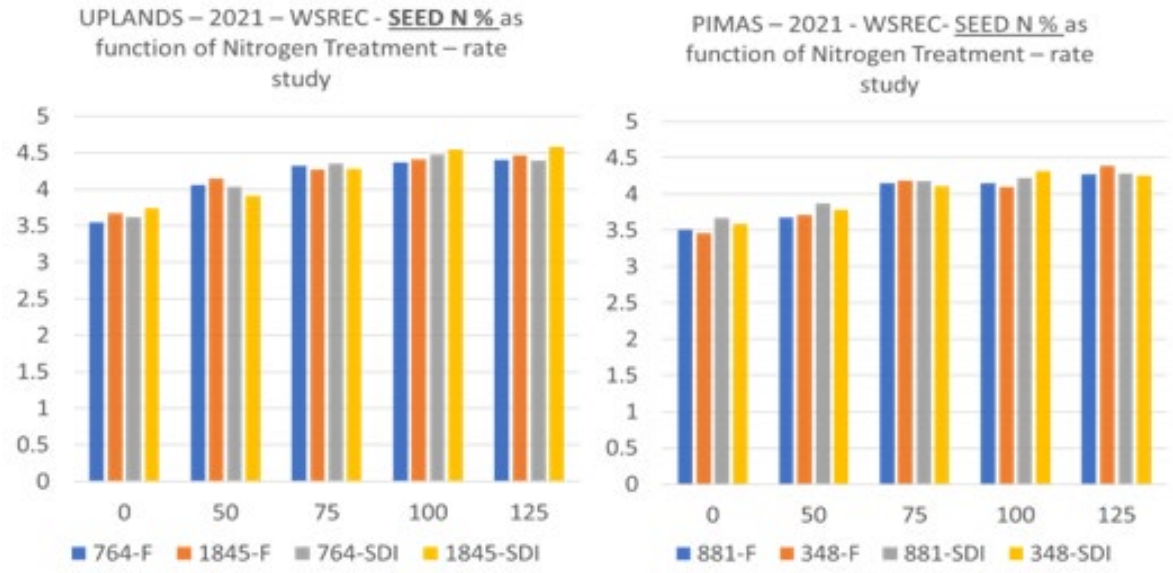

Figure 4. Seed nitrogen concentration for Upland and Pima cotton in WSREC nitrogen rate trial in 2021 as a function of nitrogen treatment (0.50,75,100,125) cultivar (Uplands: Phy764WRF, DP1845B3XF: Pimas: Phy 881RF, DP348RF) and irrigation treatment (F=furrow, SDI=subsurface drip). Seed collected during harvest, analyzed after ginning and delinting.

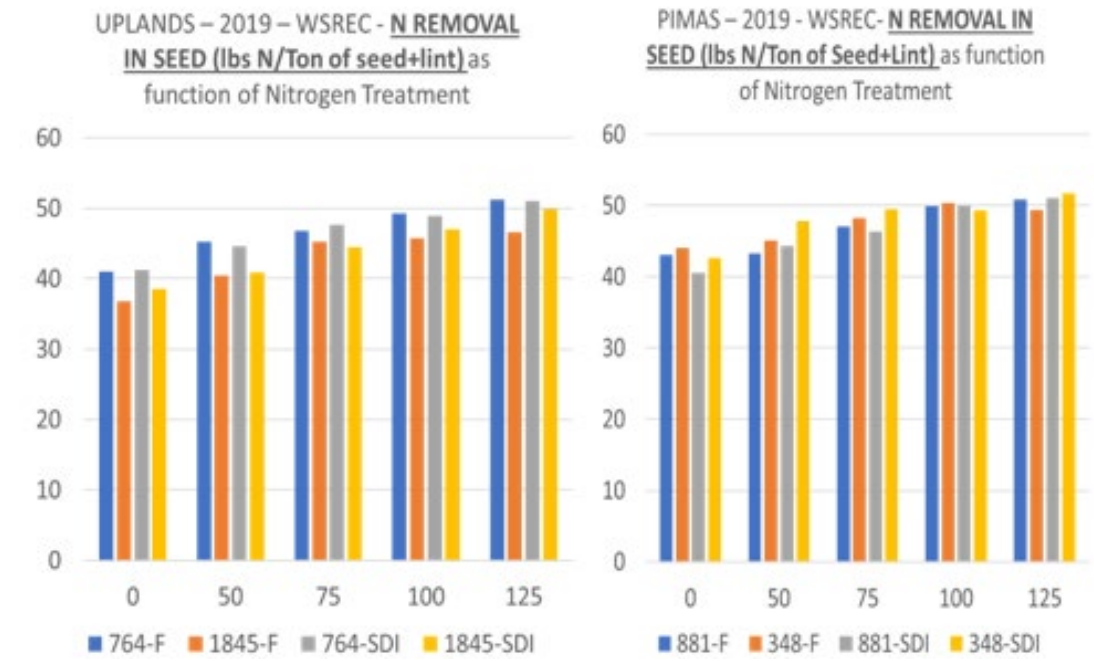

Figure 5. Nitrogen removed from the field (Lbs N) per ton of seedcotton in Upland and Pima cotton in WSREC nitrogen rate trial in 2019 as a function of nitrogen treatment (0.50,75,100,125) cultivar (Uplands: Phy764WRF, DP1845B3XF: Pimas: Phy 881RF, DP348RF) and irrigation treatment (F=furrow, SDI=subsurface drip).

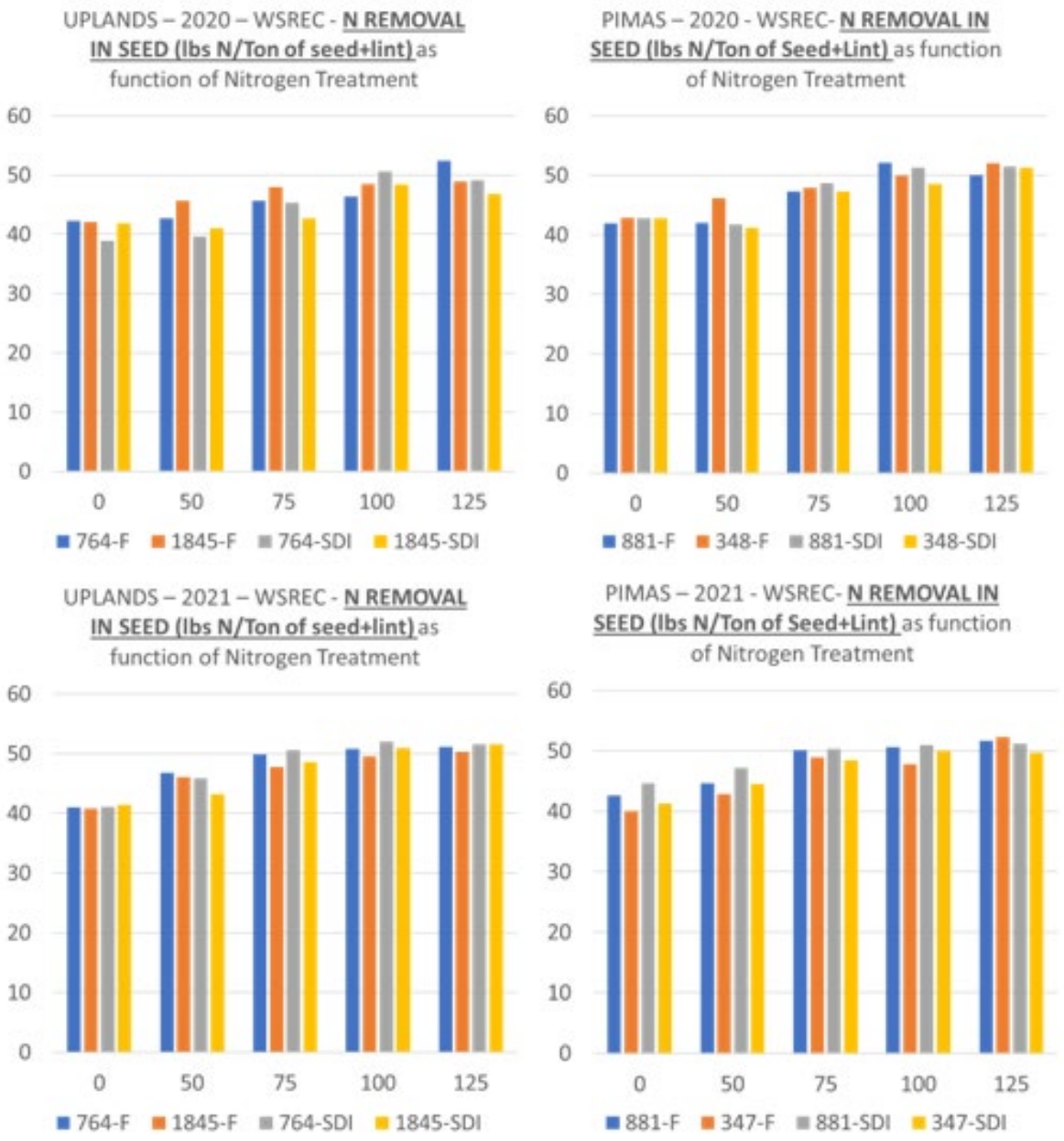

Figure 6. Nitrogen removed from the field (Lbs N) per ton of seedcotton in Upland and Pima cotton in WSREC nitrogen rate trial in 2020 and 2021 as a function of nitrogen treatment (0.50,75,100,125), cultivar (Uplands: Phy764WRF, DP1845B3XF: Pimas: Phy 881RF, DP348RF) and irrigation treatment (F=furrow, SDI=subsurface drip).

Table 14. Petiole NO_3-N guidelines for Pima versus Acala / Upland types of cotton under irrigated conditions in California. Values shown are based on results of multiple prior studies plus current project nitrogen rate study at University of CA ANR West Side Research Center.

Petiole Nitrate (NO3-N) – in ppm				
	Upland Cotton		Pima Cotton	
Growth Stage	*Borderline to Deficient*	*Sufficient Upper Level*	*Borderline to Deficient*	*Sufficient Upper Level*
Early square	<13-14,000	>17-20,000	<10,000	>12-14,000
1st flower	<10-12,000	14-18,000	<6-7,000	>8-10,000
1st flower + 10 days	<7000-10,000	12,000-14,000	<4,000-5,000	>6,500-8,000
Peak bloom	<3,500-5,500	>7,000-9,000	<2,500-3,500	>4,500-6,000
Early open boll	<1,500-2,000	>3,500-4,500	<1,000-1,500	>2,500-3,000
10-15 days after cutout	<750-1,200	>1,500-2,000	<750-1,000	>1,250-1,500
** Experiences with fertigated SDI (drip) cotton are that lower end of ranges shown are adequate & higher values in ranges are more typical for split-fertilized furrow irrig cotton*				

Table 15. Change in soil NO_3-N in 0-to-4-foot depth zone and 4-to-8-foot depth zone between planting time and post-harvest sample dates in nitrogen rate study at UC West Side REC for Pima variety Phy-881RF in 2019, 2020, 2021 studies. Values shown are average NO_3-N concentrations for 0-4 ft and 4-8 ft zones of soil, based on averages across three replications.

Year	Nitrogen Treatment	Change in Soil NO_3-N (lbs NO_3-N/acre) between Planting and post-harvest sample timing					
		Furrow-Irrigated			Subsurface Drip (SDI)		
		0-4 feet	4-8 feet	Net Change (0-8 ft)	0-4 feet	4-8 feet	Net Change (0-8 ft)
2019	0	-57* (7)**	-22 (6)	-79	-44 (6)	-25 (6)	-69
	50	-39 (4)	-17 (3)	-56	-26 (5)	-24 (7)	-50
	75	-23 (4)	-8 (4)	-31	-29 (4)	-4 (4)	-33
	100	-11 (3)	-5 (3)	-16	16 (4)	-9 (3)	7
	125	19 (5)	11 (4)	30	23 (5)	-10 (4)	13
2020	0	-44 (7)	-19 (6)	-63	-49 (5)	-18 (5)	-67
	50	-23 (5)	-11 (3)	-34	-34 (4)	-10 (4)	-44
	75	-12 (3)	-6 (2)	-18	-19 (5)	-6 (3)	-25
	100	-9 (2)	4 (5)	-5	11 (5)	-7 (5)	4
	125	19 (4)	5 (3)	24	26 (7)	-5 (2)	21
2021	0	-37 (7)	-15 (3)	-52	-31 (4)	-13 (4)	-44
	50	-41 (6)	-11 (5)	-52	-34 (7)	-5 (2)	-39
	75	-19 (5)	-12 (4)	-31	-27 (5)	2 (3)	-25
	100	-15 (3)	8 (3)	-7	-5 (3)	7 (2)	2
	125	9 (3)	14 (4)	23	6 (4)	18 (4)	24

* the "-" value indicates a reduction in the amount of NO_3-N occurred between planting and harvest timing, indicating potential use of NO_3-N by plants, or possibly through leaching.
**values shown in (parentheses) are standard error of the mean.

M. Factsheet / Database:

This project “Pima Cotton Nitrogen Management, Uptake, Removal – Impacts of Varieties, Subsurface Drip and Furrow Irrigation” (project #18-0597) had the following objectives: (1) Evaluate for modern pima cotton cultivars the impacts of N application amount, variety and irrigation method (subsurface drip versus furrow) on total plant nitrogen (N) uptake and removal of N with harvest; and (2) utilizing multiple grower farm sites with moderate to high yield potential and different soil types, determine N removal with harvest and above-ground plant N uptake at late open boll timing.

Project Investigators were Robert Hutmacher (UC Cooperative Extension Specialist, UC Davis Plant Sciences Dept.), Daniel Munk and Brian Marsh (UC Cooperative Extension Farm Advisors, Fresno and Kern Counties, respectively), with assistance from UCCE Farm Advisors Jorge Angeles (Tulare/Kings/Fresno Co.’s), Lynn Sosnoskie and Jose Carvalho DeSouza Dias (Merced County).

San Joaquin Valley cotton growers aim for high yields to be able to cover production costs and pay for increasing costs of inputs such as irrigation water, fertilizer and crop protection scouting and chemical applications. These yield goals can be a significant incentive to apply higher rates of fertilizer nitrogen (N) to increase chances of achieving high yields. However, elevated amounts of applied fertilizer N can also bring the added risk of excess N applications and groundwater contamination. Regulatory decisions made by the State Water Board and other agencies raise the likelihood of a range of efforts to require more tightly managed use of fertilizer and manure-based N sources. Pima cotton is a relatively large acreage crop for which there has been only limited data on responses to N fertilizer or plant N uptake and removal with harvest. In this project, we conducted both University research center and grower field site trials to evaluate responses of modern Pima cultivars to N management under practices conducive to high lint yields.
This project provides improved information for growers and consultants on Pima cotton nitrogen fertilizer rate responses and updated and more broad-based data to assess nitrogen removal with the harvested products (primarily seed, plus some waste produced during ginning). Yield responses to a range of applied fertilizer N plus upper soil residual NO_3-N were evaluated under both furrow and subsurface drip irrigation during three years in both Pima and Upland cotton cultivars at the UC-ANR West Side Research and Extension Center near Five Points (Fresno County). Grower field sites with Pima variety trials were utilized in Kern, Kings, Tulare, Fresno and Merced Counties each year to also collect samples analyzed to assess N removal with harvest (N removed from fields as seed and gin trash) for Pima cotton cultivars. Very little of this type of data was previously available for Pima cotton. Since over 85% of the U.S. Pima cotton crop is grown in California, and Pima is the primary type of cotton grown in California (about 80% of the total output from CA), it was important to establish N removal with harvest data for this important crop.

Highlights

- Nitrogen removed with the harvested seed from the Pima seedcotton crop has been quantified in this study across multiple years in different soil types and a range of yield levels. Amounts removed in seed range from 44 to 52 lbs N per ton of seedcotton,

averaging about 49 lbs N per ton. This information will assist growers and consultants in improving estimates for minimum crop nitrogen needs for a range of yield potentials.

- While recognizing the important impacts of pest pressure on seedcotton yield potential in any year, the fertilizer N rate study portion of the project determined that both Pima and Upland cultivars had similar yield responses to applied fertilizer N rates.

- When lint plus seed are harvested and then processed at a cotton gin, extraneous leaf, stem and boll fragments (called gin trash) remain after separating seed and lint. Nitrogen removed as gin trash ranged from approximately 4 lbs N per ton of seedcotton (lint plus seed) to almost 15 lbs N per ton, with an average of 7 lbs N per ton of seedcotton in gin trash. This average N content would equal about 14 lbs of N/acre for a 4-bale lint/acre cotton crop (good yield with modern cotton cultivars).

- In the West Side REC fertilizer N rate study in both Pima and Upland cotton cultivars tested, crop yield and total dry matter responses to applied nitrogen fertilizer amounts were not significantly different when the crops were furrow-irrigated versus subsurface drip (SDI) irrigated, even though fertilizer application methods were different for these irrigation types (two-timing split applications for furrow, drip injection for SDI).

- In fertilizer N rate studies, yield responses to fertilizer N plus pre-plant soil NO_3-N in the upper 2 feet of soil in general leveled off between about 150 to 190 lbs N/acre, with the higher amounts associated with high yield potential situations.

Prior information on harvest removal of N for pima cotton was previously limited to one study conducted under lower yield levels, leading to some questions and uncertainty for estimated N removal for Pima since the results from that study were not in alignment with N removal data for Upland cotton. Results of this study, with many more measurement locations and multiple current commercial varieties serve to verify that the N removal levels and fertilizer N rate responses in pima cotton are quite similar to those more broadly available for Upland cotton under irrigated conditions. Such information helps improve the ability of growers and consultants to better match fertilization application amounts with crop removal levels under conditions with profitable yields.

N. Products – examples

The cotton yield response to N fertilization rates, seed nitrogen and gin trash concentration summaries, and N removal in harvested seed and gin trash summaries have been provided to Dr. Geisseler of UC Davis LAWR Department, and he included this summary information on Pima cotton and Upland cotton N removal in a revision of the N guidelines and N removal data posted on the CDFA-FREP website on crop nitrogen. This information was provided initially to him mid-2021, and later updated as we completed data analyses and had revised information available.

We have also repeatedly reported on results of this study to the Board of the CA Cotton Ginners and Growers Association during board meetings and will provide copies of this report to them for their continuing updates to CA Cotton growers and associated industry.

Later in 2024 and 2025, our next steps with the Cotton Industry partners will be to prepare one or more manuscripts for journal publication plus possible popular press articles to disseminate useful findings for researchers and industry. The project PI will plan to work with the CA Cotton Ginners and Growers Association on these efforts.