A. Cover Page

Title: Improving Pomegranate Fertigation and Nitrogen Use Efficiency with Drip Irrigation Systems

1. **Project Leader(s)**

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CV's for project Directors are in Section H.

2. **Project Cooperator(s)**

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Commitment letters from the Cooperators are in Section H.

3. **Supporters**

Baryohay Davidoff, Ph.D., Chief, Agricultural Water Management and Financial Support Office, (retired), California Department of Water Resources, P.O. Box 942836, Sacramento, CA 94236-0001.

Deborah Hamlin, CAE, Executive Director, The Irrigation Association, 6540 Arlington Blvd, Falls Church, VA 22042-6638.

Clarence Prestwich, Chief Water Management Engineer, USDA-NRCS,1201 Lloyd Blvd., Suite 1000 Portland, OR 97232.

Inge Bisconer, Technical Marketing and Sales Manager, TORO Micro-Irrigation Business, 1588 N. Marshall Ave., El Cajon, CA 92020-1523.

Suduan Gao, Ph.D., Research Soil Scientist, USDA-ARS-SJVASC, 9611 S. Riverbend Ave. Parlier, CA 93648. (559) 596-2870.

Rationale for Support

The increasing need for water conservation and improved surface water and groundwater quality was emphasized by our supporters, as well as the growing importance of the emerging pomegranate crop. DWR bulletin 160-05 estimates 2030 California's population will reach 48 Million people and will require an additional 2 MAF of water (1.0 ac-ft/year per family of 5 people) of clean water for municipal supplies.

Support Letters

The original support letters from the first project are included as discussed with Mr. Edward Hard on 3/28/2012. These are located in Section H.

4. CDFA Funding Request Amount/Other Funding

Year	Requested from CDFA	In-Kind Value USDA-ARS	In-Kind Value UC and consultant
2013	$50,000*	$145,650.00	$63,000.00
2014	$50,000*	$145,650.00	$63,000.00
2015	$50,000*	$145,650.00	$63,000.00

*Each year funding from CDFA/FREP will cover the student costs, orchard maintenance costs, 47% of the Consultant time and 70% of travel costs.

The In-kind value includes the salaries of the principal and cooperator investigators, the ARS and UC support staffs and laboratories, and the 53% in-kind contribution from the Consultant time and 30% of the travel cost.

In Kind Funding Contributed by Cooperating Organizations

Organization	Contributed Value	Contact	Email	Phone
TORO Micro-Irrigation	$20,000	Inge Bisconer	inge.bisconer@toro.com	(619) 596-4291
LAKOS Filters	$5,500	Claude Laval	claval@lakos.com	(559) 255-1601
Dorot Control Valves	$5,350	Zeev Barylka	zeevdorot@gmail.com	(559) 217-1571
Paramount Farming Co.	$4,000	Erik Wilkins	ErikW@paramountfarming.com	(661) 301-3251
Verdegaal Brothers	$1,260	Jim Gregory	Jgregory@verdegaalbrothers.com	(559) 552-8104
SDI+	$19,494	Claude J. Phene	claudejphene@gmail.com	(559) 298-0201
Total	$55,604			

B. Executive Summary

1. Problem

A recent UCD report on groundwater quality released on March 13, 2012 and entitled: "Nitrate in Drinking Water Raises Health Concerns for Rural California" indicated that "one in ten people living in California's most productive agricultural areas is at risk of exposure to harmful levels of nitrate contamination in their drinking water" (Harter, Lund, Kostyrko and Kerlin, 2012).

2. Project Objectives, Approach and Evaluation

The overall objective is to optimize water-nitrogen interactions to improve FUE of young and maturing pomegranate and to minimize leaching losses of nitrogen. Specific objectives are:

a. Determine the real time seasonal nitrogen requirements (N) of DI- and SDI-irrigated maturing pomegranate that improve FUE without yield reduction and minimize NO_3-N leaching.

b. Determine the effectiveness of three nitrogen injection rates with DI and SDI on maintaining adequate N levels, plant growth and yield in maturing pomegranates.

c. Determine the effect on crop water use of automated high frequency DI and SDI irrigation, based on hourly lysimeter ET_c and develop crop coefficients (K_c) using CIMIS reference evapotranspiration (ET_o) for maturing pomegranate.

d. Develop fertigation management tools that will allow the growers to achieve objective "a" and present those results to interested parties at yearly held field days and seminars.

e. Determine if concentrations of macronutrients (P, K, Ca, Mg) and micronutrients (Zn, Cu, Mn, Fe, B, Se) and healthy bioactive compounds in soil, peel and fruit are influenced by precise irrigation/fertigation management with DI and SDI.

Project Approach

This project is an extension of the project being conducted at the University of California, Kearney Agricultural Research Extension (KARE) Center. It uses a statistically replicated layout on a 3.5-ac field. Pomegranate trees (*Punica granatum L var. Wonderful*) were planted in 2010 with rows spaced 16 ft apart and trees in the rows are spaced 12 ft apart. The two main treatments (surface drip irrigation (DI) and subsurface drip irrigation (SDI) at 20-in. depth) and three N sub-treatments (N application rates of 50, 100 and 150 % of required N, based on bi-weekly tissue analyses) are replicated 5 times (Fig. 7 gives a detailed schematic of the plot layout). To ensure accurate irrigation management, hourly ETc measured with the KARE weighing lysimeter is used to automatically irrigate the orchard (1.0 mm/irrigation). Potassium (K_2S) and phosphorus (PO_4-P) are applied by continuous injection of P=15 ppm and K=50 ppm to maintain adequate levels. The pH of the irrigation water is automatically maintained at 6.5+/-0.5. The trees have been established and the summer of 2012 will be the first year of differential N treatment. All trees were treated uniformly in the first two years to insure uniform establishment.

Seasonal N and water requirements of surface drip irrigated (DI) and subsurface drip irrigated (SDI) pomegranate will be measured and used to determine fertilizer use efficiency (FUE) and NO_3-N leaching. We will determine the effectiveness of N-application rates at 50, 100 and 150 % of required N on maintaining adequate leaf tissue N-levels, plant growth, yield and fruit quality. Automated high frequency DI- and SDI-based on hourly lysimeter ET_c will be used to establish basic yearly water requirements for maturing pomegranate and to develop yearly crop coefficients (K_c) using CIMIS ET_o. Tools for growers to achieve objective "a" will be developed and will be presented to interested parties at yearly field days and seminars. Macronutrients concentrations of P, K, Ca, Mg and micronutrients Zn, Cu, Mn, Fe, B, Se and healthy bioactive compounds in soil, peel and fruit that are influenced by precise irrigation/fertigation management will be measured and statistically analyzed.

3. Target Audience

Pomegranate acreage in California is now about 30,000 ac. From 2006 to 2009, the number of acres in California has increased from 15,000 ac. in 2006, to 29,000 ac. in 2009" (Day, 2009). The audiences will be the Fertilizer and Pomegranate industries and growers looking for improved water/nutrient management techniques for new crops that may also be potentially grown with low quality waters. An audience of 133 people attended the 2011 UCCE Pomegranate meeting at the KARE Center. The information will also be of value to the UC Cooperative Extension personnel.

C. Justification

1. Problem

The California Department of Water Resources (DWR) Bulletin 160-05 states: "In the future, water management challenges will be more complex as population increases, demand patterns shift; environmental needs are better understood…" (L. Snow, 2005). DWR bulletin 160-05 also estimates that 2030 California's population will reach 48 Million people and will require an additional 2 MAF of water (1.0 ac-ft/year per family of 5 people). Phene (2010) has explained how significant volumes of water can be conserved by switching large gravity irrigated acreage to subsurface drip irrigation. A recent UCD report on groundwater quality released on March 13, 2012 entitled: "Addressing Nitrate in California's Drinking Water with a Focus on Tulare Lake Basin and Salinas Valley Groundwater" indicated that "one in ten people living in California's most productive agricultural areas is at risk of exposure to harmful levels of nitrates contamination in their drinking water" (Harter, et al., 2012).
California accounts for about 12% of the US food production and California water shortages and water quality deterioration have significant impacts the nation as well as California. Developing efficient water/fertilizer practices for surface drip and subsurface drip irrigated specialty crops, such as pomegranate, will alleviate the severe, recurring water availability shortages and prevent groundwater quality deterioration.

2. CDFA/FREP Goals

The FREP goals are to provide grant funding for research, demonstration and education projects that advance the environmental and agronomic use and handling of fertilizing materials. This proposal addresses CDFA/FREP's initial concern of nitrate contamination in ground and surface water by limiting the applied N to that needed spatially and timely by the crop (Objective "a & c"). In addition:
--This proposal addresses the CDFA/FREP's expanded research areas to include agronomic efficiency and the management of crop nutrient requirements for a rapidly growing pomegranate crop irrigated by DI and SDI (Objectives "a" & "b").
--This proposal also addresses the development of fertigation management recommendations that will allow the growers to achieve objective "a" for specialty crops and for these results to be presented to interested parties at yearly field days and seminars (Objective "d").
The objectives of this research project extension are to apply state-of-the-art-technology to optimize water- nitrogen interactions to improve the fertilizer use efficiency (FUE) of young and maturing pomegranate and to minimize leaching losses of NO_3-N and N_2O gaseous emission.

3. Impact

California agriculture is facing severe, recurring water availability shortages, groundwater quality deterioration, and accumulation of salts in the shallow, perched water table. Although much of the State is affected by a growing population and environmental restrictions, these problems have reached a critical level in the San Joaquin Valley and more specifically on the highly productive west side of the valley. In 2009, because of lack of water many fields were fallowed and the ensuing economic crisis caused new unemployment levels never heard of in the past (40% unemployment in Mendota, and 20% averaged over Fresno County, the country's highest agricultural producing county in the US). Not so long ago, 1.5 M ac of cotton was grown in the San Joaquin valley. For economic reasons, most of that cotton has been replaced by perennial crops such as almond, pistachio, and now pomegranate . However, these perennial tree crops require more water than cotton, therefore, new water management systems (such as SDI) must be demonstrated and adopted to sustain their yield and quality when water availability decreases.

Long-term solutions

In response to water shortages and rising water and energy costs, California growers are changing their irrigation practices from flood and furrow irrigation to sprinkler and microirrigation. Trend changes in irrigated acreage are shown in Table 1 by irrigation methods for the years 1990 and 2000 and percentage change in irrigation methods during this period (adapted from the Department of Water Resources, Bulletin160-05, dated December 2005). However, many growers are still using conventional fertilizer methods such as: soil incorporating and banding methods that apply most fertilizers early in the season when crops need it the least. These fertilizer application methods are not efficient or well suited for DI and SDI irrigation methods. Several field demonstrations to compare N application with fanjet vs SDI/fertigation for almond, citrus, Pistachio and pecans have shown large differences in N-requirements while sustaining or increasing yield. Results shown in Figure 1 indicate the potential reduction in N use.

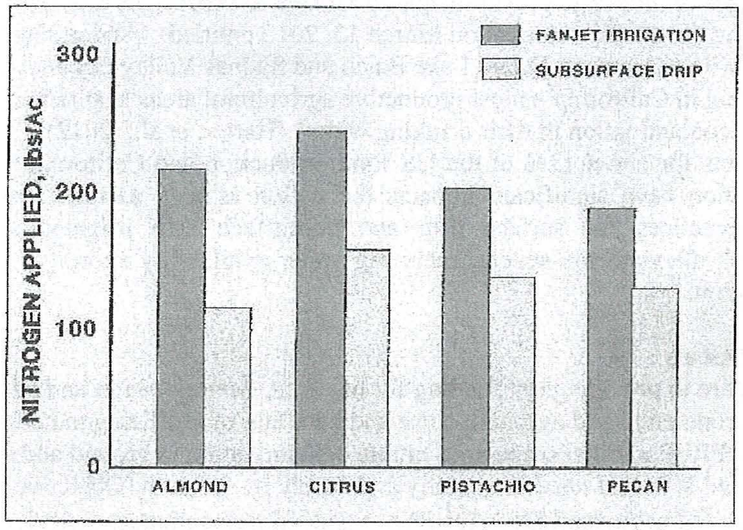


Figure 1. The potential reduction in N use when SDI/fertigation based on demand is practiced.

Table 1. Trend changes in irrigated acreage (in Million ac.) by irrigation methods for the years 1990 and 2000 and percentage change in irrigation methods during this period. (adapted from L. Snow, the California Department of Water Resources, Bulletin 160-05, December 2005).

Irrigation method	1990		2000		Change from 1990 to 2000
	Area	% of Total	Area	% of Total	% Change in acreage
Gravity (furrow, flood)	6.5	67	4.9	51	- 16
Sprinkler	2.3	24	2.8	29	5
Drip/micro	0.8	9	1.9	20	11
TOTAL	9.6	100	9.6	100	

5. Related research

Research and demonstration have shown that well managed surface drip (DI) and subsurface drip irrigation (SDI) systems can eliminate runoff, deep drainage, minimize nitrate leaching, surface soil and plant evaporation and reduce transpiration of drought tolerant crops (Ayars et al., 1999; Phene et al., 1989; Phene et al., 1993; Ben Asher, J. and Phene, C. J., 1993). Reduction of runoff and deep drainage can also significantly reduce soluble NO_3-N losses and improve groundwater quality (Phene & Ruskin, 1995). The total success of DI and SDI methods depends on the knowledge and management of fertigation, especially for deep SDI. Reductions in wetted root volume, particularly if combined with deficit irrigation practices, restricts available nutrients and impose nutrient-based limits on growth or yield. This is particularly important with immobile nutrient such as phosphorus (P). Avoiding nutrient deficiency or excess is critical to maintaining high water and fertilizer use efficiencies (WUE & FUE)

(Phene et al., 1993; Phene, C. J.. 2002) This interaction has been demonstrated for field and vegetable crops but no similar research has been conducted for new perennial crops such as pomegranate (*Punica granatum L.*).

During the 1980's, the USDA-ARS Water Management Research Laboratory research staff conducted lysimeter-based research on irrigation/fertigation of several field and vegetable crops to determine accurate crop coefficient (K_c) and N-P-K fertigation requirements based on real time plant measurements (Ayars et al., 1999; Phene et al., 1989; Phene et al., 1993; Ben Asher, J. and Phene, C. J., 1993).

Figure 2 shows the tomato Crop (var. UC-82B) coefficient (K_c)=ET_c/ET_o) for SDI irrigated/fertigated plant, grown on a Panoche Clay Loam soil and developed based on daily lysimetric crop evapotranspiration (ET_c) measurements and reference ET (ET_o) measured by the CIMIS weather station at the UCREC in Five Point, CA.

Figure 3 shows the tomato crop petiole percent NO_3-N requirements based on weekly chemical analyses and seasonal growth periods measurements (var. UC-82B) and measured for 100 t/ac tomato crop grown at Five Point, CA. The polynomial regression of these data shows an excellent relationship that is being used by some growers to determine their N requirements for top marketable production.

Figure 4 shows the effects of accurate N-P-K fertigation on tomato marketable yields, water use efficiencies and applied water (var. UC-82B). Marketable yields ranged from 56 to 100 t/ac for a tomato crop grown on a Panoche Clay Loam at University of California West Side Research Extension Center (WSREC) in Five Points, CA.

Figure 5 shows the mean residual soil nitrate concentrations (from 0 to 112-in. depth) in a Panoche Clay Loam soil irrigated by DI and SDI systems, obtained from three sample locations across the bed and three replications in the Spring of 1988 following a relatively high N application in 2007 (270 lb N/ac) and prior to planting and application of water and fertilizers (Phene et al., 1995).

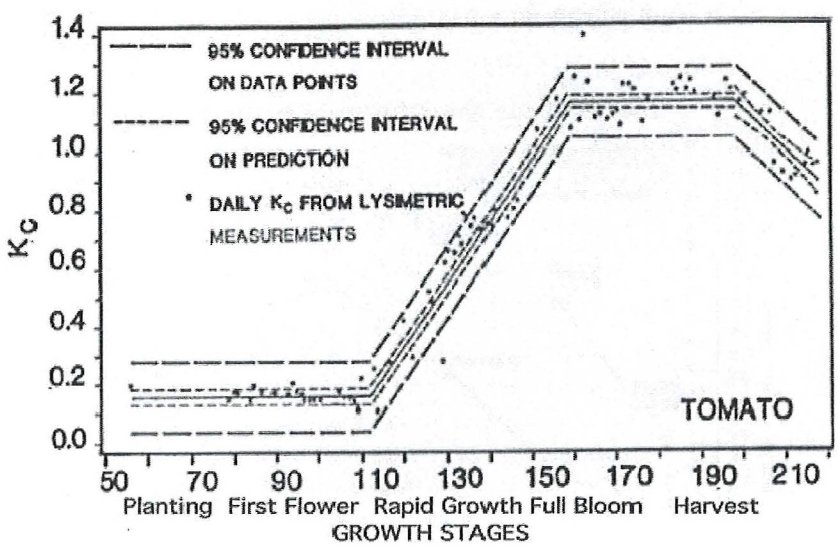


Figure 2. Tomato Crop (var. UC-82B) coefficient (K_c)=ET_c/ET_o) for SDI irrigated/fertigated plant, grown on a Panoche Clay Loam soil and developed based on daily lysimetric crop evapotranspiration (ET_c) measurements and reference ET (ET_o) measured by the CIMIS weather station at the UCREC in Five Point, CA.

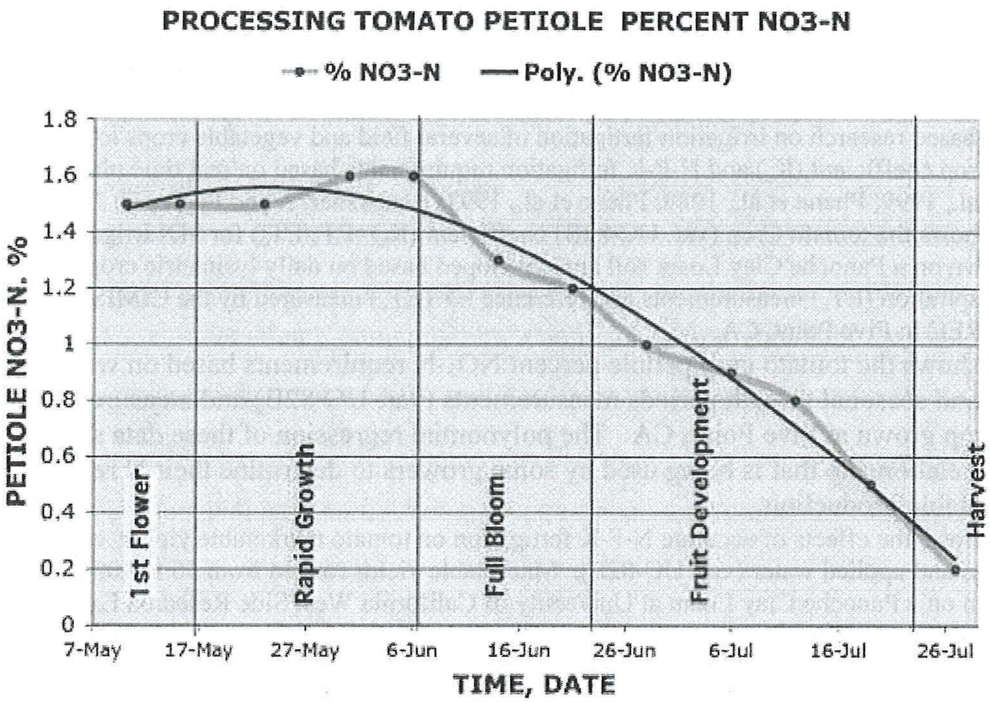


Figure 3. Tomato crop petiole percent NO_3-N requirement based on weekly chemical analyses and seasonal growth periods measurements (var. UC-82B) and measured for 100 t/ac tomato crop grown at Five Point, CA. Polynomial regression of these data shows an excellent relationship that is being used by growers to determine their N requirements for top production.

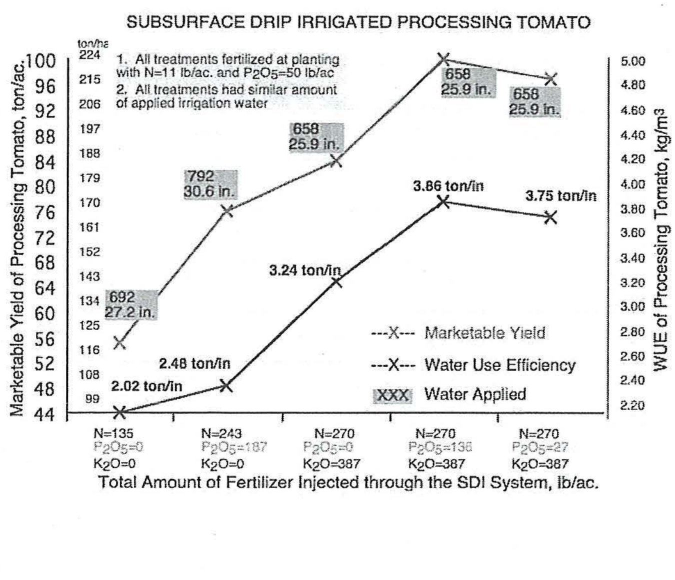


Figure 4. Effects of accurate N-P-K fertigation on tomato marketable yields , water use efficiencies and applied water (var. UC-82B). Marketable yields are ranging from 56 to 100 t/ac for a tomato crop grown on a Panoche Clay Loam at UCREC in Five Point, CA.

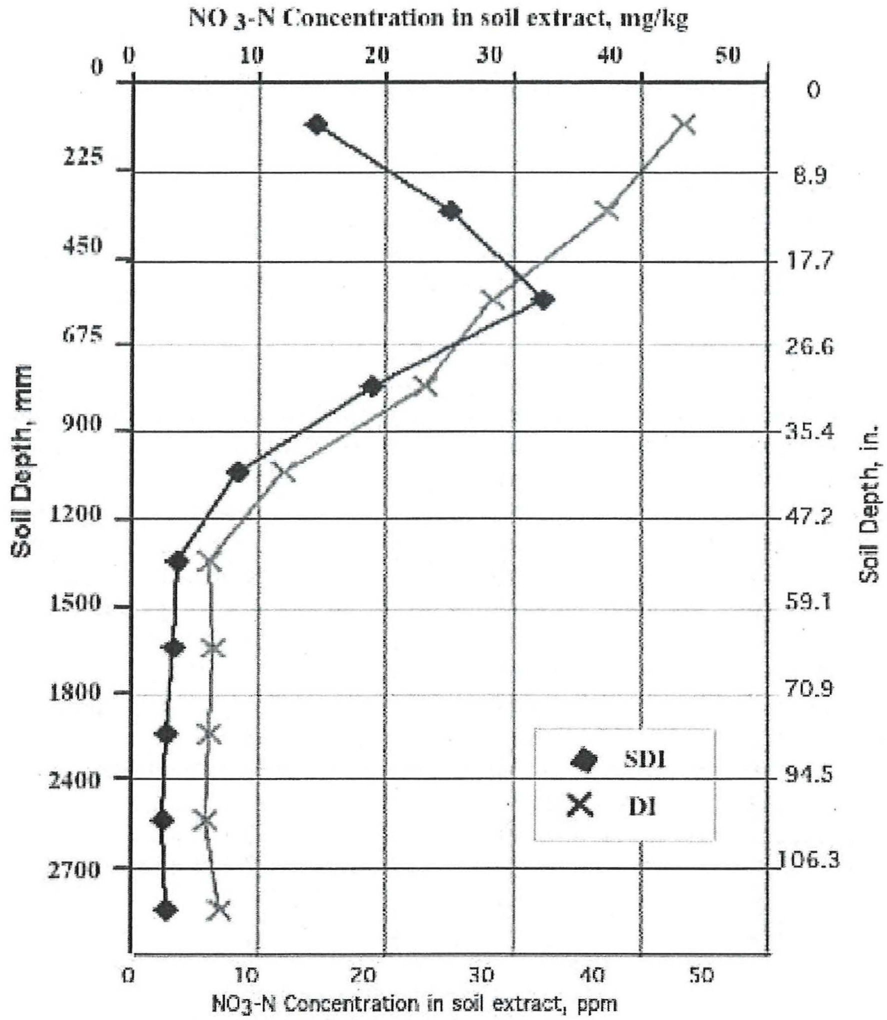


Figure 5. Mean residual soil nitrate concentrations (from 0 to 112-in. depth) in a Panoche Clay Loam soil irrigated by DI and SDI systems, obtained from three sample locations across the bed and three replications in the Spring of 1988 following a relatively high NO3-N application in 2007 and prior to planting and application of water and fertilizers (Phene et al., 1995).

Based on this ARS research conducted in the 1980's with fertigated SDI systems, the processing tomato industry has converted to SDI and the tomato yields have more than doubled and water savings have simultaneously increased by 20-30% (a large farm on the west side has produced average tomato yields of 80 t/ac). Since California accounts for about 12% of the US food production, the California water shortages and water quality deterioration impacts the nation as well as California. Developing efficient water/fertilizer practices for DI- and SDI-irrigated specialty crops such as pomegranate will alleviate the severe, recurring water availability shortages and groundwater quality deterioration. Furthermore, results from this research will also be applicable to perennial crops such as almond (1 million acres) and pistachio.

Early results obtained in the first two years of this Pomegranate project, the recommendations provided by the reviewers of the original project, and the recent successful implementation of subsurface drip irrigation/fertigation practices with crops such as processing tomato indicate that the 3-year requested extension would provide similar valuable results, such as those presented in Figures 1-3 to help alleviate California's critical water and environmental conditions encountered by perennial crops.

During the next three years we will be making detailed analyses of the nitrogen uptake and balance throughout the plant and soil, as well as yield and quality responses to N-fertigation and DI/SDI high frequency irrigation, and general plant development.

The second annual report covering the activities of the second year of the project (2011) are included in section I of this proposal. The results include applied water, soil nitrate distribution, and shaded area. The project will be run in 2012, the last funded year, with the differential nitrogen treatments.

6. Contribution to knowledge base

Results from this project will be presented at conferences, seminars, workshops and grower and fertilizer industry field days. Scientific publications will be submitted to peer-reviewed journals from the American Society of Agronomy (ASA), the American Society of Agricultural and Biological Engineers (ASABE) and the American Society of Horticultural Science (ASHS). Popular publications will be submitted to the California Farm Press, California Agriculture and other similar popular publications. CDFA/FREP interim and final reports will be made available for the rapidly growing pomegranate industry. In 2010, an initial field day was conducted at the site and was attended by about 40 people. On November 29, 2011, we gave 30-minute presentation on the project at a pomegranate extension meeting conducted by UCCE at UC KARE Center in Parlier, CA. An audience of 133 people (full house) attended and subsequently, the presentations were posted on the UC KARE Website under UC KARE Pomegranate Lysimeter Project. Daily data on irrigation, fertigation, evapotranspiration, are automatically posted daily on the website. A field day is planned for June 2011 as well as participation in the CDFA/FREP meeting and the UC KARE -UCCE pomegranate meeting in November 2012.

New information to be generated—Although a small acreage of Pomegranate has been grown under conventional farming methods for a long time, the increasing demand resulting from the newly promoted nutritional aspect of this fruit has created a rapid increase in acreage. The pomegranate has been of recent interest for its nutritional and antioxidant characteristics (Orak, 2009). The fruit is consumed fresh, or it can be processed into juice, syrup, jams or wine. Mineral nutrients and phenolics are natural components present in the fruit, and they play an important role in maintaining fruit quality and nutritive vale for human consumption (Mirdehyhan and Rabemei, 2007). Pomegranate is also a rich source of polyphenols, and contain substantial amounts of protocatechinuie acid, chlorogenic acid, caffeic acid, ferulic acid, coumaric acid, and catechin (Poyrazoglu et al., 2002) Such polyphenols have been implied to exert antioxidant, anti-inflammatory and anti-atherosclerotic properties against some diseases (i.e., osteoarthritis, prostate cancers, heart disease). Pomegranate juice, which is rich in some specific flavonoids (unique tannins such as punicalagen and anthocyanines), was recently shown to possess anti-atherogenic properties secondary to its very potent and antioxidative characteristics (Li et al., 2006). All of the activities may be related to diverse phenolic compounds present in the pomegranate juice.

Mineral nutrition can also vary markedly. Amounts of potassium, calcium, sodium, magnesium, phosphorus, zinc, iron and copper are highest in juice and seeds. Data are, however, non-existent on the effects of DI and SDI fertigation practices on improving mineral composition and phenolic content in the fruit during growth and development of pomegranate fruit. We hope to determine the fertigation strategy and appropriate harvest date for pomegranate fruit that will achieve the most adequate levels of minerals and for influencing phenolic content of the new health produce-pomegranate fruit.

Pomegranate fertilizer (N-P-K) requirements to generate data similar to those shown in Figure 5 for total tomato N-P-K uptake from above ground plant samples will be measured biweekly during the whole season.

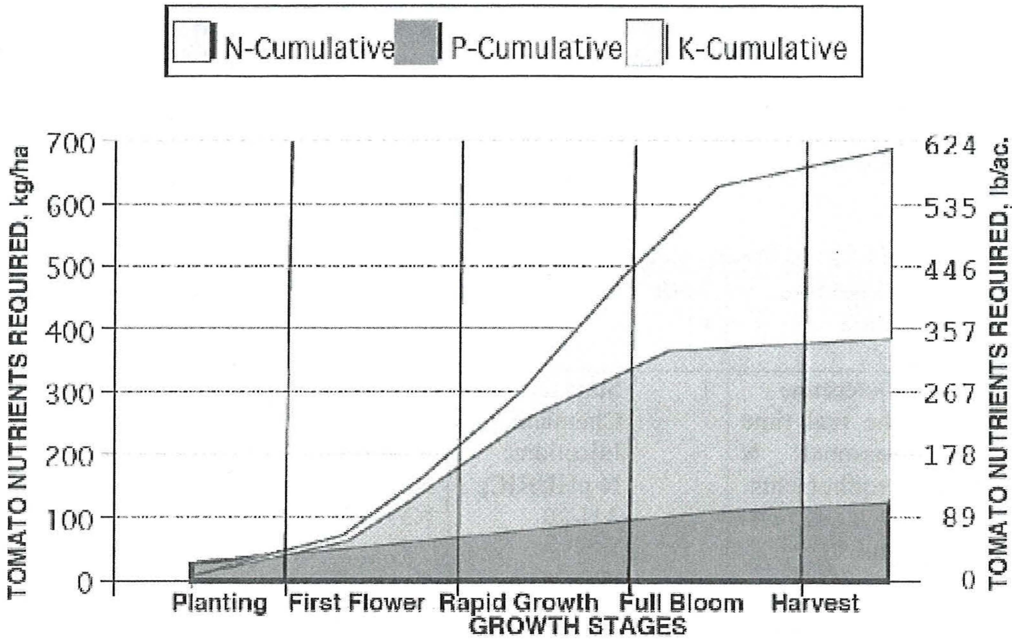


Figure 6. Total 1987 tomato N-P-K uptake from above ground plant samples measured biweekly for the whole season at the UC-WSREC, Five Points, CA. This crop yielded a maximum-achieved 100 t/ac (see Figure 3 for more details).

7. Incentives for growers to adopt proposed practices - With increasing population, growing pressure from environmental groups, ensuing water shortages, increasing energy costs, the agricultural community is constantly looking for economic alternatives. Previous research and demonstration have shown that well managed surface drip (DI) and subsurface drip irrigation (SDI) systems can eliminate runoff, deep drainage, minimize surface soil and plant evaporation and reduce transpiration of drought tolerant crops with simultaneous yield increases and economic advantages.
Reduction of runoff and deep drainage also significantly reduces soluble fertilizer use and losses thus improving both surface and groundwater quality. The total success of DI and SDI methods depends on the knowledge and management of fertigation, especially for deep SDI. Following these encouraging results, the processing tomato industry is converting large acreage to SDI and on the average nearly doubled its yields while significantly reducing water and fertilizer uses. As an example, Fresno County has successfully converted 95% of its 100,000 ac. processing tomato acreage to SDI systems and has achieved average yields of 60 t/ac. Similar results can be achieved with pomegranate.

D. Objectives

1. The overall objective of this project is to optimize water-nitrogen interactions to improve FUE of young and maturing pomegranate and to minimize leaching losses of nitrogen. Specific objectives are:
    a. Determine the real time seasonal nitrogen requirements (N) of DI- and SDI-irrigated maturing pomegranate that improve FUE without yield reduction.
    b. Determine the effectiveness of three nitrogen injection rates with DI and SDI on maintaining adequate N levels in maturing pomegranates.
    c. Determine the effect of real time seasonal nitrogen injections (N) with DI- and SDI-irrigated maturing pomegranate on N leaching losses.
    d. Develop fertigation management tools that will allow the growers to achieve objective a and present these results to interested parties at annual field days and seminars.

e. Determine if concentrations of macronutrients (P, K, Ca, Mg) and micronutrients (Zn, Cu, Mn, Fe, B, Se) and eventually healthy bioactive compounds in soil, peel and fruit that are influenced by precise irrigation/fertigation management with DI and SDI.

E. Work Plans and Methods

Project tasks, subtasks, methods and personnel are shown by objective for the three years in the tables 2 to 6 below.

Table 2. Summary of tasks, subtasks, methods and personnel for specific objective a.

Year	Specific Objec. #	Objective Title	Task #	Task Title	Subtasks	Methods	Personnel*
2013 2014 2015	a	Determine the real time seasonal N requirements (N) of DI- and SDI-irrigated maturing pomegranate ...	1	Start fertilizer Chemical Injections: N-pHURIC, AN-20 K_2S H_3PO_4	Initiate N-treatments N1=50% N2=100% N3=150%	Measure and Adjust concentrations to achieve objective via objective measurement of fertilizer tank levels	CJP, RS, JEA
			2	Measure N-uptake	Biweekly tissue samples	N-P-K analyses	RS, RTC
			3	Measure Fruit Yields & Calculate NUE of DI & SDI systems	Marketable Fruit harvested	NUE=Fruit Yield/N applied	JEA, CJP, GSB, RSJ, KRD

*CJP – Claude J. Phene, RS – Richard Schoneman, JEA – James E. Ayars, RTC – Rebecca Tirado-Carbola, GSB – Gary S. Banuleos, KRD - Kevin R. Day, RSJ - R. Scott Johnson, BCP – Becky C. Phene

Table 3. Summary of tasks, subtasks, methods and personnel for specific objective b.

Year	Specific Objec. #	Objective Title	Task #	Task Title	Subtasks	Methods	Personnel*
2013 2014 2015	b	Determine effectiveness of 3 nitrogen injection rates with DI and SDI on maintaining adequate N levels, plant growth and yield in maturing pomegranates	1	Biweekly leaf tissue N measurements		Total N chemical analyses	JEA, RSJ. CJP, RS, RTC
			2	Yearly whole tree N measurements		Total N chemical analyses	JEA, RSJ. CJP, RS, RTC
			3	Develop seasonal N-P-K requirement tools	Sample tissue biweekly and develop N-P-K curves	See Figure 3 for an example of curves	CJP

Table 4. Summary of tasks, subtasks, methods and personnel for specific objective c.

Year	**Specific Objec. #**	**Objective Title**	**Task #**	**Task Title**	**Subtasks**	**Methods**	**Personnel***
2013 2014 2015	c	Determine the effect of high frequency DI and SDI irrigation...and develop yearly K_c based on CIMIS ET_o for maturing pomegranate.	1	Monitor CIMIS weather Data at Parlier Station	CIMIS daily Download For ETo and Precipitation	Graph accumulated daily values	BCP, CJP
			2	Monitor Lysimeter Data at orchard site	ETc, Precip. Drainage Tank fill Irrigation	Lysimeter Daily download via internet	BCP,CJP
			3	Crop K_c for maturing pomegranate	Calculate K_c=ETc/ETo	For an example of K_c, see Figure 2 in write up	CJP
			4	Irrigation of SDI & DI Systems	Measure & control Flow, Pressures, water pH and ECw	Monitor hourly/daily measurements via internet	BCP,CJP, RS
			5	Measure Fruit Yields & Calculate WUE of DI & SDI systems	Marketable Fruit harvested	WUE=Fruit Yield/water applied	CJP
			6	Lysimeter Tank Chemical	Analyze water sample for N	Adjust concentrations	RS, RTC, CJP

Table 5. Summary of tasks, subtasks, methods and personnel for specific objective d.

Year	**Specific Objec. #**	**Objective Title**	**Task #**	**Task Title**	**Subtasks**	**Methods**	**Personnel***
2014 2015	d	Develop fertigation management tools...and present those results at annual field days and seminars.	1	Development of fertigation management tools will be finalized and presented	1. Schedule field days, 2. Presentations at yearly UCCE Pomegranate meetings, 3. Cooperate with popular publications,	See Figure 3 for an example of curves to be presented and available on the UC KARE website	JEA, RSJ, KRD, CJP RTC
			2	Develop peer-reviewed publications	Present at Irrigation Association, CA Agronomy society, etc…		JEA, RSJ, KRD, CJP RTC

Table 6. Summary of tasks, subtasks, methods and personnel for specific objective e.

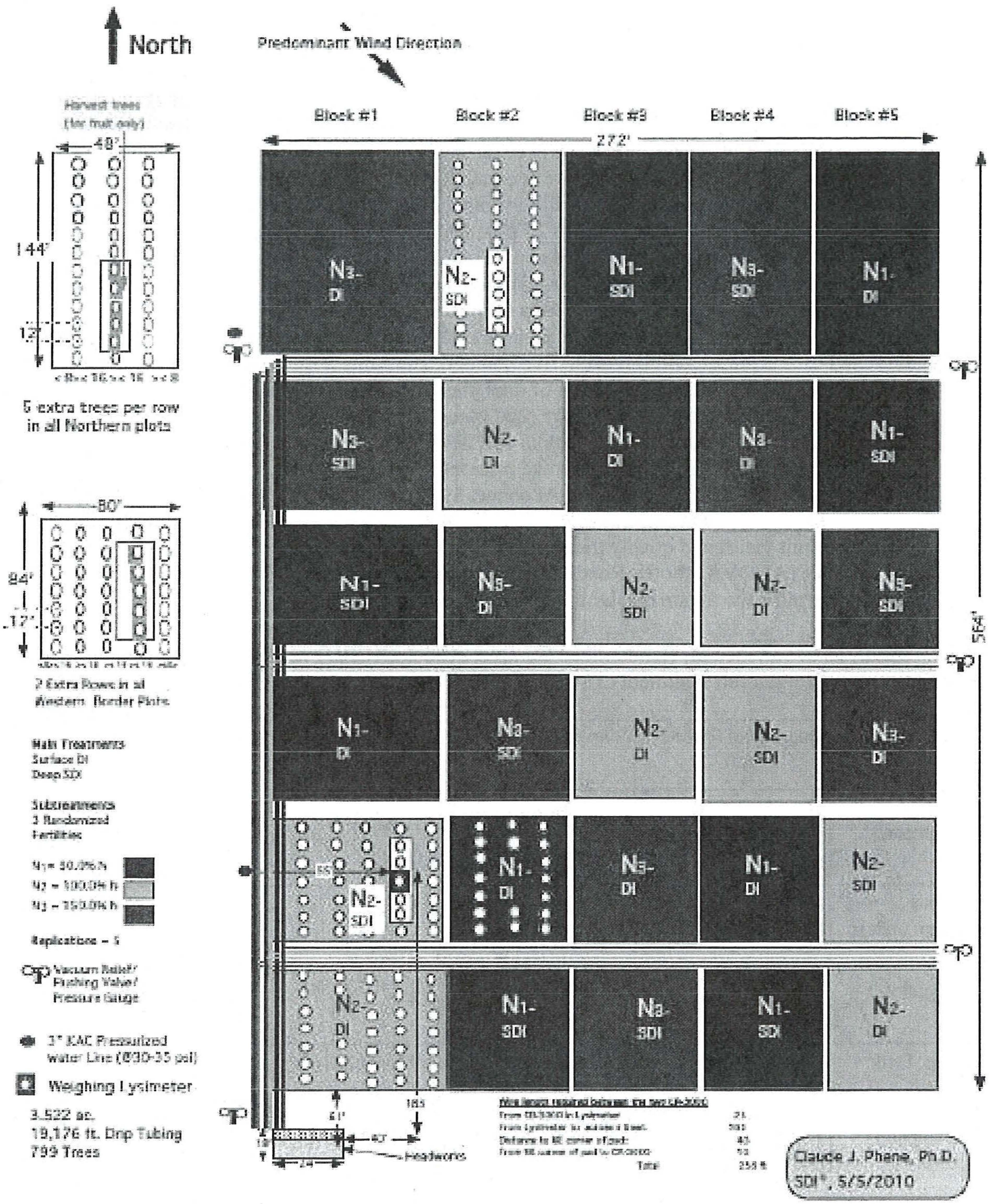
Year	**Specific Objec. #**	**Objective Title**	**Task #**	**Task Title**	**Subtasks**	**Methods**	**Personnel***
2013 2012 2015	e	Determine if macronutrient concentrations of (P, K, Ca, Mg), micronutrients (Zn, Cu, Mn, Fe, B, Se) & bioactive compounds in soil, peel and fruit are influenced by precise irrigation/fertigation management with DI and SDI.	1	Mark flowers at full bloom to provide fruit samples for each irrigation and fertigation treatment.	Measure macronutrient concentrations of (P, K, Ca, Mg) in soil, peel and fruit	Chemical analyses	GSB, RSJ, KRD, CJP, RTC
			2	Use fruits identified in task #1	Measure micronutrients concentrations of (Zn, Cu, Mn, Fe, B & Se) in soil, peel and fruit	Chemical analyses	GSB, RSJ, KRD, CJP, RTC
			3	Use fruits identified in task #1	Measure healthy bioactive compounds in soil, peel and fruit	Chemical analyses	GSB, RSJ, KRD, CJP, RTC
			4	Determine if measurements in Tasks 1,2,3 are influenced by precise N-fertigation management with DI and SDI		Statistical analyses	GSB, RSJ, KRD, CJP, RTC

2. Methods

This project is being conducted at the UC KARE Center and uses a statistically replicated 3.5-ac. randomized complete block design layout (RCBD). Pomegranate trees (*Punica granatum L var. Wonderful*) were planted in 2010 with rows spaced 16 ft apart and within row spacing of 12 ft apart. The two main treatments (DI and SDI at 20-in. depth) and the three sub-treatments (N application rates of 50, 100 and 150 % of required N, based on bi-weekly tissue analyses) are replicated 5 times (Figure 7 is a detailed schematic of the plot layout). To ensure accurate irrigation management, hourly ET_c measured with the KARE lysimeter is used to automatically irrigate the orchard (1.0 mm/irrigation). Potassium and PO_4-P are applied by continuous injection of P=15 ppm and K=50 ppm to maintain adequate levels. The irrigation water pH is automatically maintained at 6.5+/-0.5. Flowers will be marked at full bloom to provide fruit samples for each irrigation and fertigation treatment. Growth and development will be followed by sampling 20 single fruit every 10 days for each treatment. Fruit will be manually peeled and dried for 4-5 days at 95^{o} F, and then ground to achieve a 60 mesh size. Four replicates will be used for each analysis and each replicate will represent five pomegranate fruits. Fruit, peels and arils powder will be extracted with MeOH and the concentration of total phenolics in the methanolic solution will be determined according to Kotamballi and Murthy (2002) and expressed as (+)-catechin equivalents. Importantly, new analytical techniques for phenols will be developed in conjunction with the Food Nutrition Laboratory in Beltsville, MD. Macro and micronutrients (except N), including selenium, will be determined after acid digestion (Banuelos and Akohoue, 1994), and analyzed by the inductively-coupled plasma spectrometry-MS at the WMU in Parlier, CA. Total N content will be determined using Kjeldhal method. Flowers, fruit yields and quality measurements will be obtained and statistically analyzed. Analysis of variance (ANOVA) for the Randomized Complete Block Design (RCBD) with sub-samples will be used to determine the treatment significance as shown in Table 7.

Table 7. Analysis of variance for Randomized Complete Block (RCBD) with subsamples, where T=Main treatment (2), n=Nitrogen sub-treatment (3), r=Replication (5)

Sources	Degrees of Freedom (df)	Sum of Squares (SS)	Mean Squares (MS)	F
Total (samples)	(Tnr)-1 (2x3x5)-1=29	$SS = \Sigma\Sigma\Sigma Y^2_{ij1} - C$ where $C = (\Sigma Y)^2/(Tnr)$		
Plots (exp. units)	(Tr)-1 (2x5)-1=9	$SSU=(\Sigma\Sigma Y^2_{ij.}/n)-C$		
Irrigation	T-1 2-1=1	$SST=(\Sigma\Sigma Y^2_{i..}/rn)-C$	MST=SST/(T-1)	F=MST/MSE
Exp. Error	T(r-1) 2(5-1)=8	SSE=SSU-SST	MSE=SSE/T(r-1)	F=MSE/MSS
Sampling Error	Tr(n-1) (2x5)x(2-1)=10	SSS=SS-SSU	MSS=SSS/Tr(n-1)	



3.

Figure 7. Detailed plot layout of nitrogen fertilizer experiment on pomegranate being conducted at the University of California Kearney Agricultural Research and Extension Center.

F. Project Management, Evaluation and Outreach

1. Management - Project leaders and cooperators will outline, train, and oversee all installations, sampling and processing activities. Project leaders and cooperators will verify authenticity of the sampling and processing activities and write necessary reports, manuscripts, organize and give presentations as needed.

Participants Work Coordination—Staff meetings and training sessions will be conducted as needed but not less than once monthly. Activity schedules will be distributed weekly or as frequently as needed.

2. Evaluation - Analytical methods (such as ANOVA, Table 7) will be used for assessing the progress and success of the project. Data and results will be scrutinized for detecting potential errors. Database and recording books will be used to collect, store and process data.

3. Outreach - Growers field days will be carried out yearly, starting in the fall of the first year, and yearly thereafter. Presentations will be given at the California Fertilizer Association, the ASA Plant and Soil Conference and at the UCCE Pomegranate meeting, in Parlier, CA, as was done in November 29, 2011. In addition, all CDFA/FREP project Requirement Reports will be provided. Also, upon request from growers and/or growers groups, as done in 2011, field meetings will be held to answer questions.

G. Budget Itemization

Attached are the proposed budget forms (in Excel) for years 2013-2015. During the next three years we will be making detailed analyses of the nitrogen uptake and balance throughout the plant and soil, as well as yield responses to N-fertigation and DI/SDI high frequency irrigation, and general plant development. With the aid of a light bar we will characterize shaded area and correlate that to the crop water use being measured using the weighing lysimeter and to the crop coefficient obtained from the weighing lysimeter and CIMIS ETo. A student assistant plus a technician are needed to complete the increased workload. The technician will coordinate the daily operation of the project and the student will assist in the data collection.

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