SUMMARY REPORT – September 2014
California Cotton Alliance Supported Project
2013 and 2014 Project Activities to Date

PROJECT TITLE: Deficit Irrigation and Alternative Pima and Acala Cotton Management

PRINCIPAL INVESTIGATOR: Bob Hutmacher, Extension Specialist and AES Agronomist – Cotton
UC Davis Plant Science Department
Director, UC West Side Research & Extension Center
Phone: (559) 884-2412 Cell: (559) 260-8957
FAX: (559) 884-2216 email: rbhutmacher@ucdavis.edu

COOPERATORS: Mark Keeley, Raul Delgado (UCD Plant Sciences Dept.)
Steve Wright, Gerardo Banuelos (UCCE Tulare and Kings Counties)
West Side Research and Extension Center staff
Seed Company Cooperators and Fertilizer Company Cooperators

OBJECTIVES OF RESEARCH:
2013 was the second year and 2014 is the third year of a field research trial that focuses on deficit drip management practices that could be utilized to tighten up and shorten the fruit production period and evaluation of these practices using both full-season commercial Acala and Pima cultivars and experimental germplasm (USDA-ARS and/or commercial companies).

Objectives of the project are to:

(1) determine cotton responses to three deficit surface drip irrigation treatments representing a range from mild to moderate deficit irrigation levels during the flowering and fruit development stage;

(2) within each irrigation treatment, evaluate impacts of single versus double-row plantings on earliness and yields in 2 varieties considered to have potential in higher density situations (double row plantings will be higher population treatments; single row will be lower population treatments)

(3) determine cultivar differences within selected Pimas and Uplands in maturity, yield and fiber quality as affected by combined treatments.

This information will help assess what value there might be in use of alternative cultivars to achieve water savings under deficit drip irrigation approaches.

BACKGROUND FOR PROJECT:
Competition for limited supplies of irrigation water are likely to continue to be a part of western U.S. agriculture for many years to come, and crops that actually are or are perceived to require moderate to high amounts of water for production will be under pressure to tighten up irrigation management practices to adjust to restricted water supplies some years. Cotton is known as one of the longest growing season annual crops in the Central Valley of California, and as such is considered moderate to high in terms of annual crop water use compared with a number of other agronomic and vegetable crops. Drip irrigation has been shown in multiple studies to be one approach that can be used that can allow reductions in total applied water, and that allows some flexibility in determining specific periods or growth stages if reduced / deficit irrigation strategies are required due to limited water availability. The investigators of this study have been involved in numerous deficit irrigation studies in recent years, including the three year project concluded in 2011 on deficit subsurface drip irrigation at West Side

REC and Shafter. In the prior project involving deficit drip irrigation using widely grown cultivars of pima and acala cotton, we developed a number of conclusions based on that trial, including:

- under drip irrigation, cotton growth and yields respond to higher pre-plant irrigation amounts (better replenishment of stored soil moisture) when moderate to even severe deficit irrigation is practiced.
- The best responses to the higher initial stored soil moisture amounts at the West Side REC location were with the moderate deficit irrigation treatments (Trts 3, 4) which involved periods of 60% and 80% replacement of estimated evapotranspiration.
- With more severe deficit irrigation treatments (Trts 5, 6, which involved longer periods of 40% and 60% ET replacement), access to more stored soil moisture helped increase yields some, but could not overcome the more severe impacts of these deficit irrigation treatments
- Impacts on hvi fiber quality were generally not seriously damaging with moderate deficit irrigation treatments (such as trts 3 and 4 with periods of 60% and 80% ET replacement). More severe deficit irrigation (trt 6 with prolonged periods of 40% and 60% ET replacement) can be more damaging to strength and micronaire, resulting potential in discounts in some years, particularly if soil water reserves are low.
- The general responses of Pima and Acala varieties to deficit irrigation have been relatively similar in terms of what levels of deficit irrigation start to impact yields

Based on those prior studies, we developed some confidence in assessing tradeoffs associated with deficit irrigation based on the value of irrigation water saved and yield and fiber quality impacts. In this current study we applied these irrigation treatments specifically to a number of commercial and experimental cultivars available for evaluation tot show potential for shorter growing seasons and hopefully reduced total season water requirements. We included the following Acala/Upland and Pima cultivars in quarter field length plots, with three surface drip irrigation treatments as the main plots:

- Acala / non-Acala Upland varieties
    - Phy-725RF
    - FM-2484 B2F
    - FM 1845 LLB2
    - DP 1048 B2RF
- Pima and experimental Pima entries
    - Phy-802RF
    - DP-360
    - PX 8262 RF (later renamed Phy-811RF)
    - Split plot (two rows each of T1000 and T9000 from Bayer – columnar type experimental)

Impacts of season production length produced by these management practices on earliness and maturity, yields, fiber quality, and estimated total season water use will be determined as part of this study. In this field trial, we used the combination of varieties with earlier maturity potential and production practices conducive to shorter production periods (more aggressive early season pest control, delayed irrigations and more aggressive plant growth regulator use) to compare with a more full season management approach and full season commercial varieties typically used by many SJV cotton growers in recent years.

Research Plan: The field trial was established at the University of California West Side REC using a 3 replication design with a split plot design. The planting in 2012 was on April 23, April 18 in 2013, and April 19 in 2014.

Treatment and plot layout: Three deficit drip irrigation treatments representing different levels of applied water and resulting in different degrees of soil water deficits and timing of occurrence of water deficits were developed for the field evaluations. Primary irrigation treatments (water application timing) were replicated three times in full length plots (300 foot length). The type of drip system used for these continuing studies is an 8-10 psi pressure system using drip tubing instead of tape, with the system surface installed in alternate furrows. The surface drip system planned was designed to be a high application rate system with most of the required water applied with about two or three work-days operation per week. Since in our earlier drip experiments there were advantages of an early season drip irrigation application of 4 to 5 inches prior to the 7 to 9 node stage (to provide some stored soil water for later use), we decided to apply a preplant irrigation to all plots. For each year of the study a preplant irrigation (furrow one of the years, sprinkler the other two) of about 5.5 inches was applied in February or March, and an initial application equivalent to 80 lbs N, 50 lbs P and 150 lbs K was applied preplant as a shanked in application in the same rows where the drip line was to be placed.

Across the three years, soil test values indicated a beginning soil nitrate-N level equivalent to about 45 lbs nitrate-N/acre in the upper 3 feet of the soil profile (2012), 57 lbs nitrate-N/acre (2013) and 39 lbs nitrate-N/acre (2014). Additional N fertilizer was injected as urea using the drip system, for a total of 145 lbs applied N per acre (2012), 140 lbs (2013) and 155 lbs (2014).

Three primary drip irrigation treatments were applied using surface drip irrigation (with drip lines placed in every other furrow, 80 inches apart), corresponding roughly with treatments 3 or 4 and 5 from our prior experiments, plus one additional treatment to evaluate the utility of lower levels of water stress during peak bloom and early boll formation followed by more severe stress in later growth stages. These corresponded with irrigation treatments to approximate the following water applications as percent of estimated evapotranspiration (ET):

Table 1. Drip irrigation treatments during different growth stages as a function of treatment #.

Growth Period	Treatment #1 (% estimated evapotranspiration)	Treatment #2 (% estimated evapotranspiration	Treatment #3 (% estimated evapotranspiration	Treatment #4 (% estimated evapotranspiration
Mid-square to early bloom	80	80	80	100
Mid-bloom to vegetative cutout	100	80	60	100
Cutout to about 20% open boll	60	80	60	80

The first three primary irrigation treatments (treatments #1, 2 and 3 above) were utilized for all four of the Upland and all four of the Pima entries. Treatment #4 was added only for the Acala variety Phy-725RF and for the Pima variety Phy-802RF to provide one treatment with only a very limited period of deficit irrigation for comparisons with the other deficit irrigation treatments, all of which represented irrigation strategies applying significantly less than full evapotranspiration replacement.

Applied Water and Soil Water Use: The baseline evapotranspiration potential numbers were collected from the CIMIS weather station located at the West Side REC about 1000 feet from the field plots, and these estimated potential ET numbers were multiplied by a crop coefficient we have determined previously at the West Side REC to determine water application amounts. Water applications were adjusted on a weekly basis to replace the percentages of estimated crop ET shown in the table above for each treatment. All water applications were metered to make sure accurate records of application amounts were collected and to ensure proper system operation.

Table 2. Drip irrigation applied water (inches) during different growth stages plus growing season soil water use (inches) in 2012 trial. Amounts shown do not include pre-plant irrigation amounts.

Growth Period	Water applications and stored soil water use between planting and harvest (inches)	Treatment #1	Treatment #2	Treatment #3	Treatment #4
Mid-square to early bloom	Applied water (AW)	5.62	5.62	5.62	7.03
Mid-bloom to vegetative cutout	Applied water (AW)	12.85	10.28	7.71	12.85
Cutout to about 20% open boll	Applied water (AW)	4.61	6.14	4.61	6.14
Planting to harvest total (in.)	Total drip applied water (AW)	23.1	22.0	17.9	26.0
Planting to harvest total (in.)	Soil water use (SW) – top 8 feet soil profile	4.6	3.9	5.6	3.5
Planting to harvest total (in.)	Total (drip applied water plus soil water use)	27.7	25.9	23.5	29.5

Table 3. Drip irrigation applied water (inches) during different growth stages plus growing season soil water use (inches) in 2013 trial. Amounts shown do not include pre-plant irrigation amounts.

Growth Period	Water applications and stored soil water use between planting and harvest (inches)	Treatment #1	Treatment #2	Treatment #3	Treatment #4
Mid-square to early bloom	Applied water (AW)	6.1	6.1	6.1	7.6
Mid-bloom to vegetative cutout	Applied water (AW)	13.4	10.8	8.1	13.5
Cutout to about 20% open boll	Applied water (AW)	4.4	5.9	4.4	5.9
Planting to harvest total	Total drip applied water (AW)	23.9	22.8	18.6	27.0
Planting to harvest total (in.)	Soil water use (SW) – top 8 feet of soil profile	4.2	3.9	5.5	3.6
Planting to harvest total (in.)	Total (drip applied water plus soil water use)	28.1	26.7	24.1	30.6

Total applied water during the growing season across the four irrigation treatments (Table 2) ranged from a low of 17.9 inches to a high of 26.0 inches in 2012, and in 2013 (Table 3) from a low of 18.6 inches (treatment #3) to a high of 27.0 inches in treatment #4. Soil water use in 2012 during the growing season was estimated at ranging from a low of 3.5 inches in treatment #4 (high water application treatment) to a high of 5.6 inches of soil water use in an 8-foot profile in treatment #3 (low water application treatment). Soil water use in 2013 during the growing season was estimated at ranging from a low of 3.6 inches in treatment #4 (high water application treatment) to a high of 5.5 inches of soil water use in an 8-foot profile in treatment #3 (low water application treatment).

Plant Density Treatments: For most of the entries in the trial, it was determined that we did not have adequate space or the right planter to do the plant density comparisons in the plot area. For one Uplands and two of the Pima entries, we did establish small plantings with a hand planter to double up rows for small micro-plots about 3 m in length to compare hand harvested yields of plants with double versus single row plantings. While we believe the population differences can be an important influence in deficit irrigation situations that may result in reduced total growth and reduced plant size, these sub-treatments were only partially included in this study for 2012 and 2013.

Plant Growth Regulator applications: With each irrigation treatment, the basic plant growth regulator treatments utilized were a relatively standard 1 to 2 applications made depending upon plant growth characteristics, starting near first bloom timing and again within 10 to 14 day intervals following first applications (number of applications were adjusted as needed based on upper canopy internode distance evaluations). Due to the fact that fruit retention was good for 2012 and 2013 and deficit irrigation treatments also held back growth, more aggressive PGR treatments were not deemed necessary.

Other Data collection: Soil water content was evaluated at immediate post planting to 8 feet depth, at first bloom to 4 feet depth, and again to 8 feet depth post-harvest using gravimetric soil samples, and with drip-applied water measurements was used to estimate total water use by treatment. Samples were collected from the West Side REC's cotton picker with bag attachment during harvest operations, and were set aside for ginning at the Shafter research gin. Differences in varieties in timing of maturity as affected by variety, irrigation treatment were determined in the bloom stage using nodes above white/yellow flower measurements, while later in boll development we used measurements of nodes above cracked boll and percent open boll measurements to assess differences in maturity. Relative levels of defoliation and desiccation achieved were also determined at two measurement dates for treatment and variety comparisons.

Yield Data – Seedcotton yields only:
Summaries of the lint yield data are provided in table 4 (2012), and Table 5 (2013) for the Acala and Pima entries in the trial.

Fruit set was very good across all treatments due to low insect pest levels experienced at the test site in 2012 as again in 2013. Very high retention levels were seen in the early season, with this resulting in what might be expected as low impacts of the more water stressed treatment (Trt #3) on seed cotton yields when compared with the yields in other, less stressed treatments (Table 3).

Yields have been reduced in the most water stressed treatment (treatment #3) in 2012 and 2013 results, and similar responses are expected based on the look of the plants and preliminary plant mapping in 2014. However, it has been encouraging to see the relatively high yield levels in treatments #2 and #3, which used significantly less water than treatments #1 and #4 in terms of applied water, but also in terms of calculated total crop water use determined using applied water and net soil water use in an 8 foot soil profile. The soil water data shown in Table 2 for 2012 and Table 3 for 2013 shows that plants in the lower water application treatments (Trt 2 and 3), even though drip irrigated, were also able to extract additional stored soil water to meet crop needs and lessen impacts of deficit drip irrigation.

2014 Project Progress – The basic layout of the drip system, varieties planted both in Uplands and Pimas, calculations used to determine applied water as a function of growth stage, and plans for harvest and additional sample and data collection for 2014 are progressing as in the prior years of the study. Since as of September, 2014 the irrigations have not ceased and it is too early for harvest, data summaries will only include 2012 and 2013 values at this point.

Table 4. Lint yield averages (no statistics provided) for four Acala/Upland varieties and Five Pima varieties as a function of drip irrigation treatment in deficit drip irrigation trial at the University of CA West Side REC, clay loam soil, 2012.

			Lint Yields (lbs / acre)			
Entry ID #	Cotton Variety & Type of cotton		Treatment #1	Treatment #2	Treatment #3	Treatment #4
A1	Phytogen-725RF	Upland	2235	2097	1876	2181
A2	FM-2484 B2F	Upland	2116	2090	1883	
A3	FM-1845 LLB2	Upland	2253	2093	1940	
A4	Phytogen-499 WRF	Upland	2291	2042	1751	
P1	Phytogen-802 RF	Pima	1884	1831	1642	1901
P2	DP-360	Pima	1791	1902	1738	
P3	PX-8262RF (Phy-811 RF)	Pima	1986	1801	1719	
P4	T-1000 (Bayer experimental	Pima	1784	1748	1545	
P5	T-9000 (Bayer experimental)	Pima	1687	1757	1518	

Table 5. Seedcotton yields (hand-picked) for two Upland and two Pima varieties in 2012 double-row vs. single-row plantings per 40 inch bed in deficit drip irrigation trail at the University of CA West Side REC.

Variety	Single vs. double row	Average plant population (1000's/acre)	Seedcotton yields (lbs / acre)		
			Treatment #1	Treatment #2	Treatment #3
Phytogen-725 RF	Single Double	41 70	5890 5680	5850 6110	5110 5400
FM-2484 B2F	Single Double	47 77	6300 6540	5790 5830	4960 5290
DP-360	Single Double	43 69	5570 5460	5280 5180	4710 4740
T-1000	Single Double	45 81	5180 5670	5320 5500	4610 4270

Seedcotton yields in the small hand picked trial to evaluate double versus single row plantings indicated relatively limited impacts of the higher density plantings on yields, with some limited improvements in yields (no statistics yet) in lower water treatment in the Upland entries tested (Table 5). The largest response, as might have been expected, was seen in the higher density plantings with the columnar growth habit Pima experimental variety (T-1000), which has limited leaf area and ground cover in typical single row, widely spaced plantings.

Table 6. Lint yield (lbs of lint per acre) as a function of variety and irrigation treatment in West Side REC study site (clay loam soil) in 2013. Values shown are as follows (uppermost value shown = average across three replications; lower value shown in parentheses ( ) within each cell is the standard deviation of the three replications).

Type of cotton	Variety	Irrig. Trt	Lint Yield (lbs per acre)		Type of cotton	Variety	Irrig. Trt	Lint Yield (lbs per acre)
Acala Upland	FM-1845 LLB2	1	2155 (173)		Pima	DP-360	1	1907 (142)
		2	2366 (10)				2	1806 (70)
		3	1989 (194)				3	1770 (144)
	FM-2484 B2F	1	2051 (147)			Phy-811 RF	1	2111 (73)
		2	2085 (128)				2	2122 (132)
		3	1858 (161)				3	1708 (187)
	Phy-725 RF	1	2141 (156)			Phy-802 RF	1	1981 (59)
		2	2048 (115)				2	2018 (12)
		3	1834 (151)				3	1959 (218)
	DP-1048 B2RF	1	2102 (90)			T-1000	1	1750 (30)
		2	2098 (26)				2	1592 (108)
		3	1795 (118)				3	1514 (128)
						T-9000	1	1796 (150)
							2	1652 (87)
							3	1570 (59)

Table 7. HVI fiber quality characteristics as a function of variety and irrigation treatment in West Side REC study site (clay loam soil) in 2013. Values shown are as follows (uppermost value shown = average across three replications; lower value shown in each cell is the standard deviation of the three replications).

Type of cotton	Variety	Irrig. Trt	Mic	Length (inch)	Strength (g/Tex_	UI	Man. Leaf Classing	HVI Color	HVI Trash	Color RD	Color +B
Acala Upland	FM-1845 LLB2	1	4.77 0.15	1.14 0.03	32.13 0.23	82.10 0.70	2.33 0.58		0.20 0.00	80.57 0.12	8.33 0.12
		2	4.87 0.06	1.13 0.02	31.60 0.92	82.13 0.46	2.00 0.00		0.20 0.00	80.83 0.47	8.27 0.15
		3	5.03 0.15	1.11 0.03	32.50 1.47	82.17 0.42	2.33 0.58		0.23 0.06	79.73 1.14	8.37 0.12
	FM-2484 B2F	1	4.60 0.20	1.17 0.02	31.23 0.76	81.17 1.26	2.00 0.00		0.17 0.06	83.03 0.32	7.63 0.38
		2	4.70 0.26	1.14 0.05	30.40 0.30	80.93 0.21	1.67 0.58		0.10 0.00	83.00 0.98	7.67 0.32
		3	4.70 0.10	1.16 0.01	31.8 0.79	81.20 0.87	1.67 0.58		0.13 0.06	83.67 0.61	7.63 0.40
	Phy-725 RF	1	4.63 0.06	1.18 0.02	34.47 1.33	82.13 1.07	1.67 0.58		0.10 0.00	79.70 0.36	8.97 0.21
		2	4.73 0.06	1.19 0.01	35.0 0.95	81.87 0.49	2.33 0.58		0.20 0.10	79.53 0.23	8.67 0.15
		3	4.50 0.10	1.16 0.02	35.63 1.37	82.47 0.29	1.67 0.58		0.13 0.06	78.70 1.39	9.13 0.21
	DP-1048 B2RF	1	4.53 0.06	1.13 0.01	28.67 0.55	81.00 0.10	1.00 0.0		0.10 0.00	82.37 0.23	8.47 0.12
		2	4.53 0.06	1.13 0.02	29.23 0.64	81.67 0.15	1.00 0.0		0.10 0.00	83.10 0.95	8.50 0.20
		3	4.77 0.35	1.10 0.02	28.63 0.67	80.77 0.59	1.00 0.0		0.10 0.00	81.77 0.35	8.60 0.20
	DP-360	1	4.00 0.10	1.41 0.02	44.67 0.90	87.41 0.46	2.33 0.58		0.50 0.17	72.77 0.47	11.23 0.12
		2	3.87 0.23	1.41 0.01	43.93 2.06	86.80 0.26	2.00 0.00		0.33 0.12	74.10 0.36	10.93 0.32
		3	3.97 0.06	1.40 0.02	43.37 1.01	87.13 0.91	2.33 0.58		0.50 0.10	73.40 0.69	11.13 0.12
	Phy-811 RF	1	3.67 0.12	1.43 0.02	43.63 1.25	86.87 1.07	2.67 0.58	1.33 0.58	0.63 0.25	73.30 1.11	10.90 0.10
		2	3.77 0.06	1.43 0.01	44.97 2.29	86.63 0.99	2.67 0.58	1.33 0.58	0.63 0.21	72.93 0.60	10.97 0.15
		3	3.63 0.15	1.43 0.02	42.37 1.59	87.10 0.52	2.00 0.00	1.00 0.00	0.40 0.00	73.03 0.64	11.07 0.38

	Phy-802 RF	1	3.77 0.06	1.48 0.01	45.17 0.25	87.33 0.15	2.33 0.58	1.00 0.00	0.47 0.12	74.43 0.42	10.67 0.15
		2	3.70 0.26	1.46 0.02	43.90 1.06	87.03 0.50	2.67 0.58	1.00 0.00	0.60 0.10	72.90 0.10	10.83 0.23
		3	3.80 0.10	1.47 0.04	42.93 3.26	87.53 0.93	2.67 0.58	1.00 0.00	0.57 0.15	73.20 0.75	11.03 0.06
	T-1000	1	4.00	1.42	37.3	86.5	2.00	1.00	0.50	79.2	8.60
		2	4.40	1.42	37.70	87.30	3.00	1.00	0.80	76.9	9.00
		3	4.20 0.00	1.39 0.01	36.67 1.00	86.40 0.20	3.00 0.00	1.00 0.00	0.67 0.12	77.30 0.75	8.93 0.32
	T-9000	1	4.15 0.07	1.39 0.06	35.90 1.84	86.75 1.48	2.50 0.71	1.00 0.00	0.55 0.07	78.45 0.92	8.50 0.00
		2	4.20	1.40	36.90	86.80	3.00	1.00	0.70	78.80	8.30
		3	4.20	1.40	36.80	87.60	3.00	1.00	0.70	77.80	9.00

Fiber quality components shown in Table 7 for the 2013 trial indicate that in general, the impacts of the different levels of stress produced by the irrigation treatments are relatively limited in impact on most fiber quality characteristics. There are some instances (with some varieties but not all varieties) where length or strength appear to be reduced slightly in the lowest water application treatment (treatment #3), which produced the greatest levels of water stress particularly from mid- to peak-bloom and into cutout and boll maturation. The impacts do not appear particularly severe in most cases, and the water savings (in a critical water shortage year, at least) can be assessed and balanced against relative impacts on yield and fiber quality. In general, the impacts seem relatively mild both on yields and hvi fiber quality characteristics if growers are in a situation where they need to conserve water based on needs for other ground or other crops, or simply lack of additional available water.

One factor influencing the relatively impacts of treatments on yields was due to the better than typical early fruit retention seen in both years of this study. With several of these treatments producing a tendency toward later season plant water deficits associated with deficit irrigation applications, it might be expected that loss of early fruit set (ie. In a high early pest pressure year), and a shift toward more reliance on later season fruit to make yields, deficit irrigation used in treatments #2 and #3 might have greater effects on yields..

Plans for Project Going Forward:
Duration of Project: This project was proposed as a three-year evaluation (ie. Year 1 = 2012; year 2 = 2013; year 3 = 2014).

Outreach and Extension of Results: Results will be reported in University of California publications as appropriate, including Field Check, as well as county farm advisor newsletters, field day handouts. Some of these reports will also be available on the internet through county websites and the UC Cotton site (http://cottoninfo.ucdavis.edu). Information will be presented through participation in CAPCA and other industry educational meetings when appropriate.

If we can provide additional information or answer some questions, please contact Bob Hutmacher (cell: (559) 260-8957) to discuss. Thank you for your support of this project.