A. COVER PAGE

Title: Improving Pomegranate fertigation and Nitrogen Use efficiency with Drip Irrigation Systems

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4. CDFA Funding Request Amount/Other Fundings

Year	Requested fromCDFA	In-Kind Value from USDA-ARS	In-Kind Value from UC
2010	$50,000*	$186,650.00	$6,500.00
2011	$50,000**	$193,150.00	$6,500.00
2012	$50,000**	$209,500.00	$6,500.00

*First year request from CDFA/FREP will cover the cost of purchasing and planting trees, the purchase and installation of the irrigation and control systems and the Consultant time and travel costs(50% donated time and travel).

**Subsequent year funding from CDFA/FREP will cover the student costs, orchard maintainence costs, and the Consultant time (50%) and travel costs.

The In-kind fundings includes the salaries of the principal and cooperator investigators and the ARS and UC support staffs and laboratories.

B. EXECUTIVE SUMMARY

1. Problem Summary

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). 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 (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 fertilizer losses and improve groundwater quality (phene (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 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 permanent crops such as pomegranate (*Punica granatum L.*).

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.
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 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 eventually healthy bioactive compounds in soil, peel and fruit are influenced by precise irrigation/fertigation management with DI and SDI.

Project Approach

This project will be conducted concurrently with an evapotranspiration (ETc) Pomegranate project at the San Joaquin Valley Agricultural Sciences Center (SJVASC). The ETc project will determine water requirements of maturing pomegranate using two large weighing lysimeters (Ayars et al., 2000; Ayars et al., 2003). To ensure accurate irrigation management, hourly ETc measured with the lysimeters will be used to irrigate the fertigation project. This proposal will use an adjoining 2-ac. Pomegranate orchard (var. Wonderful). Trees will be planted with rows spaced 18 ft apart and trees in the Harvest rows will be spaced 8 ft apart. Trees in border rows will be spaced 5 ft. apart and will be dug up and harvested twice yearly for total nutrient uptake measurements during the first 4 years. Figure 3 is a schematic of the proposed plot layout, showing main irrigation treatments and fertility sub treatments. The main irrigation treatments are DI and SDI (installation depth = 18-20 in.) systems. The fertility sub-treatments are 3 N treatments (70% of adequate N, adequate N, based on biweekly petiole analysis and 130% of adequate N, all applied by continuous injection). Potassium and PO4-P will be applied by continuous injection of P=15 ppm and K=50 ppm to maintain adequate levels. The pH of the irrigation water will be automatically maintained at 6.5+/-0.5. Tree and fruit responses will be determined by canopy measurements, pruned plant biomass and bimonthly plant tissue analyses. When appropriate, flowers, fruit yields and quality will be measured and statistically analyzed.

3. Target Audience

Pomegranate acreage in California is now about 29,000 ac. and Kevin Day noted that "from 2006 to 2009, the number of acres in California planted with pomegranate trees has increased from 12,000 or 15,000 acres in 2006, to 29,000 acres in 2009" (K. Day, 2009). The rising demand for juices with healthy bioactive compounds, mineral nutrients and high antioxidant contents are partially contributing for this growth. Pomegranate is a drought tolerant crop that can be grown on saline soils. The target audiences will be the Fertilizer and Pomegranate industries and the community of growers looking for improved water/nutrient efficient management techniques for new crops that may also be potentially grown with low quality waters.

C. JUSTIFICATION

1. Problem

California agriculture is facing severe, recurring water availability shortages, groundwater quality deterioration, and accumulation of salts in the shallow, perched water table. To compensate for the lack of sufficient surface water, growers on the west side of the SJV are pumping from deep saline aquifer, bringing salts to the surface that are causing drainage issues and irrigated acreage to be drastically reduced. Huge unemployment and economical losses are incurred, as exemplified this year. These problems are especially critical on the west side of the San Joaquin Valley and as a result, many marginal income crops are no longer grown. Table 1 shows yearly precipitation (top) and runoff (bottom) for long-term averages and various drought periods. The present drought started in 2006-2007 (3rd column from left) and is continuing for 2008-2009; presently precipitation in Fresno, CA is totaling 7.11 in. During droughts, water deliveries are reduced or even stopped and if water stress is severe enough to limit plant growth, fertilizer application should be reduced proportionally. This can only be accomplished if fertilizers are applied frequently and only as needed by the crop.

Table 1. Yearly precipitation (top, inches) and runoff (bottom, MAF) for the long-term average and drought periods in: (1975-1977), (1986-1992) and (2006-2007) (adapted from L. Snow, the California Department of Water Resources, Bulletin 160-05, dated December 2005).

Precipitation (inches) — **July 1 to June 30 Precipitation Totals**

City	Average	06-07	75-76	76-77	86-87	87-88	88-89	89-90	90-91	91-92	98-99	99-00	00-01	01-02
Eureka	39.55	38.52	33.55	17.56	27.93	32.31	34.88	26.83	25.11	21.92	49.99	36.44	22.84	40.66
Redding	37.00	22.73	22.90	20.97	21.48	30.22	33.53	29.93	22.07	28.42	30.87	34.28	30.15	28.86
San Francisco	20.26	11.66	7.73	11.05	10.74	14.34	13.77	11.87	13.47	18.21	16.91	20.69	16.24	19.32
Sacramento	18.20	12.22	7.25	7.53	12.81	15.37	15.13	19.40	14.73	16.68	15.27	23.74	17.31	17.08
Fresno	10.95	6.06	8.18	7.61	9.32	8.07	8.73	9.45	9.77	11.05	7.01	12.91	10.56	7.03
Santa Barbara	16.32	7.24	7.83	15.90	10.91	14.06	8.76	5.76	16.74	18.33	12.04	25.10	23.68	9.07
Bakersfield	6.23	3.06	4.37	4.19	5.56	5.55	3.74	3.30	5.95	7.00	6.96	5.15	5.77	3.59
Long Beach	12.11	2.12	4.98	6.78	7.59	8.25	6.09	6.39	9.99	13.76	8.47	6.60	10.90	2.21
Los Angeles (Civic Ctr)	14.89	3.21	7.22	12.31	7.66	12.48	8.08	7.35	11.47	21.00	9.09	11.57	17.94	4.42
San Diego	10.21	3.83	9.11	8.08	9.61	13.18	5.65	7.84	11.79	12.93	6.71	5.76	8.58	2.99
Riverside	10.09	1.70	7.89	6.70	6.65	9.27	6.94	5.80	10.53	11.18	5.86	5.19	7.35	3.30
Redlands	13.37	3.93	9.65	12.45	10.51	12.92	8.28	7.79	14.07	15.72	7.76	7.86	10.31	3.58
Death Valley	2.28	1.83	3.44	2.74	1.96	5.78	0.68	0.57	1.77	2.59	1.24	1.23	2.70	0.46

Runoff (MAF) — **Water Year Totals (October 1 to September 30)**

Index	Average	06-07	75-76	76-77	86-87	87-88	88-89	89-90	90-91	91-92	98-99	99-00	00-01	01-02
Sacramento Valley Index	8.33	6.2*	5.29	3.11	5.86	4.65	6.13	4.81	4.21	4.06	9.80	8.94	5.76	6.35
San Joaquin Valley Index	3.29	2.0*	1.57	0.84	1.86	1.48	1.96	1.51	1.96	1.56	3.59	3.38	2.20	2.34

*Estimates

2. CDFA/FREP Goals

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 "c"). In addition:

a. This proposal also 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 and capable of being grown with saline irrigation water (Objectives "a" & "b").

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").

3. Impact
As mentioned in the problem statement, 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 are fallow 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 and much of it on the west side. For economic reasons, most of that cotton has been replaced by perennial crops such as almond, pistachio, grapes and now pomegranate and other salt semi-tolerant crops.

Since the late 1980's the processing tomato industry has converted slowly to SDI and the tomato yields have nearly 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.

4. 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 2 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, Bulletin 160-05, 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.

Table 2. 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
Fertigation research in DI and SDI has demonstrated the ability to adjust the injection of fertilizer-N (and P and K) to accurately match crop needs and reduce or eliminate nitrate-N drainage losses (Phene et al. 1995). For ten consecutive years (1984-1993), the USDA-ARS, Water Management Research Laboratory in Fresno conducted lysimetric research on several field crops grown on permanent beds at the UC-WREC, Five Points CA, on the west side of the California San Joaquin Valley (Phene et al., 1993; Ayars et al., 1999). DI and SDI results averaged over these years have shown that slightly under-irrigated crops can potentially conserve significant water without decreasing yields and the drainage component can be nearly eliminated, except during precipitation events. Similarly, lysimetric ET research with grapevines and peaches conducted at the

UC Kearney REC have shown that slightly under-irrigated crops can potentially conserve significant water without decreasing yields and thus, the drainage component can be nearly eliminated (Johnson et al., 2005; Williams et al., 1992; Williams et al., 2003 (2)).

Table 3 shows the yearly values (12 months) of grass reference ET (ETo) and crop evapotranspiration (ETc), precipitation (P), irrigation application (Iw), drainage (D) from the crop lysimeter, and water use efficiency (WUE) for DI and SDI systems for these field crops (Phene et al., 1993).

The total 1987 tomato N-P-K uptake from above ground whole plant samples was measured biweekly for the whole season and is shown in Fig. 1. The N-P-K fertilizers were injected in the irrigation water throughout the season at rates adjusted to meet plant requirements determined by weekly petiole analysis. Nitrogen from N-phuric, CAN-17 and potassium nitrate totaled 241 lb/ac. Phosphorus (as P_2O_5) from white phosphoric acid was continuously injected at a rate of 15 ppm and totaled 121 lb/ac. Potassium (as K_2O) from potassium nitrate was injected at rates matching plant requirements and totaled 345 lb/ac. Marketable tomato yield were respectively 100 t/ac. for the SDI and 91 t/ac. for the DI treatment (Phene et., 1992, 1993).

To demonstrate the minimal N-leaching loss resulting from this management practice, the soil was sampled from the 1987 DI and SDI (SDI lateral at 18.0-in. depth) irrigated tomato beds early in 1988 (a year when precipitation was higher than average). Figure 2 shows mean residual soil nitrate concentrations (from 6.0 to 112-in depth) in a Panoche Clay Loam soil irrigated by DI and SDI systems. These soil samples were taken from three locations across the beds and three treatment replications in the Spring of 1988 prior to planting and application of water and fertilizers (Phene et al., 1995). Significant nitrate-N concentrations differed only above the location of the SDI system and were constantly minimal below 51 in. depth. These results indicate that even following above average precipitation and relatively large injection of nitrogen in 1987, nitrogen leaching losses were largely prevented, thus increasing FUE and crop yield. Similar results can be achieved and should be demonstrated with pomegranates.

Table 3. Yearly values (12 months) of grass reference ET (ETo) and crop evapotranspiration (ETc), precipitation, irrigation application, drainage from the crop lysimeter, and water use efficiency (WUE) for DI and SDI systems for several crops grown by the USDA-ARS, Water Management Research Laboratory from 1984-1993 in cooperation with the UC West Side REC, Five Point, CA (adapted from Phene et al., 15th Intern. ,Cong. on Irrig. & Drainage, The Hague, Netherlands 1993).

CROP	YEAR	ET_o	CROP ET_c & SOIL E	PRECI.	IRRIGATION APPLICATION	DRAINAGE	WUE*	
							DI	SDI
		in.	in.	in.	in.	in.	lb/ft^3	
Tomato	1984	71.8	37.8	4.1	27.2	0	0.140	0.137
Tomato	1985	67.7	33.7	5.0	31.2	2.3	0.138	0.139
Cantaloupe	1986	67.0	34.0	6.6	21.7	3.5	0.105	0.113
Tomato	1987	65.2	31.2	7.4	25.9	1.4	0.218	0.242
Cotton	1988	62.3	38.5	8.1	27.3	3.3	0.174	0.195
Sweet Corn	1989	59.6	27.3	3.4	26.3	0.08	0.181	0.182
Tomato	1990	63.7	34.5	5.7	30.4	1.5	0.158	0.165
Fallowed**	1991	62.6	12.0**	7.2	0**	0.83	N/A	N/A**
Winter Wheat**	1992	60.7	15.2**	7.8	13.8**	0.28	N/A	N/A**
Cotton	1993	60.1	31.6	12.3	21.7	3.5	N/A	N/A
Means	84-93	64.1	33.6	6.8	26.5	1.8	0.159	0.170

* WUE is defined as total above ground dry matter yield divided by the irrigation water applied.
**ETc, Irrigation Application, Drainage and WUE data are not included in calculation of means.

6. Contribution to knowledge base
   a. Project 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 and other similar popular publications. CDFA/FREP interim and final reports will be made available for the rapidly growing Pomegranate industry.

   b. New information to be generated—Although a small acreage of Pomegranate has been grown under conventional farming method 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 also 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.

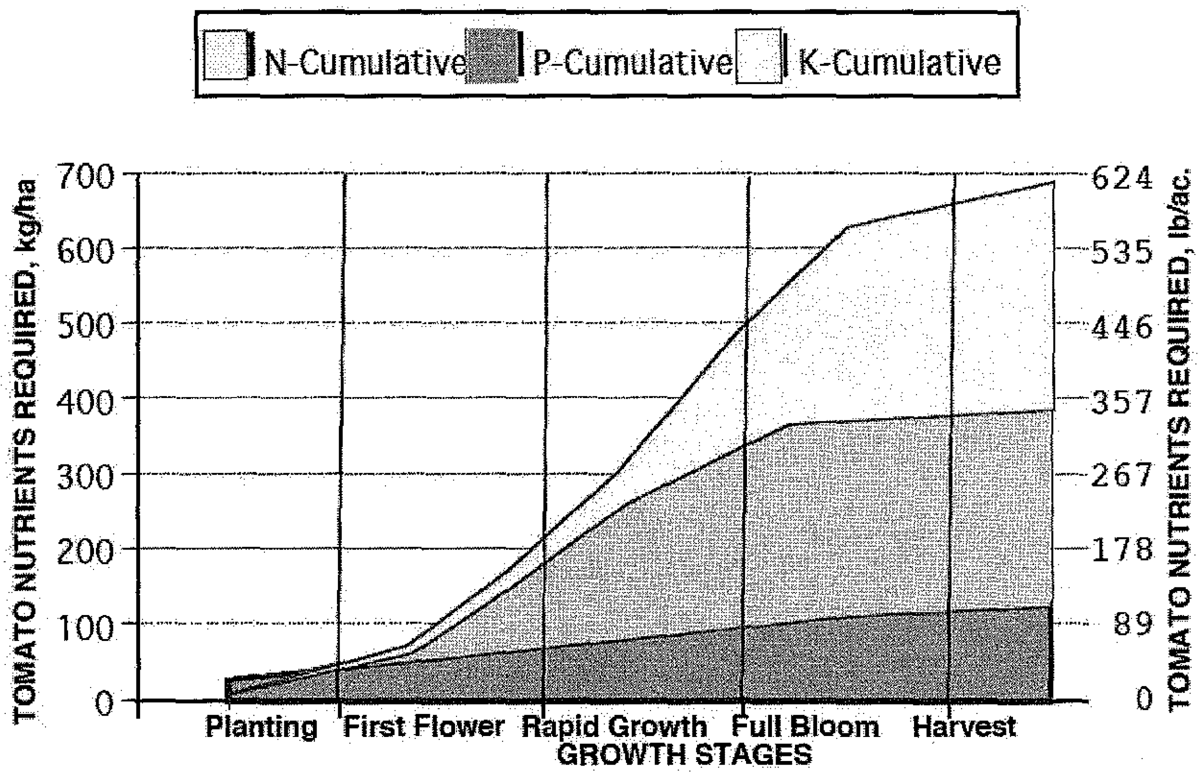

Figure 1. Total 1987 tomato N-P-K uptake from above ground plant samples measured biweekly for the whole season at the UC-WSREC, Five Points, CA.

7. Grower Use

Incentives for growers to adopt proposed practices—With increasing population, growing pressure from environmental groups, ensuing water shortages and growing 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 losses and improve 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 started to convert to SDI and on the average they nearly doubled their yields while significantly reducing water and fertilizer uses. Similar results can be achieved with pomegranate.

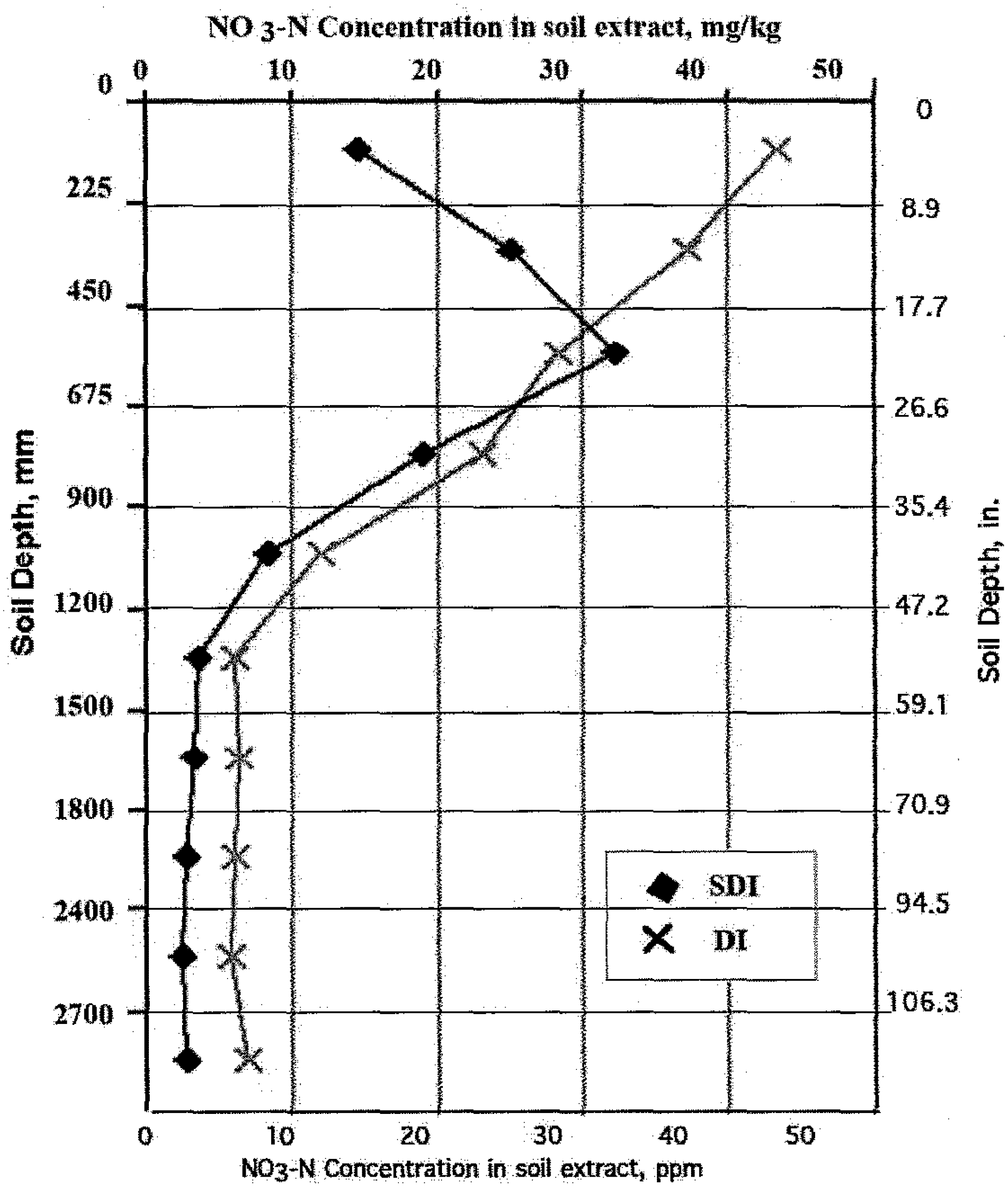

Figure 2. Mean residual soil nitrate concentrations (from 0 to 112-in. depth) in a Panoche Clay Loam soil irrigated by DI and SDI systems, obtained from three sample locations across the bed and three replications in the Spring of 1988 prior to planting and application of water and fertilizers (Phene et al., 1995).

D. OBJECTIVES

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 1 and present these 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 eventually healthy bioactive compounds in soil, peel and fruit that are influenced by precise irrigation/fertigation management with DI and SDI.

E. WORKPLAN AND METHODS

This project will be conducted concurrently with an evapotranspiration (ET_c) Pomegranate research project at the USDA-ARS San Joaquin Valley Agricultural Sciences Center (SJVASC). The ET_c project will determine accurate water requirements of young, maturing pomegranate using two large weighing lysimeters (one under normal soil/water conditions and the other under saline conditions in the presence of a shallow saline water table). To ensure accurate irrigation management, hourly ET_c measured with the lysimeters (normal conditions) will be used to irrigate the fertigation project.

This proposal will use an adjoining 2-ac. Pomegranate orchard (var. Wonderful). Trees will be planted with rows spaced 18 ft apart and trees in the Harvest rows will be spaced 8 ft apart. Trees in border rows will be spaced 5 ft. apart and extra trees will be dug up and harvested twice yearly for total nutrient uptake measurements during the last 4 years of the project. Figure 3 is a schematic of the proposed plot layout (complete randomized block with sub-treatments) showing main irrigation treatments and N-fertility sub-treatments. The main irrigation treatments are DI and SDI (18-20 in. depth) systems. Dual drip irrigation laterals The fertility sub treatments are 3 N treatments (70% of adequate N, adequate N, based on biweekly petiole analysis and 130% of adequate N, all applied by continuous injection of AN-20). Potassium and PO4-P will be supplied by continuous injection of P=15 ppm and K=50 ppm to maintain adequate levels. The pH of the irrigation water will be automatically maintained at 6.5+/-0.5. Tree growth will be determined by trunk and canopy measurements and pruned plant biomass.

In years two and three, 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 95F, 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 determines 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 completely randomized design (CRD) with sub-samples will be used to determine the treatment significance as shown in Table 4.

Task and sub-tasks to achieve objectives for year #1
a. Prepare orchard area and fumigate soil as needed.
b. Sample soil and determine initial nitrate-nitrogen status.
c. Install and test irrigation, fertigation and control systems.
d. Plant pomegranate trees and begin uniform irrigation/fertigation.
e. Start tissue sampling if time permits.
f. Measure trunk diameter and canopy size.
g. Install soil moisture sensors and start monitoring soil matric potential.

Task and sub-tasks to achieve objectives for year #2
a. Determine the real time seasonal nitrogen requirements (N) of DI- and SDI-irrigated maturing

pomegranate that improve FUE without yield reduction. Bi-weekly tissue analyses will be used to provide N-uptake rates under three N application levels and will be used to fertilize the 100% N level accordingly.

b. Determine the effectiveness of three nitrogen injection rates with DI and SDI on maintaining adequate N levels in maturing pomegranates. Yearly whole tree harvesting and analyses for total nitrogen (and other nutrients) will provide total N-uptake under three N application levels.
c. Determine the effect of real time seasonal nitrogen injections (N) with DI- and SDI-irrigated maturing pomegranate on N leaching losses. Soil samples will be collected down to two meters and analyzed for soluble N concentration and to determine the treatment effects on N-leaching losses.
d. Develop fertigation management tools that will allow the growers to achieve objective 1 and present these 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 eventually healthy bioactive compounds in soil, peel and fruit are influenced by precise N-fertigation management with DI and SDI.
f. 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 95F, and then ground to achieve a 60 mesh size.
g. Soil matric potential measurements will be used to determine the direction of the hydraulic gradient and the N-leaching potential.

Task and sub-tasks to achieve objectives for year #3

a. Items a-g described for year #2 will be continued in year #3.
b. Development of fertigation management tools will be initiated. These tools will eventually allow the growers to achieve the objectives and goals of this project. The obtained results will be presented to interested parties at field days and seminars.

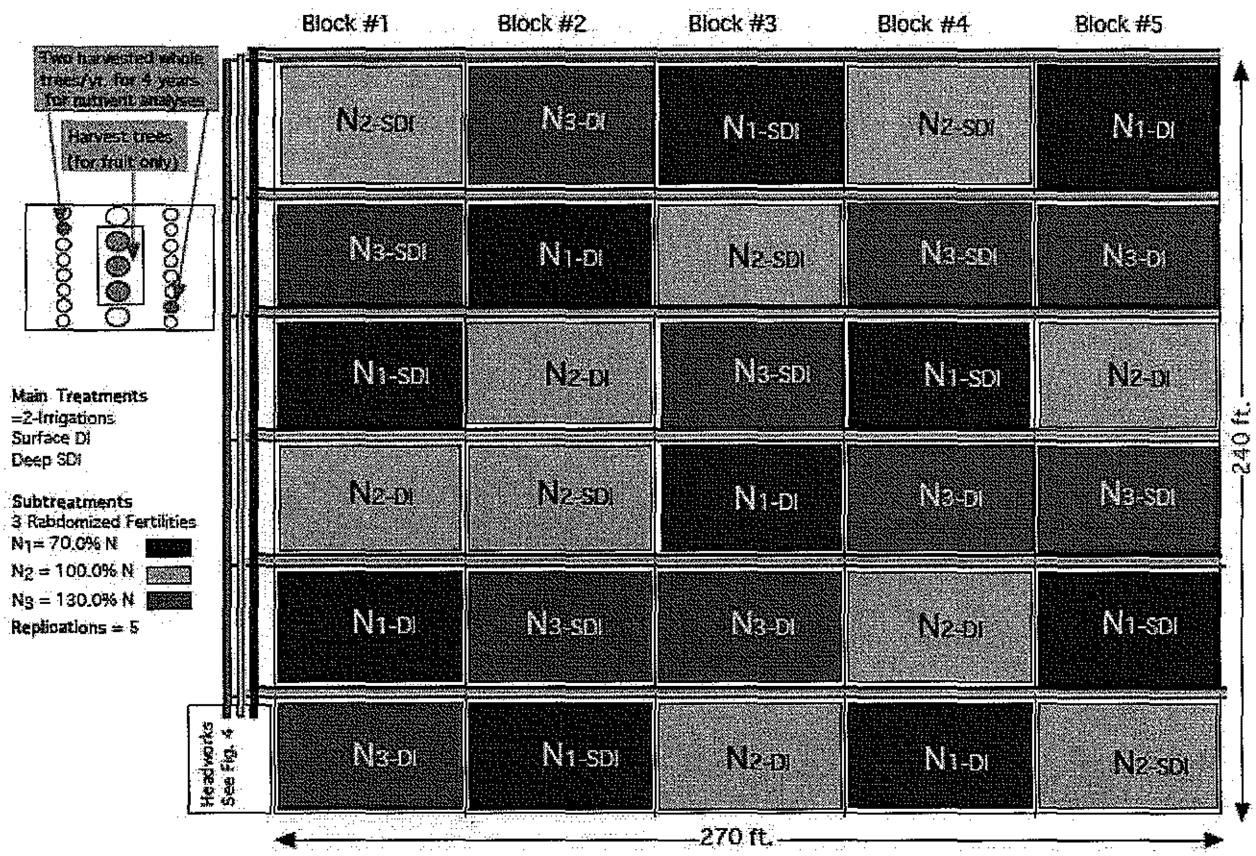

Figure 3. Two-acre pomegranate orchard plot layout showing main irrigation treatment (surface Drip DI and deep susurface drip SDI), three fertility sub-treatments (N1, N2, and N3) and the yield and harvested trees.

Table 4. Analysis of variance for Completely Randomized Block (CRD) 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)	

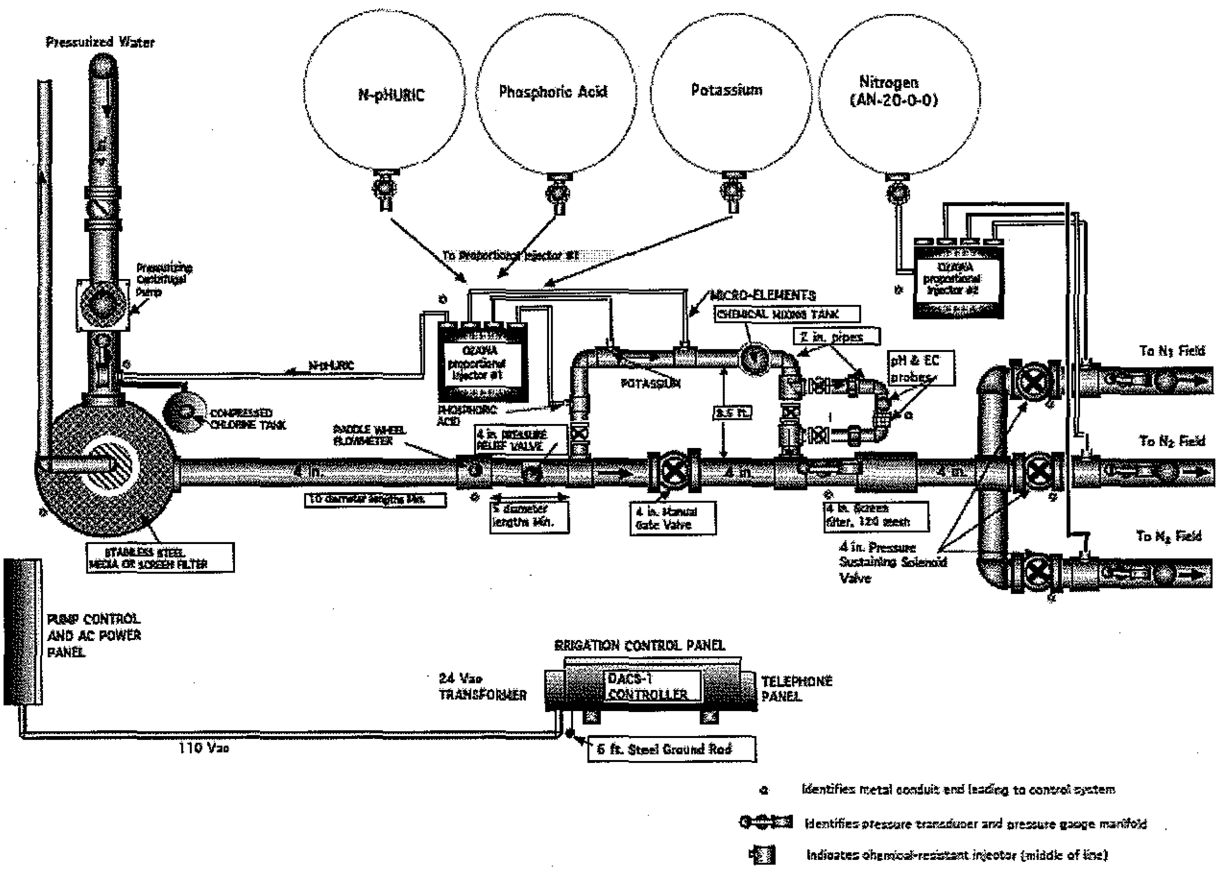

Figure 4. Pomegranate orchard irrigation headworks, fertigation and control system layout showing fertigation proportional injection pumps and supply tanks, pH and EC_w measurement manifold, and flow and pressure measurement instruments.

F. PROJECT MANAGEMENT, EVALUATION AND OUTREACH

1. Management
   a. Role of Project Leaders and Cooperators—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 and organize and give presentations as needed.
   b. 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 For Primarily research-oriented project—Analytical method (such as ANOVA) 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, the ASABE Annual Meeting, the SSSA Annual Meetings and peer-reviewed publications after completion of the project. In addition, all CDFA/FREP project Requirement Reports will be provided.

G. BUDGET ITEMIZATION

Yearly budget using the CDFQ/FREP Budget Sheet are attaché

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