Proposal to CA Department of Food and Agriculture – FREP PROGRAM – Cover Page

Project Title: Developing Nitrogen Management Strategies to Optimize Grain Yield and Protein Content while Minimizing Leaching Losses in California Wheat

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Supporters: (not providing direct project funding):
Salary and support for Principal Investigators is provided by the University of California. Trials will be conducted at Univ. CA Research and Extension Centers and with grower cooperators. The University subsidizes about 2/3 of full cost of projects at the following Research and Extension Centers which are some of the sites that will be used for the proposed research.

Univ. CA West Side Res. & Extension Ctr
P.O. Box 158, Five Points, CA 93624-0158
(559) 884-2411

Intermountain Res. & Ext. Ctr
2816 Havlina Road, PO Box 850
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Names of supporters: Mr. Geoff Schultz (Penny Newman Grain Co., Fresno, CA); Mr. Nathan Heeringa (Innovative Ag Services, LLC, Hanford, CA); Mr. J.W. Cope (Winema Elevators, Tulelake, CA). letters provided in the appendix to this proposal

Funding Amount Requested from CDFA-FREP program: Three year project support requested as follows: 1st year: $75,000 2nd year: $75,000 3rd year: $75,000

Other Funding: California Wheat Commission; funding = $32,500 per year; contact information: Janice Cooper, President; 1240 Commerce Ave, Suite A, Woodland, CA 95776; (530) 661-1292; FAX: (530) 661-1332; info@californiawheat.org; UC West Side REC and UC Intermountain REC indirect support for projects (see Budget for details)
Agreement Manager’s Contact Information: UC Regents, Sponsored Programs; Plant Sciences Dept. contact: Ms. Carol Mills; Plant Sciences Dept–MS/2, Univ. CA Davis, 1035 Wickson Hall, One Shields Avenue, Univ. CA, Davis, CA 95616; phone: (530) 752-0130; cdmills@ucdavis.edu.
SECTION B: Project Summary

The primary goal of the proposed study is to evaluate the timing and rate of nitrogen (N) fertilizer applications that optimize grain yield and protein content while reducing the potential for N leaching in hard and durum classes of spring wheat grown in California. The study will span three years, employ two experimental approaches, and include multiple varieties and locations across California’s diverse wheat agroecosystems. The work will improve our understanding of the interaction of timing and rate choices in N fertilizer management, wheat productivity, protein content, and soil profile nitrate levels post-harvest resulting from N fertilizer management strategies. This information will be communicated to wheat growers throughout the state and serve to improve the productivity and profitability of this cropping system while reducing environmental impacts of N fertilizer use.

Wheat is an important commodity in California’s agricultural economy, ranging from about 675,000 to almost 800,000 acres grown in recent years. For the hard and durum classes of wheat, which in 2012 comprised over 90 percent of the wheat acreage in California, achieving high protein content can impact the price that growers receive and, thereby, their profitability. For hard red spring wheat a producer receives a premium for grain protein greater than 14% in northern California and 13% in the southern San Joaquin Valley, and a discount for wheat with less than the required grain protein (Orloff et al, 2012; Orloff and Wright, 2011). As a result, growers of the hard and durum wheat classes seek a combination of both high yield and high protein content to maximize the profitability of their crop.

Since high yields are generally accompanied by low protein content, the combination of high yields and high protein content can be biologically difficult to achieve, particularly with some of the newer, higher-yielding varieties. This can serve as a significant incentive for growers to apply high rates of fertilizer N in order to increase their chances of achieving desired grain protein percentages. However, in the past year, applications of nitrogen (N) to cropland in the form of fertilizers or manure have received increased attention due to groundwater nitrate studies by the United States Geologic Survey and UC Davis researchers (Harter et al 2012). These studies report that agricultural applications of N (from both organic and inorganic sources) are largely responsible for the high nitrate levels observed in groundwater in the study areas (Tulare Basin and Salinas Valley), with the implication that N fertilization practices might impact groundwater nitrate in other crops and production regions throughout California.

New research is needed to evaluate a range of N management approaches that could achieve profitable yield and protein levels while reducing the potential for leaching losses for wheat varieties commonly grown in the state. The objectives of the proposed study are to determine the best rate and timing of split N applications to achieve economically viable high yields with desired protein content, while at the same time improving nitrogen use efficiency. Proper nitrogen fertilizer management decisions should depend on: (1) the range of crop nitrogen requirements that can achieve acceptable crop yield and quality; (2) practices that consider and improve utilization of residual as well as applied nitrogen; and (3) practices that limit or prevent nitrogen losses or excess leaching below crop active root zones.
To accomplish these research objectives a series of trials are proposed for widely different production areas, including the intermountain area of northern California, a location in the southern Sacramento Valley area, and two locations in the southern San Joaquin Valley. Representative wheat varieties prominent in each production area will be evaluated to determine their yield and protein content as influenced by the combination of residual soil nitrate-N and the timing and quantity of N fertilizer applications. Varieties to evaluate at each site have yet to be chosen, but the goals will be to select varieties of commercial interest that: (1) represent the wheat classes grown in the respective study areas including durum, hard red and hard white varieties; (2) possess a range of yield potentials.

In addition to measuring the impacts of different combinations of split applications of N fertilizer on wheat yield and grain protein, the study will also quantify the treatment effects on nitrate-N concentrations deep into the soil profile. Soil samples will be collected to a depth of eight feet both pre-plant and post-harvest, with greater analytical emphasis placed on the post-harvest soil sample in order to capture the full-season effects of the nitrogen management treatments. The soil nitrate data will provide an estimate of crop nitrogen utilization and can also be used to assess whether nitrogen management practices at the test locations produced net gains (additions) or net reductions (crop export or leaching) of nitrate-N in different parts of the soil profile. While not suitable for a full nitrogen balance calculation (since the focus is only on soil nitrate-N), these measurements will provide estimates of soil-specific nitrate-N values that are likely to result in leaching losses if rainfall or irrigation water applications produced deep percolation.

Growers and consultants want a better understanding of the degree of risk that they undertake (in terms of yield and grain protein) when they incorporate changes into their management practices. The proposed project will be considered successful if the results improve N management guidelines for wheat by delivering a suite of soil, plant and fertilizer management information that allows growers and consultants to determine likely N fertilizer needs and responses based on yield goals and residual soil nitrate N. The improved N management information that would result from this project will equip California wheat producers and regulatory agencies with essential information on the approaches necessary to produce the most profitable wheat crop while reducing the potential for nitrate leaching that can accompany the over-application of N.

SECTION C: Justification.
The primary production factors that affect protein content in wheat grown for grain are cultivar selection and N fertility management. The struggle to attain both high yields and high protein percentages can have economic consequences for wheat producers, and can be a significant incentive for growers to consider higher fertilizer N applications in order to increase their chances of achieving higher grain protein percentages, which command a premium price when protein levels equal or exceed 13 to 14 percent, depending on the production area and type of wheat (Jones and Olson-Rutz 2012; Brown et al, 2005; Ladha et al, 2005).

An understanding of typical N uptake patterns in wheat development will help to illustrate the potential impacts of differential N fertilizer application rates and timing on yield and protein levels. Nitrogen uptake is slow from emergence through early tillering, then rapidly increases with further tiller development through the stem elongation and leaf expansion phases of growth (Brown et al, 2005). Stem elongation through booting represents the growth stage with the
highest N uptake rates (2.5 to 3 lbs N per day). Meanwhile, flowering through kernel filling and
on to mature grain represent growth stages with more redistribution of plant N and much lower
continued N uptake (Munier et al, 2006; Brown et al, 2005). Available nitrogen in the plant
establishment and vegetative (pre-boot) growth stages can have important influences on yield
potential by affecting: (1) the number of tillers per surface area (often the most important
determinant of yield potential); (2) the number of kernels per head; (3) kernel size; and (4) the
breakdown of prior crop residues by microorganisms that can temporarily tie up plant-available
N. Late-season N levels or supplemental N fertilizer during the flowering through grain filling
stages can still affect yield by increasing kernel size. However, since tiller number and kernel
number per head have already been established at this stage, the potential impact on yield is
diminished.

High total application amounts for fertilizer N do not necessarily guarantee high grain protein
content, since average root zone N levels and plant uptake may have declined by the boot stage
of growth and beyond. Very high early N applications can also be undesirable due to greater
potential for excess vegetative growth and lodging. For this reason, many growers split N
applications, applying a portion pre-plant or during earlier vegetative growth stages, and a
second portion between boot through about 2 weeks post-flower. Relative to applying all the N
pre-plant, split applications boost available N during the grain filling period when grain protein
levels are more likely to be impacted (Jones and Olson-Rutz, 2005; Brown et al, 2005). Some
prior work by Ottman and Thompson, 2006 and Orloff and Wright, 2012 indicates that late-
season (post-boot stage) applications should be in the range of 30-50 pounds of N per acre.
Nonetheless, more work is needed to assess how the response to late-season N application rates
is impacted by yield potential, different classes or cultivars of wheat, and target protein levels.

Yields generally increase while grain protein decreases under conditions with generally non-
limiting soil water availability most of the production season. This occurs because, under
irrigation or in higher rainfall years, the conditions are created for higher grain yields (due to
increases in the number of heads, seeds per head, and seed size). It is often seen that under low
to moderate soil N availability conditions, added nitrogen fertilizer at first improves yield and
may even reduce protein content until available soil N is sufficient to fully support development
of all set seed. In terms of the impacts on crop growth, yield and protein content, the following
general viewpoints exist in wheat production: (1) available N in the earlier wheat growth stages
(pre-boot) is important in determining yield potential; (2) late-season (reproductive growth stage)
N levels are more important in affecting grain protein levels; and (3) late-season N can come
from applied fertilizer N or from redistribution within the plants. Research is required to better
understand these processes and the availability of N (from residual, mineralized and applied N)
and their effects on yield and protein content as well as how they interact across diverse
environments and among key commercial varieties.

Past research projects have estimated that the amount of total available N required for favorable
yields and protein ranges for hard red spring wheat are at least 1.6 lbs of total available N per
bushel at lower yield levels to over 2.0 lbs total available N per bushel (or about 3 lbs N per 100
lbs of grain). In good production years, grain yields in CA can often be in the range of 3.5 to
nearly 5 tons/acre. Research conducted in the 1980’s by University of California researchers to
improve grain protein focused primarily on moderate yielding / higher protein wheats such as
Yecora Rojo (Wright et al. 2008, Munier 2006). Newer varieties can often yield about a ton/acre higher than varieties such as Yecora Rojo, but most are lower in protein. Late-season N has been shown to improve protein but the levels needed to consistently achieve higher protein and yield combinations are not well established for most areas of the state. Research is needed to evaluate the effectiveness of late-season N application to improve the protein content of a range of varieties with different yield and N accumulation characteristics. Wheat N studies conducted in 2012 by Orloff, Wright, and Hutlmacher were consistent with earlier studies in that they demonstrated that varieties differed in N uptake and yield potential.

Traditionally, most growers apply at least two thirds or more of the total seasonal N preplant while some growers may even apply the entire amount preplant. There are sound practical reasons for this approach. Growers can oftentimes apply less expensive sources of N preplant and logistically it may be easier to apply N preplant than during the growing season. However, high preplant applications of N are more susceptible to leaching from heavy rainfall or irrigation and it has been shown that preplant applications alone to not provide sufficient N late in the growing season to achieve desired protein levels to avoid price penalties (Orloff and Wright, 2011 and 2012). Sometimes growers over-apply N to achieve both yield and protein goals in fewer applications, but this can lead to inefficient fertilizer use and reduced profitability, and could be the cause of unwanted environmental consequences such as possible nitrate leaching. Currently, there are issues concerning nitrate leaching in groundwater, especially in the southern San Joaquin Valley, but eventually these concerns may be considered in other wheat production areas in the state, bringing the impact of this research to the statewide level.

One approach that could be important in improving N use efficiency is to time N applications to more closely match periods of peak crop uptake in order to meet yield and protein goals. It is important for there to be sufficient N available for crop needs at critical growth stages without applying excess nitrogen. Applying more of the N later in the season to better match crop demand may also increase soil N late in the season and the amount of N available in the plant to be remobilized to enhance grain protein. Applications should also be adjusted for yield goals or likely yield potential. The higher the yield, the more applied N would be needed late-season to affect protein percentages. Raising the yield and protein content through the efficient application of N would provide the most advantageous economic impact for California’s growers. An alternative approach to improve N use efficiency and increase protein content could be through the use of N-stabilizer products (such as urease inhibitors) or controlled- and slow-release N fertilizers. The controlled release fertilizers could provide more gradual N release potentially reducing N losses and extending the availability of N to plants. Coated fertilizer products slow the release of the N and N stabilizer products slow the rate of N transformations. These products also have the potential to reduce N volatilization losses.

There are economic incentives for growers to adopt and test improved practices that can result from this study. Wheat production is only economically viable if growers maintain high yields with low-input costs. With the high cost of fertilizers and their application, growers need to maximize N use efficiency while at the same time minimize the number of fertilizer applications. This project will address the issue of input costs of such fertilizer applications while evaluating the trade-off between protein content and yield. By the end of the project, researchers will identify some economically favorable applications, which can then be integrated into the
practices of California’s wheat industry. The information provided by this project should improve the knowledge base for California wheat producers and regulatory agencies, better defining N applications needed to produce the most profitable crop (in terms of yield and quality) while reducing the dangers of N losses associated with possible nitrate leaching. This project is directly linked to the Fertilizer Research and Education Program’s goals of:
(a) Increasing the availability of information about improving efficient use of fertilizers
(b) Better managing agricultural nitrogen fertilizers to minimize nitrate movement below the root zone and improve crop N use efficiency
(c) Develop educational materials or improved guidelines to improve grower and consultant abilities to better match fertilization practices with crop N needed for profitable yields with reduced N losses.

SECTION D: The specific objectives of this research are to:
1. Compare the yield and protein content of the most popular hard red, hard white, and durum spring wheat varieties in response to a range of N application treatments to determine their N-use-efficiency.
2. Evaluate N management schemes utilizing different of rates and split applications of N to determine the effectiveness preplant applications (front loading the system) versus delayed applications to more closely match plant uptake. The effect of these N schemes on yield and grain protein will be quantified in three different wheat production regions in California (southern San Joaquin Valley, Sacramento Valley, and northern intermountain area).
3. Determine the concentration of nitrate-N occurring at different depths in the soil profile at the end of the production season as a function of N rate and application timing for various locations/soil types to estimate nitrate accumulation or movement below the root zone and potential for deep percolation losses.
4. Assess the value of soil nitrogen quick test for in-season soil nitrate-N evaluations in the 0 to 2 foot zone in the soil profile.
5. Measure the effect of N application timing and rate on flag leaf total N to determining if tissue N can be used to indicate the need for a late-season N application to achieve desired grain protein content.
6. Evaluate the effectiveness of different slow release nitrogen sources to determine if the same or greater N response can be achieved with fewer applications.
7. As information is developed in the study, present information to appropriate grower groups, consultants and industry to give opportunities for feedback and to refine concepts of workable changes in N management approaches.

SECTION E: Work Plans and Methods

Task 1. Selection of Research Sites, Finalization of Sampling Schemes, Decide on Sample-handling Protocols (January, 2014 or earlier)
In order to not delay the start of the project by an entire year, if the FREP funding for the project is announced sometime in the fall of 2013, plans will be to use other funds to initiate the project, since this is a winter planted crop (mid-to late fall for SJV and Sac. Valley sites, April 2014 for
the first year in the Intermountain northern CA site). Meetings will be held upon receipt of the grant to develop final protocols for sampling protocols and plans, and discussion of field identification needs. For initial sampling, sample collection materials will be purchased and laboratory methods and grower cooperators will be completed.

**Task 2. Establishment of N Fertilizer Rate and Timing Treatments and collect samples and data.** *(Late fall through Summer, 2013-2014, 2015, 2016)*

Subtask a. select research sites, choose varieties to use
Subtask b. preplant soil sample collection and analysis
Subtask c. planting and establishment of baseline fertilization needs (P, K) and residual nitrate (fall / winter for SJV and So Sacr Valley, April in IREC)
Subtask d. continue with split application treatments during season (begin in May and end in July in IREC; begin in winter and end in May in SJV and So Sacr. Valley)
Subtask e. Harvest for yields, and collect samples for grain quality, protein in June in SJV and So Sacr. Valley sites, September in IREC, all three years.

**Task 3. Tissue Sampling (Spring-SJV & So. Sacr Valley sites, summer at IREC) – all years**

Subtask a. plant tissue / leaf samples collected at research sites across treatments specified in Component One and Two studies.
Subtask b. tissue samples submitted for analyses (late Spring, SJV and Sacr. Valley sites, late summer at IREC site)


Subtask a. Samples will be collected beginning in June at SJV site each year, July in So. Sacr. Valley sites each year, and in September each year at IREC northern CA site.

**Task 5. Laboratory Analysis.** *(fall and winter, 2014, 2015, 2016)*

Subtask a. Grinding of samples followed by nutrient analysis (Nitrate-N, limited ammonium-N, P, K to represent the site conditions) using widely accepted protocols for each parameter
Subtask b. Protein analysis – standard accepted whole grain protein protocols

**Task 6. Data Analysis and Interpretation (each year, various times of year)**

Subtask a. Data entry, quality control of raw data
Subtask b. Statistical analysis, regression analysis, correlations
Subtask c. data summary presentations, interpretation, analysis

**Task 7. Reporting and Outreach.** *(2014, 2015, 2016)*

As project results are developed and properly reported, yearly updates of information and summary materials on the projects will be made available through trade journal and popular press articles where appropriate, through on-line resources available to the California Wheat Commission, Fertilizer Research and Education Program and University of CA Cooperative Extension newsletters where appropriate. In addition, our analyzed and summarized results will be presented in field day meetings as well as industry meetings such as small grain workgroup meetings, Alfalfa and Grains Symposium meetings, and the CA Plant and Soil Conferences.
Methods Used:

Experimental Sites: Field trials will be located in three distinct production areas of the state: (1) the intermountain area of northern CA (Siskiyou County); (2) the southern San Joaquin Valley wheat production area (Kings, Fresno Counties); and (3) a location in the southern Sacramento Valley. Moderate to high yield potential sites will be selected for each of the production areas. In the Intermountain area, experiments are planned at the University of CA Intermountain Research and Extension Center in Tulelake, CA (possibly also in a Scott Valley grower field one of the years); in the San Joaquin Valley two experiment sites are planned at the University of CA West Side Research and Extension Center and in one grower field in Kings or Tulare Co.; and in the Sacramento Valley, one site is planned at a grower field or on the UC Davis University Farm.

Applied Fertilizer Nitrogen Treatments: There will be two component parts of this field study for wheat nitrogen management. The first component will have a more limited number of N application treatment combinations, but will include more varieties in order to evaluate specific cultivar responses to N rate in terms of grain yield and protein content. The second component study will focus on the response of a single cultivar to a much broader range of N fertilizer application rates and timings.

Component Experiments – Fertilizer Used:

a. The nitrogen fertilization treatments shown in the following sections described as COMPONENT ONE and COMPONENT TWO experiments will be established to investigate impacts of different total N applications and timing of split applications on grain yields, grain protein, and impacts on soil nitrate utilization and zones of use and accumulation in the soil profile. Urea will be the fertilizer source used because it is a common fertilizer material and can be applied uniformly in research plots. Although many growers in the Central Valley water-run other sources of N fertilizer, this is not feasible in small plot studies with so many different treatments. However, the results from these studies would still be relevant to water-run N applications.

b. Preplant N applications will be adjusted to account for residual soil nitrate found in preplant soil samples taken at each research site. N application treatments will consider estimates of soil nitrate-N and ammonium-N (if reasonable for how samples have to be handled) in the upper 3 feet in the soil profile.

Component One Experiments: Depending on the test location, a minimum of three and a maximum of five varieties will be selected to receive the fertilizer N application treatments shown below. The number of varieties selected at each site will depend on what the project leader in that region thinks is necessary to represent the range of yield potentials and other varietal/class characteristics that might impact responses to N treatments. Yield and protein content will be measured in all treatments. Post-harvest soil samples for soil nitrate-N evaluation will be taken to a depth of 8 feet from all N treatments in two of the varieties. The treatments shown in the following table have a limited number of N application treatment combinations to focus on cultivar and wheat class differences in responses to N rates and their differences in ability to accumulate N for high grain protein. A flowering stage N application is eliminated in this study to better detect cultivar and wheat class differences in protein. This study will be conducted at one southern San Joaquin Valley research site and at the Intermountain location in northern California.
Table 1. Component One study with 3 to 5 varieties per test location and 5 treatments.

<table>
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<tr>
<th>TREATMENT</th>
<th>Preplant or Early Season Application (lbs N/acre) *</th>
<th>Tilling Application (lbs N/acre)</th>
<th>Boot Growth Stage Application (lbs N/acre)</th>
<th>Flowering Growth Stage Application (lbs N/acre)</th>
<th>Total N Applied (lbs/acre)</th>
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* The above values shown for total N Applied are considered anticipated ranges of preplant N fertilizer applications, but they may be adjusted up or down depending upon preplant soil N analyses in the upper 3 or more feet of soil profile.

Component Two Experiments:
The second component study will evaluate a much broader range of N fertilizer application rates and timings, focusing on how to best meet crop needs and maximize N use efficiency. Yield and protein content will be measured in all treatment combinations. Pre-plant soil samples will be taken in selected plots to characterize the initial conditions, and post-harvest soil samples will be taken from all treatment combinations to a depth of 8 feet from each plot for soil nitrate-N evaluations. For a select group of sample locations at each test site, beginning of season soil samples will also be tested for adequacy of PO4-P and exchangeable-K (for pre-test supplemental fertilizer decisions) and for basic characteristics such as soil organic matter percentage, pH, and EC.

All of the treatment combinations shown in Table 2 in the following section showing Component Two N application treatments will be conducted at all test locations. A few additional N treatments (rate:timing combinations) may be added at each test location when the project leader in the region feels that there are appropriate additional treatments based on cultivar characteristics, yield potential or soil characteristics. Precise rate and timings may vary slightly by location to best simulate grower practices. For example, the tillering stage application may be split into two applications (at tillering and jointing stage) to better simulate water-run applications in areas where that practice predominates with growers.

Table 2. Component Two study with 1 variety per test location and 19 or more N fertilizer application treatments focusing on different combinations of N fertilizer application rates and timings of N applications.
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<tr>
<th>TREATMENT</th>
<th>Preplant or Early Season Application (lbs N/acre) *</th>
<th>Tillering Application (lbs N/acre)</th>
<th>Boot Growth Stage Application (lbs N/acre)</th>
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* * The above values shown for total N Applied are considered anticipated ranges of preplant N fertilizer applications, but they may be adjusted up or down depending upon preplant soil N analyses in the upper 3 or more feet of soil profile.

The above treatment combinations shown for Component Two will be conducted at each test location. As many as three additional N treatments (rate:timing combinations) may be added at each test location when the project leader for that region feels that they are appropriate additions based on cultivar characteristics, yield potential or soil characteristics at the site.

**Controlled-release / Inhibitor Type Fertilizer Source Evaluations** – as part of Component Two trials. We propose to include in this Component Two program an evaluation of a small number of controlled-release N fertilizer and inhibitor-type fertilizer products to determine if they can be used preplant for gradual N release to reduce the need for multiple N applications and to minimize the potential for leaching nitrate below the root zone of the wheat. The total number of additional treatments in these studies may include three different types of controlled-release and inhibitor/stabilizer types of fertilizers, tested only at two timing and fertilizer rate (225 lbs and 300 lbs N/acre) combinations. The timing and rates used with these products will be matched to
other existing rate/timing combination treatments shown in Table 2 (treatments #8 and 10 at the 225 lbs/acre rate and treatments #14 and 16 at the 300 lbs/acre rate) to allow comparisons at the same rate/timings with and without the controlled release or stabilizer materials.

Varieties to be tested: Varietal differences in responses to different timings and amounts of nitrogen applications will be evaluated within each of the nitrogen treatments imposed in this study. In the discussion of Component One and Component Two N treatments already presented in this proposal, the focus of the study is on hard wheat and durum classes of wheat that are recognized as having protein levels responsive to later-season available N. Varieties will be chosen that are appropriate for and suited to the different production areas. Prominent varieties in the Intermountain area are different from the commonly used varieties in the San Joaquin Valley production area. In the Component One studies that include multiple varieties, northern California locations will include three varieties of hard red spring wheat, while in the southern San Joaquin Valley location one hard red spring, one hard white spring, and one durum spring wheat variety will be evaluated.

Plot Size, Layout, Yield and Protein Content Measurements: All treatments utilized (variety by nitrogen treatment combinations) will be replicated four times at each site. Each plot will be approximately 10 by 25 feet in size and will be arranged in a randomized complete block design. Grain yield will be determined using machine harvesters appropriate for research plots, with the center 1/2 to 2/3 of the plot area harvested after border areas are removed. Grain protein content will be determined on representative subsamples collected at harvest time using industry standard analytical methods. An analysis of variance will be performed on all data.

Deep Soil Sampling for Nitrates – Preplant and post-harvest: We will use a Giddings soil sampler to collect samples to a depth of eight feet below grade in order to closely monitor the presence of N in the soil at and below the crop root zone. Samples will be analyzed at one foot increments down to 4 feet and then 4-6 feet and 6-8 feet depth zones. These data will be used to provide a crop nitrogen utilization estimate (applied N plus estimate of residual soil nitrate-N use) during the growing season, and to describe whether management practices used produce net gains (additions) or net losses (use) of nitrate-N in different parts of the soil profile. These evaluations can provide estimates of quantities of nitrate-N that may be prone to leaching losses if rainfall or irrigation water applications produce deep percolation.

Irrigation Applications and Soil Water Monitoring: It will be important to measure applied irrigation water and within-season rainfall at each test location due to possible impacts on interpretation of changes in soil profile nitrate concentrations during the production season. Efforts will be made to avoid irrigation water applications that exceed soil water storage capacity in the upper 8 feet of soil, the reason being that if applied irrigation water plus rainfall significantly exceeded the soil water storage capacity with depth, some of the nitrate within the 8 foot sampled depth of the profile could be leached below the deepest depth measured in our soil sampling, underestimating the potential for nitrate leaching losses. For this reason, we will measure gravimetric soil water content in samples collected to 6 to 8 feet (depending upon the experimental site) close to planting timing and again near harvest. In addition, in three field replications, matric potential soil sensors will be placed at four depths (1, 2, 3 and 4 feet depth)
assist in determining potential for deep percolation that could impact amount and zones of soil nitrate accumulations at each site.

**Plant Tissue Sampling:** The focus of plant tissue testing is to quantify the treatment effects on plant tissue N content and to assess whether the effects are consistent enough to use as relative indicators of plant N status. An accurate indication of plant N status prior to heading will help growers and crop consultants determine the need for late-season N applications to meet protein goals. The flag leaf will be sampled at flag leaf emergence and total N concentration determined. Sampling methods will be similar to those described by Tindall et al (1995).

**SECTION F: Project Management, Evaluation, and Outreach**

The project leaders are experienced in conducting separate as well as cooperative field research projects. Throughout this research project, meetings and teleconferences will be utilized to develop data collection plans and to ensure coordination of project activities. The sites in the southern San Joaquin Valley will be managed by Steve Wright and Robert Hutmacher, the sites in Siskiyou County will be managed by Steve Orloff; and the southern Sacramento Valley location will be managed by Mark Lundy. All investigators and some staff at their locations will be involved in soil and plant sampling, harvest operations, and in the analyses of data.

As an indication of how recommendations derived from N management research projects can be utilized for adjusting N fertilizer management practices, we will consider some of the approaches we used based on a prior research project that involved two of the Project Investigators for this proposed trial, a project entitled *Field Evaluations and Refinement of New Nitrogen Guidelines for California Cotton*. That project was conducted between 1996 and 2003 by UC Cooperative Extension personnel using commodity group and FREP funding. The results of that cotton research, which concerned yield and N uptake responses, soil nitrate uptake and accumulation patterns with different N management practices have since been integrated into decision practices for many California cotton growers using a variety of outreach approaches (Hutmacher et al. 2000; Roberts et al 2001; Hutmacher et al. 2002). Similar research approaches applied to wheat could provide similar information to improve nitrogen management recommendations for wheat producers.

To describe the cost/benefit analysis of the methods of N fertilizer application tested in this study, we propose to use the field research plot data in a table comparing: (a) the nitrogen material and application costs with (b) grain price and grain protein % including premiums and discounts. By substituting different nitrogen prices and grain prices plus estimated application costs, a table can be developed to indicate the tradeoffs between the costs of supplemental N and the economic value of improved yield and/or protein percentage.

Barriers to adoption of improved N management programs (potentially including reduced N applications and split N applications) that may optimize the combination of yield and protein levels while reducing leaching loss potential include:

(a) The tendency of growers to want to apply an extra “measure” of N fertilizer to avoid losses in yield or reduced protein levels (an “insurance” type of application);

(b) Extra effort and expenses associated with multiple (split) N fertilizer applications versus larger, one time applications;

(c) Uncertainty regarding the interactions between irrigation system efficiencies and the likelihood of nitrate leaching losses;
(d) Preference for using preplant applications of N allowing growers to use less expensive sources of N and the assurance that N has already been applied, avoiding difficulties in scheduling top dress applications when irrigations are not required.

During outreach activities we will try to address these potential barriers to grower adoption mentioned above and deal with questions based on the data produced from this project. We plan on soliciting grower and industry feedback regarding issues to resolve to improve implementation of practices that may improve economic yields and nitrogen utilization efficiencies. As project results are developed and properly reported, yearly updates of information and summary materials on the projects will be made available through trade journal and popular press articles where appropriate, through on-line resources available to the California Wheat Commission, Fertilizer Research and Education Program and University of CA Cooperative Extension newsletters where appropriate. In addition, our analyzed and summarized results will be presented in field day meetings as well as industry meetings such as small grain workgroup meetings, Alfalfa and Grains Symposium meetings, and the CA Plant and Soil Conference as information is developed, as those venues can be good ways to reach growers and consultants.

References Cited


Tindall, T.A., J.C. Stark, R.H. Brooks. 1995. Irrigated spring wheat response to topdressed nitrogen as predicted by flag leaf nitrogen concentration. J. Prod. Agric. 8:46-


SECTION G: Budget Narrative

Personnel Expenses:
Personnel expenses for each Project Investigator are expected to cover a small portion of the salary and benefits of staff that will be partially supported also through other funding sources. 

**Hutmacher Program:** Staff Research Associate III or Princ. Ag Tech. – expected 20% time support for assistance with field work, data collection, data analysis = $6450 FY13-14; $13,000 FY 14-15; $13,700 FY15-16; and $6550 FY16-17.

**Wright Program:** Staff Research Associate - expected 20% time support for assistance with field work, data collection, data analysis = $6450 FY13-14; $13,000 FY 14-15; $13,700 FY15-16; and $6550 FY16-17.

**Orloff Program:** Field Assistants, one or more to be determined – expected 20% time support for assistance with field work, data collection = $3850 FY13-14; $8,000 FY14-15; $8600 FY15-16; $4150 FY16-17.
Lundy program: Field Assistants, one, not currently employed – expected 25% time support for part of year for assistance with field work = $2,100 FY13-14; $4500FY14-15; $5000FY15-16; $2400 FY16-17.

Operating Expenses:
Supplies and Equipment: Soil and plant sampling require supplies for collecting, storing and preparing samples for later analyses, and will include boxes, sealable containers, soil grinding equipment and repair supplies. We may require an additional soil grinder to deal with large numbers of soil samples in the multi-site trials. Large scale collection of soil samples in deep soil profile sampling will require supplies and repair parts and some work on our existing Giddings trailer mounted motorized soil auger/sampler. Replacement parts for that equipment typically include replacement Kelly bars, augers or cores, engine repairs and hydraulic lines. It is expected that these supplies and minor equipment will constitute most of these expenses.

Travel: Private vehicle or University vehicle travel to research sites and to coordination meetings or outreach events are the travel expenses expected for each investigator. The levels of funding requested will only cover part of these travel expenses, but other funding sources will be used to assist with those costs.

Services, Other Expenses: The majority of the funds shown as “testing lab charges” will be for soil and plant samples for mostly nitrate analyses that will be submitted to the UC Davis analytical laboratory. We feel strongly that for consistency across locations and years that there is an advantage to utilizing this same laboratory for most analyses during the duration of the test. A limited number of soil and plant tissue samples will be submitted to private analytical labs as needed if data is needed in a short time frame to allow determination of nutrient levels for application decisions. The likely need for these private lab services will be for preplant fertilizer application decisions each year. Supplemental funds from other sources such as the CA Wheat Commission are expected to also cover some of these analytical costs for soil and plant samples. University of CA Research Center recharge costs at Intermountain and West Side REC will also be one of the service expenses for the project.

Other Funding Sources:
California Wheat Commission is providing funding at the following levels for the current related smaller project = $32,500 per year (spread across support for Huttmacher, Orloff and Wright programs). Funding at approximately this same level is expected to continue and be redirected to support this expanded project if CDFA-FREP program funds are secured. Contact information: Janice Cooper, President; 1240 Commerce Ave, Suite A, Woodland, CA 95776; (530) 661-1292; FAX: (530) 661-1332; info@californiawheat.org;

University of CA Research and Extension Center Support for research sites proposed for the University of CA West Side REC and Intermountain REC would be in-kind support and subsidy provided outside of recharge expenses. Depending upon labor hours and land support provided to these projects, support would be expected to be in the range of $4,000 to $4,500 per year at each site, and could be several $1000 more if substantial station labor hours are required to conduct the trials. Contact information: (a) Univ. CA West Side Res. & Extension Ctr, P.O. Box 158, Five Points, CA 93624-0158, phone: (559) 884-2411; (b) Intermountain Res. & Ext. Center, 2816 Havlina Road, PO Box 850, Tulelake, CA 96134; phone: (530) 667-5117