A. Cover Page

1. Project Title: Field Evaluation and Demonstration of Controlled Release N Fertilizers in the Western United States

2. Project Leaders: Charles A. Sanchez, Professor, University of Arizona, 6425 W. 8th Street, Yuma, AZ 85364, phone 928-782-3836, e-mail sanchez@ag.arizona.edu

Richard Smith, Farm Advisor, Cooperative Extension Monterey County, 1432 Abbott Street, Salinas, CA 93901, phone 831-759-7357, e-mail rifsmith@ucanr.edu

3. Cooperators:

Cooperators will include vegetable producers in California and southern Arizona and manufactures of controlled release technologies. We have secured letters of commitments from a subset of these including Ocean and Desert Mist Farms, A. Duda & Sons, Top Flavor Farms, J. V. Farms, Agrium Advanced Technologies, and J. R. Simplot Company.

4. Supporter(s).

NA

5. CDFA Funding Request

$224,967.0

6. Agreement Manager

The official agreement manager is the Arizona Board of Regents. The administrative contact is Ms. Sherry Esham of the University of Arizona Sponsored Project Services.
B. Executive Summary

1. Problem

Nitrogen is the nutrient most limiting to crop production in the western United States. Because of the rigid produce quality standards enforced by the market, vegetable crops receive appreciable amounts of N fertilizer for optimal yield and quality. Amounts of N applied range from 200 to 400 kg/ha and crop recoveries are generally less than 50%.

There are numerous possible fates of fertilizer applied N, in addition to the desired outcome of crop uptake. The urea and ammonium components of the N fertilizer might be lost through ammonia volatilization. The nitrate-N might be lost to leaching with irrigation water below the crop root zone possibly impairing surface and ground water. Nitrate might also be lost as N₂ and N₂O gasses via denitrification processes affecting air quality and climate. The global warming potential of N₂O is 300 times that of CO₂ and N fertilizer is estimated to account for one-third the total greenhouse gas production in agriculture. Furthermore, all forms of N might be immobilized into the organic soil fraction by the soil microbial population where availability to the crop is delayed.

Both California and Arizona have mandated Best Management Practices (BMP’s) to varying degrees. These practices generally involve timing, amounts, and placement of N, and irrigation water application. The use of controlled release N (CRN) fertilizer sources is another promising option. Controlled-release N sources have shown positive results for vegetable production. Early work in Arizona has shown CRN sources to be highly effective for lettuce under some conditions. Recent work in the low desert of the southwestern United States evaluated the response of lettuce, broccoli, cauliflower, celery, and spinach to controlled release N fertilizer. The use of CRN was compared to soluble N fertilizers applied pre-plant and soluble N fertilizers applied in split-side-dress applications. Under several production scenarios, the use of CRN strategies was economically favorable. There was also variation in the efficacy of the various CRN technologies.

Despite positive feedback from producers at field days and workshops, there has been little adoption of using CRN management. More recently, we have conducted a few preliminary demonstrations in grower fields. In these situations, growers have seen the positive results in combinations of enhanced production, lower N fertilizer inputs, and increased economic returns. This has further enhanced their interest in adopting these technologies. We have come to the realization that cultural change will require our working with producers within their production scenarios.

2. Objectives, Approach, and Evaluation

The objective of this project is to conduct experiment-demonstrations with CRN technologies in vegetable producing areas in California with a wide range of CRN technologies available. Experiment demonstrations will all occur with grower-cooperators and CRN management will be compared to their standard practices. Success will be discerned by data collected, grower interest, and grower implementation. We will compile data on grower participation, interest, and adaptation.
3. Audience

The principal target audience will be vegetable producers in the western United States. However, crop advisors, extension agents, crop consultants, fertilizer retailers and wholesalers, and environmental regulators will derive information from this project.

C. Justification

1. Problem

Intensive vegetable production in the southwestern U.S. receives large annual applications of nitrogen (N) fertilizers. Amounts of N applied range from 200 to 400 kg/ha and crop recoveries are generally less than 50% (Mosier et al., 2004). There are numerous possible fates of fertilizer applied N in addition to the desired outcome of crop uptake (Sanchez and Dorege, 1996; Havlin et al., 2005). The urea and ammonium components of the N fertilizer might be lost through ammonia volatilization. The nitrate-N might be lost to leaching with irrigation water below the crop root zone possibly impairing surface and ground water (Sanchez, 2000). Nitrate might also be lost as N\(_2\) and N\(_2\)O gasses via de-nitrification processes affecting air quality and climate. Furthermore, all forms of N might be immobilized into the organic soil fraction by the soil microbial population where availability to the crop is delayed. The global warming potential of N\(_2\)O is 300 times that of CO\(_2\) and N fertilizer is estimated to account for one-third the total greenhouse gas production in agriculture (Strange et al., 2008). One study reported that N fertilization (inorganic or organic) accounted for 75% of the greenhouse gas emissions from agriculture production (including production, application, and nitrous oxide emissions) and after N is accounted for there are no significant differences between conventional, organic, or integrated farming practices (Hiller et al., 2009).

N management in the western United States remains a continuing challenge. Both California and Arizona have mandated Best Management Practices (BMP’s) to varying degrees. These practices generally involve timing, amounts, and placement of N, and irrigation water application. The use of controlled release N (CRN) fertilizer sources is another promising option. The successful implementation of CRN management where appropriate will reduce adverse environmental impacts of fertilizer N and improve profitability in California and the western United States in general.

2. FREP Mission and Research Priorities

This project addresses multiple FREP priorities. We work with a technology known to improve fertilizer use efficiency when used under proper conditions (Managing Agricultural Nitrogen). We demonstrate the use of the technology in real world field production scenarios (Demonstrating Agronomically Sound uses of Fertilizer in the Field Scale). These demonstrations are themselves an effective outreach tool but we will augment them with field days and workshops (Education and Outreach)

3. Impact
We know from a decade of research on University Research farms that controlled release N fertilizers under certain conditions improve yields, provide favorable economic returns to growers, and reduce adverse environmental impacts of N on the environment. Although growers express approval of results at field days at these university research farms, there was no adaptation of these practices. Based on a few preliminary demonstrations we conducted with industry funding in 2013-2014, 50% of the growers we worked with have placed orders for CRN product. It seems that barriers to change are diminished considerably when we work within a grower’s production scenario. Our aim in this FREP proposal is to expand these experiment demonstrations to showcase the positive production, economic, and environmental impacts we already know are possible from controlled studies on research farms. This project team was assembled to have impact in California’s two principal vegetable production areas (the low desert and the central coast).

4. Long Term Solutions

We anticipate that the experiment-demonstration proposed here will enhance and hasten acceptance of these technologies by growers. As adaption of these technologies expands, the impact they have will increase in scale. Furthermore, short term environmental benefits will compound themselves over time into longer term impacts of greater magnitude.

5. Related Research

For over a decade we have been conducting field research with controlled release N fertilizers (CRN). These studies were conducted at University Research Farms with lettuce (*Lactuca sativa*), broccoli (*Brassica oleracea* group Italica), cauliflower (*Brassica oleracea* group Botrytis), carrots (*Daucus carota*), celery (*Apium graveolens*), spinach (*Spinacia oleracea*), onions (*Allium cepa*), tomatoes (*Solanum lycopersicum*), peppers (*Capsicum sp.*), watermelons (*Citrullus lanatus*), and sweet corn (*Zea mays*), using replicated, randomized, complete-block or split-plot treatment designs. A few simplified demonstrations in grower fields were also conducted. A summary of observed responses are shown in Table 1.

Although most observed responses are positive for CRN management, there are a number of possible outcomes when using controlled release N fertilizers. These include: 1. Reduction in yield compared to conventional N fertilizer practices. 2. No response compared to traditional N management practices. 3. A reduction in N fertilizer required for optimum production compared to conventional N fertilizer management 4. Improved yield and quality compared to conventional N fertilizer management and 5. A combination of reduced N fertilizer required for maximum production in addition to improved yield and quality.

Table 1. Summary of responses for various vegetable crops to CRN management over the past decade.

<table>
<thead>
<tr>
<th>Response</th>
<th>Crop</th>
<th>System</th>
<th>Frequency</th>
<th>Soil Texture</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRN=PP&gt;SD</td>
<td>Lettuce</td>
<td>University Experiment</td>
<td>2</td>
<td>Clay</td>
</tr>
<tr>
<td>SD=CRN=PP</td>
<td>Lettuce</td>
<td>University Experiment</td>
<td>4</td>
<td>Clay loam</td>
</tr>
<tr>
<td>WR=CRN=PP</td>
<td>Cauliflower</td>
<td>University Experiment</td>
<td>3</td>
<td>Clay loam</td>
</tr>
<tr>
<td>WR=CRN=PP</td>
<td>Broccoli</td>
<td>University Experiment</td>
<td>3</td>
<td>Clay loam</td>
</tr>
<tr>
<td>SD=CRN=PP</td>
<td>Lettuce</td>
<td>University Experiment</td>
<td>1</td>
<td>Clay loam</td>
</tr>
<tr>
<td>-----------</td>
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</tr>
<tr>
<td>SD=CRN=PP</td>
<td>Broccoli</td>
<td>University Experiment</td>
<td>2</td>
<td>Loamy sand</td>
</tr>
<tr>
<td>CRN=SD=PP</td>
<td>Lettuce</td>
<td>University Experiment</td>
<td>1</td>
<td>Clay loam</td>
</tr>
<tr>
<td>CRN=SD=PP</td>
<td>Lettuce</td>
<td>University Experiment</td>
<td>4</td>
<td>Loamy sand</td>
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<td>Lettuce</td>
<td>University Experiment</td>
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<td>Cauliflower</td>
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<td>Loamy sand</td>
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<tr>
<td>CRN=SD</td>
<td>Cauliflower</td>
<td>University Experiment</td>
<td>1</td>
<td>Clay loam</td>
</tr>
<tr>
<td>CRN=SD</td>
<td>Carrot</td>
<td>University Experiment</td>
<td>1</td>
<td>Loam</td>
</tr>
<tr>
<td>CRN=SD</td>
<td>Sweet corn</td>
<td>University Experiment</td>
<td>1</td>
<td>Loam</td>
</tr>
<tr>
<td>CRN=SD</td>
<td>Tomato</td>
<td>University Experiment</td>
<td>1</td>
<td>Loamy Sand</td>
</tr>
<tr>
<td>CRN=SD</td>
<td>Watermelon</td>
<td>University Experiment</td>
<td>3</td>
<td>Loam and</td>
</tr>
<tr>
<td>GSP&gt;CRN</td>
<td>Lettuce</td>
<td>Grower Demonstration</td>
<td>1</td>
<td>Clay loam</td>
</tr>
<tr>
<td>CRN=GSP</td>
<td>Broccoli</td>
<td>Grower Demonstration</td>
<td>2</td>
<td>Clay loam</td>
</tr>
<tr>
<td>CRN=GSP</td>
<td>Celery</td>
<td>Grower Demonstration</td>
<td>1</td>
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<tr>
<td>CRN=GSP</td>
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<td>Grower Demonstration</td>
<td>1</td>
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<tr>
<td>CRN=GSP</td>
<td>Spinach</td>
<td>Grower Demonstration</td>
<td>1</td>
<td>Loamy sand</td>
</tr>
<tr>
<td>CRN=GSP</td>
<td>Lettuce</td>
<td>Grower Demonstration</td>
<td>1</td>
<td>Loamy sand</td>
</tr>
</tbody>
</table>

PP=Preplant conventional; SD=sidedress conventional; WR=water run conventional

Controlled release N fertilizer can sometimes reduce yields compared to conventional practices when product release rates are mismatched with crop demand (Figure 1) or when a rapid release rate associated with high soil temperatures, in combination with less-than-optimum placement, results in osmotic stress or ammonia toxicity to the crop (Table 2). We will address the occurrence of these situations and management practices to avoid them later in our discussion.
Table 2. Marketable yield of iceberg lettuce to N management practice in a grower field in Yuma. In this situation the CRN product released N very rapidly due to warmer-than-expected soil temperatures in the fall of 2012. In combination with shallow placement, there was a stand reduction that ultimately resulted in lower marketable yields.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Practice</th>
<th>Marketable Yield (MT/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GSP</td>
<td>55.8</td>
</tr>
<tr>
<td>2</td>
<td>CRN#1</td>
<td>47.9</td>
</tr>
<tr>
<td>3</td>
<td>CRN#2</td>
<td>45.2</td>
</tr>
<tr>
<td>LSD</td>
<td></td>
<td>4.9</td>
</tr>
</tbody>
</table>

The grower standard practice (treatment 1) was an N program incidental N in MAP, and sidedess and water run UAN32 for total N program of 260 lbs N/A. Treatment 2 was N in MAP, 112 lbs N/A as ESN pre-plant, and reduced sidedress water and run program (250 lbs N/A total). Treatment 3 was N in MAP, 188 lbs N/A as ESN pre-plant, and one water run (239 lbs N/A total).

Another possible outcome to CRN management is production responses similar to conventional N management (Figure 2). This occurs where N timing by conventional management is adequate and N leaching and denitrification losses are minimal. This is the situation we sometimes observe on heavier textured soils and where irrigation management is generally good. The only advantage of a controlled release program under this situation is reduced tractor cost for side dressing or top dressing N, and this cost savings infrequently covers the higher costs of CRN.

The third, fourth, and fifth scenarios, where CRN management produces definitive positive responses, occur where leaching and denitrification losses of N are potentially large. The frequency for positive responses increase as soil textures become increasingly coarse, and irrigation management more problematic. In some situations we observe primarily a clear reduction in the amount of N required for maximum yield (Figure 3) and in others we get a reduction in the N required for yield and clear production benefits (Figure 4 and Table 3). When using conventional side-dress fertilizer programs, we have shown on heavy textured soils that two side-dress applications are often adequate because N leaching losses are small when irrigation management is near optimum (Sanchez and Doerge,
However, as soils become increasingly coarse, the number of split applications needed for optimum management increases, up to eight or more, and here we encounter logistical limitations as side-dress applications only occur after cultivations and most vegetable crops are seldom cultivated more than twice. These problems are compounded for shallow-rooted crops such as spinach, lettuce, celery, and onion which extract N primarily from the upper foot of soil.

Drip (and to some extent sprinkler) irrigated production systems present additional opportunities for split application. In arid climates where drip irrigation is utilized and where essentially all crop water requirement is applied through irrigation, the best designed controlled release N can only produce results equal to well managed fertigation program. However, in situations where rainfall can be substantial and cause leaching, and where fertigation is mismanaged or non-uniform, controlled release programs can result in positive benefits compared to fertigation. Finally, in many situations the most economical way to use CRN products is in combination with a program using standard, soluble N fertilizers (Figure 5). In some cases CRN conserves N
during the intervals between split applications of soluble fertilizer, and allows for greater production and more economical returns. In other cases there is some benefit to backing up a CRN program with a small water run N application near the end of the season.

As noted above, CRN performs poorly when N release rates are mismatched with crop demand. Studies were conducted to develop a method to predict N release rates from CRN products and develop a tool to recommend specific products for specific crop planting and harvest windows. Initial studies involved weighing CRN products into nylon mesh bags and burying the bags 7 to 8 cm into the soil within vegetable production fields. Soil temperature measuring data loggers were installed in each site and the mesh bags were excavated approximately every 7 to 14 days after burial. Replicate samples pulled at each recovery date were digested, and total N was determined in the laboratory. An example of the data collected is shown in Figure 6 for ESN in fall 2011. An example of predicted release rate to temperature summation using a base of 5C is shown in Figure 7.

The 5C base was initially used based on release rates measured under varying temperatures in the growth chamber. More, recently we have abandoned using the 5C base as a result of observations that some release occurs below 5C.

We also have developed a laboratory test that is more user friendly than the buried bag field approach. For each CRN product, release curves in water were analyzed at four temperatures. N release was estimated through non-destructive monitoring of changes in refractive index over time of an aqueous solution containing 10 g product in 100 mL of water (refractive index method) (Figure 8). The expression \( DD = D(T) \times T^\gamma \) accurately relates percent release to DD. A graphical procedure is used to determine \( \gamma \) at each temperature. Curve fitting of \( %R \) vs \( DD \) provides an expression or equation by which to calculate \( %R \) from temperature data. DD accumulated for a given time period following product application to the soil is fed into the release equation to calculate percent release.

![Figure 6. Release of N from ESN in fall 2011.](image-url)
Figure 7. Relationship between temperature summation (DD5) and release of ESN ($y=0.263+0.000507x$; $R^2=0.89$)

Figure 8. Measured release rates from Duration under laboratory conditions. These data are used with temperature summations for alternative crop planting and harvest windows based on long term data bases of weather and crop growing periods to match product to crop growing period with products. Thus, we now have the tools for matching product release rates with anticipated crop demand. We have compiled a data base for ESN and several Duration and Polyon CRN products. We will use these tools to match up other viable CRN products.
The final issue we wish to address in this section is our experience based on crop damage due to high release rates at high soil temperatures. In the desert this sometimes occurs in the fall plantings, as late as October 15. It is not possible to simply use a product with a thicker coating or a slower release rate because N release will be not be sufficient most of the late fall early winter growing period. We have observed the risk can be minimized by band placement away from seeds or transplant roots. If the fertilizer is banded 5 cm below and 5 cm to the side of the plant line, damage due to osmotic stress or ammonia toxicity is minimized (Figure 9). Because N moves to the plant roots by mass flow, there does not seem to be an advantage to band placement in other planting windows (Figs. 2 and 4). In these situations, fertilizer can be broadcast and disked on flat ground or applied in broadcast over rows and power mulched into beds (Figure 10).

Figure 9. Banding CRN for demonstrations in 2013-2014.

Figure 10. Broadcast spreading over beds and subsequent power-mulching.

6. Contribution to knowledge base

Although we have conducted a decade of research with controlled release fertilizers on University Research farms, and our principal objective of this project is to work in producer fields to facilitate technology transfer, we have encountered new challenges as we worked under more diverse scenarios in production fields in 2013-2014. Soil types, irrigation practices, application methods, and tillage systems all interact to impact the performance of controlled
release fertilizers. Continued work in diverse conditions will enhance our existing data base and identify potential outlier situations, better define boundary conditions, and possibly identify new opportunities.

7. Grower Use

Our primary objective in conducting these experiment-demonstrations in grower fields is to facilitate technology transfer. Working within the grower’s culture hastens technology transfer. The incentive for growers using these technologies will be enhanced yield and quality, simplified and less costly fertilizer applications, and lower fertilizer costs. In a subset of the regions we will work, impending environmental regulations will also provide incentives for adaptation.

D. Objectives

The objective of this project is to conduct experiment-demonstrations with controlled release N fertilizers in California and southwestern Arizona with a wide range of technologies available.

E. Work Plans and Methods

1. Work Plan

All experiment-demonstrations will be conducted in grower fields with producer cooperators. These will be conducted in Imperial County (Imperial Valley and Bard (also across the river in Yuma), Riverside County (Coachella Valley), and Monterey County (Salinas Valley). The products used will be based on our existing and growing data base on N release rates reconciled with historical weather data bases and specific planting and harvest windows within the sub-regions. We already have release rates for ESN (AAT), Duration (AAT), Polyon (AAT), and GalXe (JR Simplot). However, we will model release rates for more commercial CRN products available.

2. Methods

**Task 1 (January 2015 to March 2015)**
Release rates for a range of products from a number of manufactures will be determined using the models we developed and described above. We will use the laboratory protocol we recently developed for CRN products. Products will be incubated in water at multiple temperatures and data will be processed as shown for figure 8 above. Where multiple products are found to have similar release rates for given planting windows, we will make final selections based on product costs aiming for maximum economic returns. The specific manufacturer and retailer will not affect our final selections.

**Task 2 (January 2015 to September 2015)**
A few experiment-demonstrations will be implemented in the Bard Valley and the Coachella Valley in spring 2015. Because funding would not begin until January 1, 2015, planting windows for many crops would have passed for the desert. Therefore, in the spring of 2015 we will focus on spinach, sweet corn, and watermelons in the desert. However, planting in Salinas
will be beginning and in this area we will focus on spinach, lettuce (all types including spring mix), broccoli, and cauliflower.

The N rates selected for any particular crop soil combination will be based on a data we have generated in small replicated plot experiments on University research centers and customized for each demonstration based on the grower practices. In small plot research, we typically observed optimal N fertilizer rates by CRN at 70% or less of those used in conventional split N application programs. In all studies we will compare optimal CRN practices to grower standard practices. Methods of application will be based on our experience but reconciled with equipment available and the growers existing practices. This project will not endorse any particular proprietary product but will include all products available to us that meet the aforementioned N release criteria.

Initially, treatments in these on-farm demonstrations will include the grower standard N management practice, the grower standard practice where N rates are reduced by 25%, and CRN management combinations where N programs are reduced by 25 and 40%. The various N fertilizer practices will be stripped in grower-cooperator fields. Soil will be collected pre-plant in all cooperator fields. Further, soil and tissue samples will be collected in-season to determine N nutritional status among treatments. Final marketable yield will be determined at maturity. In all studies we will collect data on soil N, midrib or petiole N, above-ground N accumulation, and marketable yield. On a subset of these sites we will estimate N leaching using resin samplers.

Task 2a. (October 2015 to March 2016)
We will implement field experiment-demonstrations in the desert (Coachella, Imperial, Yuma, Bard) with lettuce, broccoli, and cauliflower. We may modify rates and methods of application based on what we learned in Task 2. Overall, most methods will be similar to task 2.

Task 2b. (February 2016 to September 2016).
We will do some work with warm season vegetables in the desert (sweet corn, peppers, melons). In Salinas we will expand evaluations into celery and carrot. We may modify rates and methods of application based on what we learned in Task 2 and 2a. Overall, most methods will be similar to Task 2 and 2a.

Task 2c. (October 2016 to March 2017)
We will implement field experiment-demonstrations in the desert with celery, carrot, and onion. We may modify rates and methods of application based on what we learned in Task 2, 2a, and 2b. Overall, most methods will be similar to Task 2a, 2b, and 2c.

Task 2d (February to September 2017)
This final season in the central coast we will focus on filling data and outreach gaps. We will focus on crops where we need more demonstration. Overall, most methods will be similar to Tasks 2, 2a, 2b, and 2c.
Task 2e (September to December 2017)
This final fall season in the desert we will also fill in data and outreach gaps but limit our
 demonstrations to crops that will be harvested before December 31. Methods will be similar as
above.

3, Experimental sites

All experimental sites will be in the low desert and in the central coast with grower cooperators.

F. Project Management, Evaluation and Outreach

1. Management

Dr. Charles Sanchez will serve as overall project coordinator. He will develop the release
models for all CRN products available to the investigators and match up these products with
specific crop planting windows in all regions where experiment-demonstrations will be
implemented. Based on these release data and augmented by economic considerations (product
cost), the PIs will select products to test in the individual field experiment-demonstrations. The
selection of products to be tested will be based on matching N release to crop N demand and on
economic considerations regardless of manufacturer.

Dr. Sanchez will also personally implement, oversee, and collect data from all experiment-
demonstration in the lower Colorado River region (Yuma, AZ and Imperial County CA) and in
the Coachella Valley, CA. Richard Smith will implement, oversee, and collect data from all
experiment-demonstrations in Monterey County, CA (Salinas Valley and adjacent areas). Dr.
Sanchez will occasionally visit a subset of the sites managed by his Co-PIs. Dr. Sanchez will
collect all data and summaries from other Co-PI to compose initial drafts of all FREP required
reporting. However, the Co-PIs will be given the opportunity to review and edit all FREP
reports before submission. The PIs will conduct extension outreach programs in their respective
areas of responsibility. The PIs will rotate attending the FREP annual conference.

2. Evaluation

Economic returns to these technologies will be evaluated in all experiment-demonstrations. We
will also compile data on cooperator adaptation of these technologies. These data will include
whether or not they adapt these technologies and to what degree (proportion of their total acreage
for specific crops).

3. Outreach

The demonstrations are outreach in themselves in that they take technologies directly to the
growers. We will compile data on growers impacted relative to total acreage of the crop in
question. On a subset of these we will hold mini-field days in the area. Growers are sometimes
sensitive about who comes on their farm so in some cases these mini-field days may be limited
to other growers for a specific shipper. In other cases, it may expand to a larger audience.
addition to these field days, all data will be shared at traditional extension venues. The following a list of planned activities that will be modified as opportunities arise.

**Planned Outreach activities**

- **March 2015**: Presentation at Southwest Agricultural Conference (Yuma, AZ)
- **August 2015**: Presentation at Fall Vegetable Workshop (Yuma, AZ)
- **November 2015**: Presentation at Winter Desert Workshop (Holtville, CA)
- **January 2016**: Presentation at grower meeting in Coachella Valley (Indio, CA)
- **February 2016**: Presentation at Irrigation and Nutrient management meeting in Salinas
- **March 2016**: Presentation at Southwest Agricultural Conference (Yuma AZ)
- **May 2016**: Presentation at Desert Agricultural Conference (Casa Grande, AZ))
- **November 2016**: Presentation at Winter Desert Workshop (Brawley, CA)
- **January 2017**: Presentation at extension meeting in Parker CA.
- **February 2017**: Presentation at Irrigation and Nutrient management meeting in Salinas
- **March 2017**: Presentation at Southwest Agricultural Conference (Yuma AZ)
- **November 2017**: Field day at Desert Agricultural Center in Holtville (Holtville, CA)

Yearly updates of the results will be published in *Monterey County Crop Notes* and the *Central Coast Agricultural Highlights* newsletters (cover Monterey, Santa Cruz, San Benito, Santa Clara, San Luis Obispo and Santa Barbara counties) in 2016, 2017 and 2018 and trade magazines (e.g. *Ag Alert* and *Vegetables West*).

**G. Budget Narrative**

**Salaries**

We have requested 80% the salary of a research technician to help set out plots and process and analyze samples. We budgeted a 3% increase each year.

**Benefits**

The ERE rate is 47.8%.

**Supplies**

This includes reagents, chemicals, and expendables for laboratory release modeling and tissue and soil analysis. These costs are higher in year 1 due to the modeling.

**Travel**

Travel to sites in grower fields in California and Arizona to plant and service experiment-demonstration plots. I will use a University vehicle so I will pay for fuel directly. I also estimate I will need about $700 per air to travel to FREP conference. That includes airfare and lodging.

**Subcontract**

A subset of the work is contracted to UC-Davis (Smith). This includes 23.4% technician in year1 and 29.5% technician in years 2 and 3 for Smith to help with plot demo work. Total wages and ERE in the UC-Davis sub are $17,997 in year 1 and $22,660 in each year 2 and 3.

This sub includes $1,625 each year for analytical work at ANR analytical lab.
This sub includes 10% indirect to UC-Davis for employee expenses as specified by sponsor. The total UC Davis sub is $21,422 in year 1 and $26,551 in years 2 and 3.

Indirect Specified by sponsor at 10% wages and employee related expenses.

**Literature Cited**


