CDFA Fertilizer Research and Education Program
2013 Request for Project Proposals

1. Project Title: Improving N use efficiency of cool season vegetable production systems with broccoli rotations

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4. Supporters
California Leafy Greens Research Board

5. CDFA Requested Funding	Year 1	Year 2	Year 3	Total
	$73,708.00	$73,846.00	$28,104.00	$175,658

6. Agreement Manager: UC Regents Office of Sponsored Research

B. Executive Summary

1. The Problem:Nitrate leaching in vegetable production in the Salinas Valley is a continuing problem that contributes to groundwater contamination and affects the ability of municipalities to access sources of drinking water that meet federal water quality standards. The Agricultural Order issued by the Central Coast Regional Water Quality Control Board (CCRWQCB) in March, 2012 proposed limits to nitrogen (N) fertilization applications for cool season vegetables. Limits on seasonal N applications were tied to the amount of N taken up by the crop, and growers were given three years to achieve a nitrogen balance ratio (N applied: N taken up by the crop) of 1.0 for double cropped vegetable rotations. This provision of the Ag Order has been stayed by court order, but it is clear that fertilizer use in cool season vegetable production will soon come under serious regulation. Strategies to improve N use efficiency such as reducing fertilization rates and improving irrigation application efficiency can help reduce loss of nitrate from leafy green vegetable production systems, but greater understanding of crop N use and uptake is needed to help growers comply with new regulations.

2. Objectives, Approach & Evaluation:The FREP funded a project (11-0558-SA) entitled, "Survey of nitrogen uptake and applied irrigation water in broccoli, cauliflower and cabbage production in the Salinas Valley" examined nitrogen uptake vs applied nitrogen to key cole crops grown in the Salinas Valley. The first year of evaluations has been completed and data for summer-grown broccoli showed that more N was taken up by broccoli than was applied as fertilizer; nitrogen uptake by broccoli averaged 323 lbs N/A while fertilizer applications averaged 181 lbs N/A, resulting in a net uptake over the amount of fertilizer N applied of 141 lbs N/A (Smith et al., 2013). This unexpected result would suggest that broccoli may fill an important role as a rotational crop in the cool season vegetable production system by accumulating leached nitrogen from the lower profile of the soil. Preliminary evaluations of the rooting depth of broccoli indicated that roots can extend down below 30 inches, indicating that broccoli may be able to extract nitrate from deeper in the soil profile than other key cool season vegetables such as lettuce (Jackson, 1995; Cahn and Smith, 2010) and spinach (Heinrich et al., in press) which were found to have the majority of their roots in the top 18-20 inches and top 12-16 inches of soil, respectively. The movement of nitrate from the top foot to the two to three foot depths in the soil profile is not well understood; the quantity of nitrate that exists at these levels is particularly susceptible to further leaching through the vadose zone and down to groundwater resources. Lettuce, spinach and other cool season vegetables are probably not capable of retrieving nitrate at the two to three foot depth in the soil. If broccoli is able to access and utilize nitrate at these deeper levels in the soil, it may be performing an important agronomic function of intercepting nitrate in the subsoil that is at risk to loss by leaching and accumulating the N in its plant biomass.

About 26% of N taken up by summer-grown broccoli is exported from the field in the harvested product. As a result, following harvest, broccoli residues may contain as much as 240 lbs N/A. The N contained in broccoli residue needs to be effectively managed if N use efficiency is to be effectively improved in cool season vegetable systems. The effective utilization of residual soil nitrate has been researched and the nitrate quick test is a key tool to utilize this source of N (Breschini and Hartz 2002; Hartz et al. 2000). However, it is unclear how rapidly broccoli residues mineralize and what proportions of the nitrogen in the residue is made available. This remains,is an area of the broccoli nitrogen cycle that needs further study.

The focus of this proposal will be to understand the role that broccoli may play in scavenging nitrate from deeper in the soil profile, thereby minimizing leaching losses and enhancing N availability for subsequent crops. Other researchers have measured similar levels of N uptake by broccoli (Thompson et al. 2002; and Bakker et al., 2009), but none have explored the potential role that broccoli can play in a cropping system. A nitrate scavenger in the cool season vegetable production system is a critical component to the efficient management of nitrate in crop production systems. Though cover crops could serve to scavenge leached nitrate in cool season vegetable production systems, high land rents have greatly reduced the use of cover crops to less than 5% of the acreage due to high opportunity costs for production of cash crops (Tourte and Klonsky 2011). Therefore, fully understanding the role of broccoli for scavenging nitrate would provide important information on how to best utilize broccoli in improving the nitrogen use efficiency of the cool season vegetable production system.

Current recommendations for evaluating the nitrogen status of the soil to guide fertilization of broccoli include evaluating the top foot of soil to determine residual nitrate available for broccoli. Also, because of its deeper rooting system, the soil nitrate threshold for sufficiency in broccoli may be lower than the 20 ppm NO_3-N value used for lettuce. This project will evaluate sampling to the second foot of soil as a tool for better estimating available residual soil nitrate for broccoli growth and determine if a lower soil nitrate threshold is appropriate for broccoli. In addition, understanding the rate of mineralization of incorporated broccoli residue is critical for efficient use of the biomass N in broccoli at the end of the cropping cycle. We will conduct mineralization studies of broccoli residue to better determine the N contribution to subsequent vegetable crops.

Admittedly this project proposes a concept that is distinct and we therefore propose a thorough educational effort, including a field demonstration and field day to explain and discuss the concepts contained in this research and incorporation of findings into the algorithms use in the online CropManage tool. In short, this proposal will provide new information on the levels of nitrate deeper in the soil of the cool season production system and a practical method of bringing it back to the soil surface where it can be utilized for further crop growth.

3. Audience: The audiences for this research are growers, consultants and others involved in managing cool season vegetable production in California. Ultimately municipalities that draw drinking water from groundwater resources benefit from improved nitrogen management.

C. Justification

1. The Problem: The cool season production areas of the Salinas and surrounding valleys, as well as the Santa Maria valley are notable for the intensity of the production and the constraints faced by the growers. Land rents and production costs are high which put pressure on the growers to intensify their rotations (Tourte and Smith 2010). As a result, two to three crops are routinely produced each year in each field. Crops such as lettuce, spinach, celery and cole crops are the dominant crops and all require robust applications of N to make it possible to produce the yield and quality demanded by the highly competitive market. For instance, on average, lettuce uptake is about 120-140 lbs N/A. Fertilizer applications to lettuce vary widely, but often exceed uptake of the crop by moderate to high levels (Bottoms et al 2012); in addition, the amount of lettuce biomass N that remains in the field following harvest can be 55-65% (Smith and Cahn, 2011). As a result, substantial amounts of residual soil N may remain in the soil following the production of a lettuce crop.

Water quality regulations implemented by the CCWQCB are challenging growers to evaluate and implement practices to improve the efficiency of applied nitrogen to vegetable crops. All of the cool season vegetables are listed as "at risk" crops and growers producing more than 1000 acres of these crops are placed into Tier 3 compliance category that has the strictest regulations concerning the movement of nitrates to surface and ground waters. These regulations will require growers to implement a certified Irrigation and Nutrient Management Plans (INMP) that justify and document N application rates applied to crops. Under proposed regulations, growers would have three years to achieve an applied nitrogen:plant uptake ratio of 1.0 for double cropped annual rotations.

The regulations have created an urgent need for development and implementation of strategies and practices for growers to make progress in improving nitrogen management and making measureable improvements in water quality. Key practices that can help growers improve nitrogen management include the use of the nitrate quick test to measure and utilize residual soil nitrate, thereby reducing the need for additional fertilizer applications when they are not needed. Improvements in irrigation efficiency are also critical to reducing the movement of nitrate to deeper in the soil profile. There have been many educational efforts to assist growers in these areas and a good deal of progress has been made.

Challenges that remain in the cool season production system include the need for a deep-rooted rotational crop that can scavenge nitrate that has been pushed too deep in the soil profile for crops like lettuce and spinach to retrieve. The shallow rooted nature of lettuce and spinach make effective nitrogen management much more difficult to achieve. Cover crops such as cereal rye, oats and other cereals could scavenge a significant proportion of nitrate that is leached past the root zone of lettuce (Jackson et al 1993; Jackson 2000), but the use of winter cover crops is limited due to the added production costs and the lost opportunity to produce a cash crop while the cover crop is being produced (Tourte and Klonsky 2011).

Observations made in the FREP funded a project (11-0558-SA) entitled, "Survey of nitrogen uptake and applied irrigation water in broccoli, cauliflower and cabbage production in the Salinas Valley" indicated that summer-grown broccoli routinely took up more nitrogen than was applied, indicating that it scavenged nitrate from the soil (Smith et al 2013). The ability of broccoli to take up large quantities of soil nitrate during the spring through fall production slot is due to its large biomass production, high nitrogen content and apparent ability to root deeply. This unexpected observation may indicate that broccoli is able to capture nitrate that may be at risk to moving into the vadose zone and to ground water resources. If broccoli utilizes nitrate at deeper soil levels, it may be performing a critical function of intercepting nitrate in the subsoil that would be potentially lost by leaching and thereby providing an important tool to tangibly reduce nitrate leaching to groundwater.

Understanding the depths to which broccoli can access nitrogen from the soil will also provide information on how to better manage nitrogen fertilization of broccoli. Soil sampling to two feet deep may be necessary to provide a better understanding of the need to fertilizer applications for broccoli. In addition, following harvest, the amount of N in the broccoli biomass incorporated into the soil was as high as 240 lbs. The rate and quantity of N mineralization from broccoli residues has not been thoroughly studied, but given the high nitrogen content of the residues, it is likely that broccoli residues can mineralize significant quantities of nitrate for subsequent crop growth.

Broccoli is grown on 52,694 acres in the Salinas and 27,248 acres in the Santa Maria valleys (Source: Ag Commissioners reports) valleys. The acreage is high because broccoli is a key rotational crop for lettuce on the Central Coast in part because it helps to break the cycle of key soilborne diseases (Subbarao, 1998). If its role as a nitrate scavenger is born out, it will provide further evidence of its roleas a rotational crop; it will be important to understand what role it can play in helping to reduce nitrate leaching in the cool season vegetable system.

2. FREP Mission and Research Priorities: This proposal addresses FREP goals by providing new information on the ability of broccoli to retrieve N deeper in the soil profile and ways to effectively utilize the scavenged N. The project addresses the following FREP goals: 1 Crop Nutrient Requirements; 2 Fertilization Practices; Fertilizer and Water Interactions; and 7 Education. By providing information on the ability of broccoli to take up N left behind by other crops in the rotation, it will help improve N cycling and utilization in cool season vegetable production.

Impacts: Given the extensive use of broccoli as a rotational crop, increasing our understanding of the impact that it is having on cycling and improving nitrogen use efficiency in the cool season vegetable system can help us make tangible improvements in reducing nitrate leaching losses to groundwater. The information developed in this project will also help improve the CropManage online tool, originally developed for lettuce through FREP funding, for managing nitrogen in broccoli/lettuce rotations.

4. Long-term solution: This project will provide key information that will allow growers to continue to make progress towards applying N more efficiently while reducing nitrate loading to ground and surface waters. This research takes advantage of the strengths of a standard rotation in the cool season cropping system; this strategy is sound because it can facilitate improvements in water quality without asking the grower to make a huge change in their behavior. If we can learn better how to tweak the system, it may provide great adoption of the beneficial practice and facilitate tangible progress on water quality issues.

5. Related Research: This line of research is rather unique. Other researchers have observed similar uptake rates of N by broccoli, but have not suggested its use as a scavenger of N in a production system (Thompson et al., 2002; Bakker et al., 2009). In addition, studies have been conducted on the impact of nitrate leaching with cover crops (Jackson, 2000; Jackson et al.,1993). However, no studies have specifically looked at the use of cash crop as a nitrate scavenger. Numerous studies have been done evaluating better utilization of residual soil nitrate, but few studies have evaluated mineralization of nitrate from broccoli residue. Studies have been conducted on optimal fertilization rates for broccoli (Sanchez et al., 1996), but no studies have examined the role of deeper soil sampling to evaluate the amount of residual soil nitrogen to provide for the N needs of broccoli. When using the soil nitrate quick test (SNQT) for guiding fertilization in broccoli, it is also unclear as to what threshold of soil nitrate would indicate a level of sufficiency. Deeper soil samples may be needed when using the SNQT for broccoli than for shallower rooted crop such as lettuce.

6. Contribution to knowledge base: This project will provide insight into difficult-to-understand aspects of cool season vegetable production: the ability of broccoli to access and utilize nitrate from the 2nd and 3rd foot depth in the soil. In addition, once this nitrate is accessed and brought to the soil surface we will measure the rate and quantity of N released from the crop residue. This will provide a multidimensional approach to the fate of nitrogen in the cool season production system and an approach for making use of this retrieved N for its intended use – crop production.

7. Grower use: Growers on the Central Coast are under pressure to improve nitrogen use efficiency to all crops. Given the pressures from municipalities to provide drinking water that meets the water quality standard of 10 ppm NO_3-N, it is critical the growers do their part to improve nitrogen use efficiency as much as possible. Having insight on how to effectively utilize broccoli as a nitrogen scavenger provides a unique and useful tool to achieve meaningful reductions in nitrate leaching.

D. Objectives

1. Determine the effective rooting depth of broccoli for removing residual N from the soil profile though direct evaluation of rooting pattern and replicated field trials

2. Adapt soil nitrate quick test for broccoli to guide N fertilizer applications by evaluating factors including soil sample depth, threshold of soil nitrate sufficiency, and crop stage.
3. Conduct commercial field trials evaluating the efficiency that broccoli can remove residual nitrate from the soil following a lettuce crop under normal production practices.
4. Examine the mineralization rate and quantity of nitrate mineralized from broccoli residue to assist its utilization by subsequent crops
5. Conduct an outreach program to growers and consultants on the results of the study and how to utilize the nitrogen scavenging attributes of broccoli to improve nitrogen utilization in the cool season vegetable production system

E. Workplan and Methods

Objective 1: Trials will be conducted at the USDA Spence facility in year on and two of the project to determine the efficiency of broccoli in scavenging N from the lower soil profile. At the beginning of the trial, soil nitrate content of the soil profile of the field will be brought to a low NO_3-N status by growing a winter cereal cover crop and harvesting and removing the cover crop biomass from the site.

Treatments will consist of a control (low N), a grower standard N regime, and 3 low N + simulated residual soil N treatments (applied at three depths). Treatments will be replicated 4 times in a randomized complete block design and plots will measure 100 ft in length x 4, 40-inch wide beds. Drip tape will be injected into the beds of the three residual N treatments at depths of 12, 24 or36 inches before bed shaping, and serve as a means to apply N to the lower profile to simulate accumulated nitrate deeper in the soil profile. We confirmed that a piece of equipment is available to inject drip tape to a depth of 3 feet in the soil (Jim Muscio, AgriFrame Fabrication, Gonzales, CA). Broccoli will be germinated with sprinklers and grown with a moderate amount of N applied at planting (70 lbs N/acre) to establish the crop. After bed cultivation at 30 days following seeding, surface drip irrigation system will be installed onall treatments. At approximately 30 days after seeding, the three treatments with the buried drip tape will receive 150 lbs N/acre in the form of nitrate ($Ca(NO_3)_2$). These 3 treatments as well as the control will receive no additional N from the surface drip system; the grower standard treatment will receive 2 N fertigations of 75 lbs N/acre each through the surface drip system.

Table 1. N fertilizer treatments

No.	Treatment	Preplant N/A	30 days after planting N/A	Total
1	Control	70	0	70
2	Standard (surface applied)	70	150[1]	220
3	Simulated residual 12" depth	70	150[2]	220
4	Simulated residual 24" depth	70	150[2]	220
5	Simulated residual 36" depth	70	150[2]	220

1 – grower standard will receive the 150 lbs N/A as two 75 lb N/A applications: 30 days after planting and 14 days later through the surface drip system; 2 – simulated residual nitrate-nitrogen will be applied at the depths indicated.

Objective 1&2: Soil mineral N will be measured at one foot increments to a depth of three feet will be evaluated three times during the crop cycle; crop biomass, biomass N and petiole nitrate will also be measured three times during the crop cycle and marketable yield will be measured at crop maturity. Broccoli N uptake from the various depths of application will be compared to theunfertilized control and grower standard fertilizer treatment. An evaluation of soil nitrate levels to 3 feet deep will be conducted at the end of the crop cycle. An evaluation of the soil nitrate levels in the top two feet will be compared with the standard one foot evaluation to determine the efficacy of sampling to two feet to determine the utility of deeper soil sampling for assessing the ability of residual soil N to supply the N needs of broccoli.

Nitrogen use efficiency (NUE) will be calculated for each treatment:

$$\text{NUE (\%)} = \text{N in crop at harvest}*100/\text{N applied}$$

Nitrogen recovery efficiency (NRE) of each residual N treatment (Trt # 3,4,5) will be calculated by comparing the uptake of N at harvest to the total amount of residual N applied:

$$\text{NRE (\%)} = [(\text{BiomassN}_x - \text{BiomassN}_0)/\text{residual N}_x]\times 100$$

Where BiomassN_x is the N (lb/acre) in the crop biomass of treatment x, BiomassN_0 is the N in the biomass of the control N treatment (70 lbs N/acre added), and residual N_x is the N applied to the crop through simulated residual NO3-Ntreatment (150 lbs N/acre).

Objective 3:To evaluate the ability of broccoli to utilize residual soil nitrate under commercial crop rotations, a survey of five commercial broccoli fields in the Salinas Valley will be conducted in each of the two years of the project, 2014-2015. Survey fields will include broccoli fields produced following a prior crop of lettuce produced during the same production season. Immediately after harvest of the prior lettuce crop, we will evaluate total N in the residual biomass and soil nitrate to a 3-foot depth to establish the baseline for the evaluations. The survey will include grower standard fertilizer application and plots with no additional N applied; there will be four replications of the grower standard and untreated control strips in each field. Total irrigation water applied to the field will be evaluated to establish the degree of leaching in each field. Soil nitrate will be monitored at one foot increments to two feet four times during the crop cycle; crop biomass, biomass N and petiole nitrate will also be evaluated four times during the cropping cycle (including harvest); the soil nitrate evaluations will provide additional data on two foot soil sampling to better further assess deep soil sampling as a tool to assess the ability of the soil to provide N for optimal broccoli growth. At harvest, soil will be sampled at one-foot increments to three feet deep in each of the treatments to assess the removal of N by broccoli from the soil profile.

Objective 4:Broccoli N mineralization dynamics will be documented in controlled incubations and in-field assays. These data will provide information to assist the CropManage web based irrigation and nutrient management tool better model the nitrogen provided by broccoli residue. Controlled incubations will be conducted on two distinct soil types in each year, utilizing crop residues from commercial broccoli production fields. Net N mineralization will be determined after 2, 4 and 8 weeks of incubation at 25 °C (simulating Salinas Valley soil temperatures between spring and summer crops) and at 2, 4, and 8 weeks at 15 °C (simulating over-winter temperature). To get a field measurement of the quantity of N put in play by broccoli residue, all above-ground broccoli residue will be removed from plots before residue incorporation, and the mineral N profile after the fallow period (whether that is 4 weeks in the summer, or 12 weeks in the winter) will be compared with plots in which residue was incorporated. The contribution of N supplied by broccoli can be calculated as the difference in soil profile mineral N where residue was incorporated compared to where the residue was removed, divided by the amount of net N.

Objective 5: In year three of the project, we will work with a commercial grower to host a field demonstration and field day illustrating the information developed by this project. The demonstration will include a field of broccoli grown following a lettuce crop. Soil samples down to three feet will be collected and the information presented to illustrate the nitrogen levels available for the broccoli crop. Methods for measuring residual soil nitrate for fertilizing broccoli will be discussed, as well as methods for utilizing the residual soil N following incorporation of broccoli residue. All of this information will be presented in the context of overall nitrogen management utilizing the CropManage web based irrigation and nitrogen management tool. The field demonstration will include a demonstration of various levels of fertility and the yield and growth response of the broccoli crop to the treatments.

Workplan Year 1

Task 1: Conduct nitrate uptake by depth evaluations, survey of nitrogen uptake by broccoli following lettuce, and mineralization of broccoli residues

Sub-task 1.1 Conduct nitrate uptake by depth evaluations

1. Install drip tape at 0, 12, 24 and 36 inches in depth applying residual N (150 lbs N/A)in replicated plots at the USDA Spence research station south of Salinas. Treatments include a low N, grower standard and the residual N applied at three depths.
2. Measure soil nitrate to three feet, crop biomass, biomass N and petiole nitrate in all plots three times during the cropping cycle

Sub-task 1.2 survey of nitrogen uptake by broccoli following lettuce

1. Conduct a survey of 5 sites of broccoli planted following lettuce on diverse soil types. Evaluations will include replications of the grower standard and an untreated control

2. Soil nitrate will be monitored at one foot increments to two feet four times during the crop cycle; crop biomass, biomass N and petiole nitrate will also be evaluated four times during the cropping cycle

Sub-task 1.3 mineralization of broccoli residues

1. Conduct soil incubations of broccoli residues on two soil types at 15 and 25 C.
2. Conduct field evaluations of nitrate mineralized from broccoli residue in commercial broccoli production fields

Sub-task 1.4 Analyze all data and prepare mid-term report to FREP

Sub-task 2.5 Reports and extension

1. Provide mid-term report to FREP
2. Report preliminary results to the annual Irrigation and Nutrient Management Meeting and UCCE newsletters

Workplan Year 2

Task 2: Conduct nitrate uptake by depth evaluations, survey of nitrogen uptake by broccoli following lettuce, and mineralization of broccoli residues

Sub-task 2.1 Conduct nitrate uptake by depth evaluations

1. Install drip tape at 0, 12, 24 and 36 inches in depth applying residual N (150 lbs N/A) in replicated plots at the USDA Spence research station south of Salinas. Treatments include a low N, grower standard and the residual N applied at three depths.
2. Measure soil nitrate to three feet, crop biomass, biomass N and petiole nitrate in all plots three times during the cropping cycle

Sub-task 2.2 survey of nitrogen uptake by broccoli following lettuce

1. Conduct a survey of 5 sites of broccoli planted following lettuce on diverse soil types. Evaluations will include replications of the grower standard and an untreated control
2. Soil nitrate will be monitored at one foot increments to two feet four times during the crop cycle; crop biomass, biomass N and petiole nitrate will also be evaluated four times during the cropping cycle

Sub-task 2.3 mineralization of broccoli residues

1. Conduct soil incubations of broccoli residues on two soil types at 15 and 25 C.
2. Conduct field evaluations of nitrate mineralized from broccoli residue in commercial broccoli production fields

Sub-task 2.4 Analyze all data and prepare annual report to FREP

Workplan Year 3

Task 3: Conduct a field demonstration to illustrate the nitrogen management benefits of a broccoli rotation. The demonstration will be conducted with a cooperating grower in a broccoli field following a lettuce rotation and data on the field will be collected and demonstrated to attendees. The results will be discussed in the context of the CropManage web based irrigation and nutrient management program.

Sub-task 3.1 Conduct field demonstration with cooperating grower

1. Take measurements of soil nitrate to three foot depths at early, mid and late in the growth cycle to illustrate levels of soil nitrate following a lettuce crop and the impact of N uptake by broccoli.
2. Demonstrate sampling to two feet as a possible method for assessing N fertilizer needs of broccoli.

Sub-task 3.2 survey of nitrogen uptake by broccoli following lettuce

1. Have field day and invite growers and consultants to view the field demonstration and discuss the use of broccoli as a tool to manage nitrogen in cool season vegetable rotations

Sub-task 3.3 Analyze all data and prepare final-term report to FREP

Sub-task 3.4 Reports and extension

1. Final report to FREP
2. Provide report of final results to the annual Irrigation and Nutrient Management Meeting and annual FREP Conference
3. Publish results in UCCE newsletters, trade journals and prepare peer reviewed manuscript for submission to a scientific journal

F. Project Management, Evaluation, and Outreach

1. Management: Richard Smith and Michael Cahn will be responsible for conducting N application by depth evaluations. Richard Smith will be responsible for survey evaluations in commercial fields and field mineralization sites. Tim Hartz and Richard Smith will be responsible for broccoli residue mineralization evaluations. Richard Smith and Michael Cahn will be responsible for the field demonstration and field day in year three.

2. Evaluation: The project will be conducted over three years and all data will be analyzed statistically and reported as mentioned below. In year three of the project, we will solicit feedback from growers and consultants on their adoption of this information into their N management planning activities through a survey at the planned field day. This information will be of great use in planning how to make the results of this research project more impactful and useful.

3. Outreach: The results of the evaluations will be reported at the annual Irrigation and Nutrient Management meeting in February in Salinas in February of 2014, 2015 and 2016. 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 2014, 2015 and 2016, trade magazines (e.g. *Ag Alert* and *Vegetables West*) and a scientific journal to provide a peer reviewed reference of the findings at the conclusion of the project. A planned field demonstration and field day will be held in year 3 of the project. In addition to these activities, the project team members are asked to give numerous talks each year at local grower meetings, in-house fertilizer company meetings, professional societies and other events where the results of this research project will be discussed and disseminated.

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G. Budget Narrative:
Personnel: We are requesting the equivalent of 55% time for a SRAII for years 1 and 2 and 25% for year 3 to conduct the research trials in Salinas. A summer student assistant is requested to assist on mineralization studies to be carried out at UCD.

Travel: Four trips per year are requested between Davis and Salinas (@$250/trip) for each year.

Equipment: Funds to cover the costs of a flow meter and data logger needed to carryout irrigation water evaluations.

Other expenses: Funds have been requested to cover rent at the USDA Research Station in Salinas in years 1 & 2. Funds to cover the cost of soil and plants sample analysis for nitrate and total N were requested for all there years: 1500 determinations in years 1 & 2 and 800 determinations in year 3.