California Wheat Commission Summary Report
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Impact of Nitrogen Fertilization Treatments on Residual Soil Nitrate Accumulation Patterns in California Wheat - *2012 sampling results and 2013 sampling done*

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Abstract / Summary
Research was conducted in wheat grown for grain with a range of nitrogen management strategies that differed in the total amount of applied N and in the timing of split N fertilizer applications. The primary projects were operated and will be reported on by the Co-PI's at the Intermountain REC location (Steve Orloff, UCCE Siskiyou County, PI) and San Joaquin Valley locations (Steve Wright, UCCE Tulare and Kings Counties, PI), with this affiliated project set up to monitor soil nitrate N levels as affected by the different nitrogen management treatments. The overall goal of the joint projects was to evaluate impacts of N application treatments and growth stage timing on yield, grain protein, and potential for significant nitrate N movement within the active crop root zones and at greater depths. This project is a continuing effort to focus on deep soil sampling as part of the overall N management field trials. Funding for this project provides for extensive deep soil sampling post-harvest in multiple nitrogen management treatments, plus some limited pre-plant soil sampling. This research should be helpful in providing insight on how to maximize nitrogen efficiency and to determine the fate of nitrogen that is not taken up by the plants.

Introduction, Background and Objectives
Proper nitrogen management is essential in wheat production for achieving acceptable levels of both yields and protein content. As yields continue to increase with wheat and other agronomic crops, it is often considered that higher nitrogen rates are requited to keep pace with crop demand. Nitrogen management in wheat can be somewhat complicated due to the effect of application timing on nitrogen partitioning within the plants. N applications made prior planting or in the early developmental stages are used primarily to encourage acceptable root and shoot growth, and in many studies over a range of locations nationwide, N availability during early growth stages had a profound impact on yield. However, early-season applications usually do not result in significant nitrogen concentrations in the grain head. Late-season N applications are often required to obtain adequate nitrogen concentrations and, thus, higher protein levels in the wheat head. However, these late-season nitrogen applications alone typically do not improve yields. Sometimes growers over-apply N in attempts to achieve both yield and protein goals with fewer fertilizer applications. Over-fertilizing can lead to inefficient fertilizer use, reduced profitability and have unwanted environmental consequences such as potential for nitrate leaching below effective crop root zones. There is concern and untested assumptions regarding the fate of applied nitrogen in the soil. Leaching in semi-arid areas such as the southern San Joaquin Valley is generally thought to be less of an issue because of low rainfall as long as irrigations are relatively uniform and efficient. Data from actual field trials in wheat production areas would assist in identifying practical approaches in N management that might help improve crop responses to applied N while reducing potential N losses.

The Co-Principal Investigators for this trial have been conducting wheat N management trials since 2011 at locations in Siskiyou County and the San Joaquin Valley, focusing on optimum nitrogen application timing and rate needed to achieve high yield, and resulting N management impacts on seed protein. Initial efforts the prior two years focused on adding deep soil sampling for residual nitrate-N post harvest in order to better understand some aspects of N uptake and zones of accumulation or use of soil nitrate-N across treatments after crop harvest. A basic reason for adding these evaluations to the N studies is concern over soil nitrate levels following fertilization and crop production, and the possibility of nitrate leaching below the active root zone. There is potential in California for increasing scrutiny and perhaps even regulation over nitrogen use in crop production.

The objectives for this component of the nitrogen management studies are to:

1. Quantify the level of residual nitrate-N in the soil profile following a wheat crop fertilized according to treatments designed to apply a range of total applied N
2. Determine the impacts of specific N fertilization treatments that apply fertilizer N at different crop growth stages on soil nitrate-N accumulation patterns with depth in the soil profile at each test site

Materials and Methods / Procedures - 2012 Studies

The basic nitrogen management treatments were imposed at two locations (Siskiyou County and southern San Joaquin Valley) in 2012. The basic treatments for the 2012 studies were as follows:

1. Control – **(unfertilized)**
2. 120 Pre-plant **(Total N 120 lbs)**
3. 120 Pre-plant + 30 lbs Flowering **(Total N 150 lbs)**
4. 120 Pre-plant + 50 lbs Tillering **(Total N 170 lbs)**
5. 120 Pre-plant + 50 lbs Tillering + 30 lbs Boot **(Total N 200 lbs)**
6. 120 Pre-plant + 50 lbs Tillering + 30 lbs Flowering **(Total N 200 lbs)**
7. 120 Pre-plant + 50 lbs Tillering + 30 lbs Boot + 30 lbs Flowering **(Total N 230 lbs)**

The treatments were applied across four grain varieties at a location in the Intermountain Region and three grain varieties and one location in the San Joaquin Valley. In addition, there was an additional nitrogen study done at Intermountain REC with 18 application rate and timing applications that match the seven treatments shown above (plus additional ones), and select treatments of that study were also sampled for the 2012 study. The samples were collected prior to significant post-harvest rains, and were targeted to occur within approximately 4 to 8 weeks after harvest. At the sampled test locations, in order to reduce the costs associated with laboratory analysis we sampled only three of the four replications. However, this is still a significant number of samples (three replications x 7 fertilizer treatments x 4 varieties). This research objective required support from the California Wheat Commission due to the high number of soil analyses required and the significant costs of nitrate analyses.

Samples were collected in one foot increments between the surface and four feet depth, and then in two foot increments from four to eight feet depths. Both of the Siskiyou County trials were sampled post-harvest, for a total of about 670 samples total at post harvest timing plus a limited additional number of soil samples collected at pre-planting or early post-planting timing to characterize initial soil nitrate profile conditions. Since the West Side REC trial was not judged to have adequate plant populations, and there were some replication losses associated with intrusion into the plots from an outside farm contractor, a decision was made to not collect and analyze deep soil samples post-harvest at the 2012 West Side REC site. The Principal Investigator at that location's trial (Steve Wright) made the determination that these issues made the test results unreliable and not necessarily representative of the expected treatment effects. Even with the decision that the West Side REC location in 2012 was not suitable for field nitrate sampling due to stand problems and harvest problems, an additional N management trial was sampled at the IREC location, and the total number of samples to be analyzed totaled over 800. The primary trial samples were analyzed in 2012, and the remaining samples from 2012 are to be analyzed with the 2013 project samples, when additional funds may be available to analyze all samples collected from all monitored sites.

In 2012, soil samples were collected at the Intermountain REC site, with the West Side REC site not sampled in 2012 for the reasons previously mentioned. Samples in 2012 included: (a) pre-plant or soon after planting in three to four locations within the trial site initially to characterize the initial soil nitrate-N status; and (b) in extensive sampling to a depth of eight feet after grain harvest.

In 2013, soil samples were collected pre-plant and post-harvest at the West Side REC site (clay loam soil) in Fresno County in July and early August. Soil samples were also collected pre-plant and post-harvest in August at the Kearney REC site (sandy loam soil) in 2013. Post harvest soil samples are to be collected to a depth of 8 feet at the Intermountain REC site in October, 2013 (not yet done at the time of this report in late September). Soil samples were collected using a trailer-mounted powered Giddings soil sampler, with samples collected at the following depths as separate samples for analysis purposes: 0-1 foot, 1-2 foot, 2-3 foot, 3 to 4 foot, 4-6 feet, and 6-8 feet. Soil samples from each year have to be air dried, ground, run through a 2 mm sieve, subsampled and prepared for analyses for nitrate N. The analyses are completed for 2012 trial work at Intermountain REC, but the analyses will not be completed likely until after submission late in 2013 at the UC ANR testing laboratory, Davis.

2011 and 2012 Soil Sampling Results:
Samples were collected in all treatments as planned at the 2011 Intermountain REC and Siskiyou County sites, and at the 2011 West Side REC site to a depth of eight feet in three replications of each of the treatments. The 2011 field trials yielded the following summary.

TABLE 1. Post Harvest average soil nitrate-N (lbs nitrate-N/acre) in **2011 field trial locations** contained in parts of the soil profile as a function of site and N treatment (values shown are averaged across all varieties). No statistical analyses have been performed yet on the data sets.

Treatment (lbs N applied at growth stage)	**Scott Valley Siskiyou County** Average lbs N as nitrate-N in lbs/ac for depth range shown			**Intermountain REC Siskiyou County** Average lbs N as nitrate-N in lbs/ac for depth range shown			**West Side REC Fresno County** Average lbs N as nitrate-N in lbs/ac for depth range shown		
	0 to 4 ft	4 to 6 ft	6 to 8ft	0 to 4 ft	4 to 6 ft	6 to 8ft	0 to 4 ft	4 to 6 ft	6 to 8ft
Untreated control	27.8	14.8	40.1	50.7	21.7	20.2	23.1	35.6	17.9
120 lbs preplant	31.7	14.1	45.2	62.4	31.0	25.8	75.3	34.2	13.2
120 preplant + 50 tillering	30.4	25.2	37.2	61.6	27.0	19.6	55.9	37.7	16.7
120 preplant, 30 flowering	35.6	21.2	42.3	90.7	37.5	19.4	53.8	33.1	17.3
120 preplant, 50 tiller, 30 boot	49.5	21.1	49.7	86.9	38.7	19.4	42.5	44.5	18.1
120 preplant, 50tiller,30flow	42.4	15.4	41.1	95.7	48.7	18.6	- no trt this site	-	-
120 preplant, 50 tiller, 30 boot, 30 flower	63.1	20.7	45.4	107.3	35.8	20.5	52.9	46.3	20.9

TABLE 2. Post Harvest average soil nitrate-N (ppm or mg/kg) at Intermountain REC field research site in 2012 soil sampling. Values shown are averages across three replications, and are separated by wheat variety. Samples were collected to a depth of 8 feet, in one foot increments to a depth of 4 feet, and in two foot increments between 4 and 8 feet depth.

Variety #1: Yecora Rojo – Intermountain REC trial – 2012 data summary soil profile sampling for nitrate.								
Depth Range (in feet)	Trt #1 Unfertilized control	Trt #2	Trt #3	Trt #4	Trt #5	Trt #6	Trt #7	
0-1 feet	5.00 (1.1)	6.24 (1.9)	8.59	9.52	6.88	10.53	12.65 (6.1)	
1-2	4.32 (0.4)	4.73 (2.1)	5.64	4.73	4.16	5.10	9.53 (1.7)	
2-3	4.16 (1.3)	5.22 (1.1)	11.18	9.57	7.22	9.80	10.34 (3.0)	
3-4	2.12 (0.8)	3.54 (1.3)	10.70	2.95	2.90	6.14	9.41 (3.7)	
4-6	2.43 (0.82)	3.49 (0.5)	3.93	2.94	4.24	6.90	6.23 (0.9)	
6-8	2.07 (1.23)	3.59 (1.3)	2.87	2.14	4.27	3.31	5.06 (2.1)	
Variety #2: Hank – Intermountain REC trial – 2012 data summary								
0-1 feet	4.67	6.71	7.71	10.11	11.06	8.61	12.69	
1-2	3.72	5.50	6.24	5.56	8.71	10.13	10.55	
2-3	4.82	5.69	6.59	10.78	12.99	12.38	11.21	
3-4	3.05	3.61	3.65	10.07	13.23	13.40	12.76	
4-6	2.53	2.17	3.46	4.83	9.85	5.01	7.23	
6-8	2.11	2.66	2.74	3.57	2.81	5.37	5.85	
Variety #3: Fuzion – Intermountain REC trial – 2012 data summary								
0-1 feet	4.05	4.29	7.09	6.84	9.96	6.80	9.65	
1-2	3.99	3.52	5.13	4.21	6.13	6.30	8.38	
2-3	4.80	4.63	7.04	7.64	7.23	5.87	13.72	
3-4	2.93	3.10	4.46	3.71	5.33	3.60	10.82	
4-6	2.86	2.60	3.99	4.18	3.87	3.33	6.49	
6-8	2.61	2.85	3.20	3.29	2.92	2.75	4.54	
Variety #4: Malbec – Intermountain REC trial – 2012 data summary soil profile sampling for nitrate								
0-1 feet	4.51	6.47	7.18	6.30	10.73	12.51	12.15	
1-2	4.21	4.79	5.71	4.48	8.09	10.84	9.67	
2-3	5.13	6.11	7.05	6.76	8.07	9.22	11.46	
3-4	2.49	3.90	2.82	4.31	4.05	9.48	8.88	
4-6	3.13	4.07	3.04	2.90	3.39	8.14	8.84	
6-8	2.74	3.22	2.34	2.47	3.02	3.48	4.31	

- Standard deviations shown in parentheses following the averages.

Additional analyses need to be done to determine treatment effects on accumulated soil nitrate-N in different parts of the soil profile, but it was evident that some of the later application timings and higher rates of soil applied N resulted in higher ending soil nitrate-N levels in the upper 4 to 6 feet of the soil profile at the Intermountain REC site in the 2012 data. Values shown in Table 3 for the Intermountain REC site in 2012 are presented in lbs nitrate-N/acre by depth groupings, with values shown for each treatment in cumulative amounts for the 0 to 4 foot depth increment, 4 to 6 foot depth increment, and 6 to 8 foot depth increment.

Similar evaluations will be done on the soil samples collected from 2013 trial sites at West Side REC, Kearney REC, and Intermountain REC after the samples have been ground and analyzed (not yet submitted at the time of preparation of this report).

TABLE 3. Post Harvest average soil nitrate-N (lbs nitrate-N/acre) in **2012 field trial locations** contained in parts of the soil profile as a function of site and N treatment (values shown are averaged across all varieties).

Treatment (lbs N applied at growth stage)	**Variety: Yecora Rojo** Average lbs N as nitrate-N in lbs/ac for depth range shown			**Variety: Hank** Average lbs N as nitrate-N in lbs/ac for depth range shown			**Variety: Fuzion** Average lbs N as nitrate-N in lbs/ac for depth range shown		
Trt number	0 to 4 ft	4 to 6 ft	6 to 8ft	0 to 4 ft	4 to 6 ft	6 to 8ft	0 to 4 ft	4 to 6 ft	6 to 8ft
Trt #1 untreated control	62.4	19.4	16.6	65.3	20.2	16.9	63.1	22.9	20.9
Trt #2	78.9	28.0	28.8	86.0	17.4	21.3	62.1	20.8	22.7
Trt #3	144.5	31.4	23.0	96.8	27.7	21.9	94.8	31.9	25.6
Trt #4	107.1	23.6	17.1	146.1	38.7	28.85	89.7	33.5	26.4
Trt #5	84.6	33.9	34.2	183.9	78.8	22.5	114.6	30.9	23.4
Trt #6	126.3	55.2	26.5	178.1	40.1	43.0	90.3	26.6	22.0
Trt #7	167.7	49.8	40.5	188.8	57.8	46.8	170.3	51.9	36.4

Discussion:
Table 1 shows summary information on soil nitrate accumulation patterns seen at post harvest timing in the 2011 studies done at three test sites, while similar data is shown in Tables 2 and 3 for 2012 data sets at the Intermountain REC. Values shown for 2011 were averaged across 3 or 4 different varieties, which differ in some growth characteristics and yield to some extent. The data analyzed shows generally higher soil nitrate-N values at the post harvest sample timing in the surface 4 feet of the higher N application treatments, indicating some residual effects of these treatments when compared with untreated control plots. There also are some differences across the three different test sites shown for the 2011 data that we will have to analyze to consider differences in soil water holding capacity and other characteristics that could impact nitrate in the soil. In all three sites, data summaries show little difference in deep (6 to 8 foot depth) soil nitrate-N between control plots and most treatments, suggesting little movement of nitrate from upper profile into that zone. There are some suggestions that soil nitrate levels were higher in some of the higher N application treatments than in control /untreated plots at the 4 to 6 foot depth at two of the three sites. Additional efforts will be made in this and the 2012 and 2013 data sets to evaluate varietal differences in the patterns seen, and how that might relate to yield differences or responses to N management practices.

Total number of soil samples to be collected during 2013 trials: The number of soil samples to be collected during post-harvest sampling in 2013 is estimated to be about a little over 600 samples (West Side REC site),

about 425 samples (Kearney REC site), and about 500 samples (Intermountain REC site). With this number of samples, we expect to utilize our full budget plus carryover funds to pay for the analyses.

Budget (planned expenditures during calendar year 2013 with CA Wheat Commission Funding)

- *Note that this project required that the Siskiyou County N project headed up by Steve Orloff and the San Joaquin Valley project headed up by Steve Wright were funded and carried out, since those projects set up the N application treatments needed to conduct this part of the study.*

Category	Amount ($)
Soil analyses (Univ. CA ANR Testing Laboratory) – nitrate analyses, plus some other baseline soil nutrient tests at each site	8,000
Soil sampling supplies, repairs to soil grinders and supplies	1,000
Repairs and supplies related to Giddings soil sampling equipment, trailer mounted	2,000
Part-time Research Asst. time, casual labor for soil preparation, grinding soils, analyses	2,000
Travel – to research sites	1,500
TOTAL	$14,500

Since the total number of soil samples collected in 2013 will be significantly higher than in 2012, we also requested that some carry-over funds from 2012 project funding be allowed to carry over for use for soil analyses (primarily) in through December, 2013. This will allow us to cover most of the Soil testing lab costs from the West Side REC site, Kearney REC site and Intermountain REC site from 2013.

Cooperative Support – Additional Proposal submitted:
The project investigators applied for additional funds for an expanded version of this project to the CA Dept of Food and Agriculture's Fertilizer Research and Education Program (FREP) earlier in 2013, and we received notification in August that we would be receiving $75,000 in funding for the project in 2014, 2015, and 2016. The FREP proposal budget we submitted indicated that we would continue to apply for funds for this ongoing project from the California Wheat Commission, so we hope to expand the project some in terms of test sites and some data collection if both funding sources are available. With FREP program funds from the submitted proposal for 2014-2016 funding, then the likely changes in our plans would include one additional test site in each of the areas (northern CA and southern SJV), addition of Mark Lundy (UCCE Colusa County) as a new cooperator on the project in Sacramento Valley, plus more detailed plant sampling at each test site. We also could consider addition of more varieties in the soil sampling to be conducted in efforts as part of the project plan.

Recommendations and Future Plans
Plans are to request continuing funds to conduct additional studies of N management options and resulting plant responses and soil nitrate responses to changes in N fertilizer application amounts and timing.