RFP #97-0365 M99-04

**CALIFORNIA DEPARTMENT OF FOOD AND AGRICULTURE**
**FERTILIZER RESEARCH AND EDUCATION PROGRAM (FREP)**

**Final Report, December, 2001**

**Project Title**: Nitrogen fertilization and grain protein content in California wheat
**Project Location**: UC Davis Agronomy Farm and Farms of Cooperating Growers in Butte, Colusa, Madera, Kings, and Kern counties
**Project Duration**: 2 years

**Project Leader:** L.F. Jackson, Extension Agronomist, Department of Agronomy & Range Science, University of California, One Shields Avenue, Davis, CA 95616-8515.

**Cooperators:** Cass Mutters, UC Cooperative Extension Farm Advisor (Butte Co.), 2279 Del Oro, Suite B, Oroville, CA 95965.
Doug Munier, UC Cooperative Extension Farm Advisor (Glenn Co.) P.O. Box 697, Orland, CA 95963.

Jerry Schmierer, UC Cooperative Extension Farm Advisor (Colusa Co.), P.O. Box 180, Colusa, CA 95930-0180.

Ron Vargas, UC Cooperative Extension Farm Advisor (Madera Co.), 328 Madera Ave, Madera, CA 93637.

Steve Wright, UC Cooperative Extension Farm Advisor (Tulare/Kings Co.), 2500 West Burrel Ave, Visalia, CA 93291-4584.
Brian Marsh, UC Cooperative Extension Farm Advisor (Kern Co.), 1031 S. Mt Vernon Ave. Bakersfield, CA 93307-2001.

**A. Interpretive Summary:** The nitrogen fertilization requirement for wheat depends on factors such as yield potential, the previous crop and residual fertility from it, soil fertility, and the amount of irrigation planned. Nitrogen fertilizer applications are made preplant, with seed, at tillering and/or at various other growth-stages during the season. In practice, total seasonal nitrogen applications may vary from 0 to over 300 lb nitrogen/acre, with some acreage over-fertilized and some acreage under-fertilized because of the difficulty of matching fertilizer need with yield potential in each growing season. Grain protein content at harvest may be higher or lower than the desirable level regardless of the total amount of nitrogen fertilizer applied. Anthesis-time nitrogen applications, in combination with irrigation, can increase grain protein content and improve baking quality of wheat. Such applications have increased grain protein content by 1-3%. Currently, however, growers are unable to predict what the final protein status of the crop is likely to be under such management – that is, is the potential 3% increase from 11 to 14% or from 8 to 11%? If the former is true, the grower may qualify for a price premium based on grain protein content. If the latter is true, no price premium will be available. Studies have shown that flag-leaf nitrogen content at anthesis is positively correlated with grain nitrogen content (but not with grain yield) and that if flag-leaf nitrogen content is greater than 4%, additional nitrogen usually is not required to achieve the target (13%) grain protein content. In order to accurately estimate anthesis-time nitrogen requirements, however, it is necessary to be able to predict both final grain nitrogen content and grain yield at anthesis. In order to produce high quality wheat consistently and economically, growers need to be able to determine: 1) if anthesis-time nitrogen fertilization is needed to reach the target (13%) grain protein level and, if so, 2) how much nitrogen fertilizer must be applied. The primary objective of this two-year project was to link nitrogen status and crop yield potential (based on crop biomass) at anthesis with a desired level of response of grain nitrogen content (i.e., final grain protein content of 13%) to specific rates of anthesis-applied nitrogen. Experiments were designed to measure the response of grain protein content to different rates (0, 30, and 60 lb nitrogen/acre) of anthesis-time nitrogen fertilization under different pre-anthesis nitrogen management practices (thus different yield potentials). Efficacy of broadcast vs. foliar-applied nitrogen also was compared.

*Description*

The project was managed within the framework of the UC Statewide Small Grain Evaluation program led by Project Leader, Lee Jackson, Extension Agronomist and Statewide Cereal Specialist. Experimental sites were among those used in the UC Regional Cereal Testing Program. For the 1999/2000 and 2000/2001 seasons, three

sites were established in the Sacramento Valley using the common wheat cultivar "Kern" and three sites were established in the San Joaquin Valley using the durum wheat cultivar "Kronos". The sites in the Sacramento Valley were the Chico State University farm in Chico (Butte County), the Erdman ranch near Grimes (Colusa County), and the UC Davis Agronomy Farm. The sites in the San Joaquin Valley were the Dupont Research Farm (Madera County), the J.G Boswell farm in Corcoran (Kings County), and the J.G Boswell Kern Lake Ranch (Kern County). University of California Cooperative Extension Farm Advisors Cass Mutters (Butte Co.), Doug Munier (Glenn Co.), Jerry Schmierer (Colusa Co.), Ron Vargas (Madera Co.), Steve Wright (Tulare/Kings Co.), and Brian Marsh (Kern Co.) arranged for use of grower fields in their counties, worked with and advised the growers on field management operations, and assisted in the application of anthesis-time nitrogen, collection of biomass samples and tissue samples for nitrogen determination, and plot harvest. Project Leader Lee Jackson's Staff Research Associate Ray Wennig (1999/2000, resigned in August, 2000) and Steve Scardaci (replaced Ray Wennig in October, 2001, resigned in July, 2001, replaced by Don Stewart in September, 2001) coordinated the sowing of the experiments, collection of soil samples, application of anthesis-time nitrogen treatments, collection of biomass and tissue samples, flag-leaf chlorophyll meter readings, harvest of the plots, and initial data analysis. Tissue and grain samples were analyzed for nitrogen content by the UC DANR Diagnostic Lab.

Experiments at each site were sown in the fall of 1999 and 2000, using the randomized complete block design with four replications. Treatments at each site consisted 30 and 60 lb nitrogen/acre as ammonium nitrate and 30 lb nitrogen/acre as foliar-applied urea applied at anthesis. The anthesis-N application was followed by irrigation. A check treatment of zero applied nitrogen at anthesis was included. Plot size was approximately 300 $ft^2$. Composite soil samples (0-12" depth) were taken at each site at the time of sowing and also just prior to the application of anthesis-nitrogen to provide information on the differing N-status of each site (Table 1). Crop management through anthesis followed accepted grower practices at each site, thus providing differing crop biomass and nitrogen status environments. Crop biomass and nitrogen content of specific tissues (flag-leaf and uppermost stem internode) were measured at the time of anthesis-applied nitrogen, 14 days post-anthesis, and at harvest. Crop biomass samples at each sampling date consisted of plants from 1-meter row/plot cut at the ground level. Subsamples of flag leaves and uppermost stem internodes were drawn from the biomass samples for total tissue nitrogen determination.

*Results and Discussion*

The sites and grower practices used provided different N-supply and grain yield environments at each location. Anthesis-N applications did not affect grain yield or agronomic characteristics despite different yield potentials at each site and different amounts of soil nitrogen available both preplant and at anthesis (immediately prior to the application of anthesis-N) (Tables 1-3).

Average flag leaf N-content at anthesis (just prior to applying the anthesis nitrogen treatments) over all sites/seasons ranged from 2.9 to 4.4%, indicating inherent variability within and between sites (Tables 4 – 5). At the measured levels of flag leaf N-content at anthesis (all lower than 4% except for the Madera Co site in, 2000/2001), responses of grain protein content to anthesis-applied nitrogen were expected. Average uppermost stem internode N-content at anthesis showed a similar level of within and between site variability to flag leaf N-content. Flag leaf N-content, uppermost stem internode N-content, and flag leaf chlorophyll readings (SPAD readings were made with a Minolta SPAD-502 Chlorophyll Meter) taken 14 days post-anthesis were not consistently affected by the different rates of nitrogen applied at anthesis. Tissue N-content and flag leaf chlorophyll may have peaked prior to the measurements and decreased by the time samplings and readings were taken due to translocation of nitrogen from flag leaf and stem tissues to the developing grain. Flag leaf chlorophyll of the durum wheat cultivar "Kronos" tended to be higher, by 5 to 13 SPAD units, than those of the common wheat cultivar "Kern" at similar flag leaf N-content (Tables 4 – 5). Different critical values for relating SPAD readings to nitrogen content (and ultimately to the need for anthesis-N topdressing to achieve target grain protein levels) may be needed for the different classes of wheat grown in California.

Grain protein content (12% moisture basis) ranged from 9.6 to 11.9% at Butte, from 9.6 to 11.8% at Colusa, from 10.7 to 12.7% at UC Davis, from 9.2 to 15.6% at Madera, from 12.6 to 14.2% at Kings, and from 12.9 to 14.2% at Kern, with a similar pattern each year at each site (Tables 4-5). The ammonium nitrate treatments (30 and/or 60 lb/acre rates of N) increased grain protein content above that of the zero anthesis-N application. The 60 lb/acre rate of N as ammonium nitrate resulted in higher grain protein content than the 30 lb/acre rate of N as ammonium nitrate, while the 30 lb/acre rate of N applied as foliar urea usually was much less effective than the 30 lb/acre rate of N as ammonium nitrate. Anthesis-N applications, even at the 60 lb/acre rate of N, were not successful in raising grain protein content of "Kern" wheat to the target level of 13.0% under the crop biomass and nitrogen status environments at the Sacramento Valley sites. Conversely, the anthesis-N applications were successful in

raising grain protein content of "Kronos" durum wheat to the target level of 13.0% at the San Joaquin Valley sites, although at the Madera site in 1999/2000, only the 60 lb/acre rate of N produced a grain protein content of over 13.0%. Predictability of wheat grain protein content remains elusive. Further analysis of the data will focus on investigating the relationship between total biomass and tissue nitrogen content at anthesis with grain yield and grain protein content at harvest, as affected by the different rates of nitrogen applied at anthesis. Future work will include a time-course of SPAD readings and plant tissue nitrogen content determinations from prior to anthesis through 14-days post-anthesis to identify the optimum time for sampling and the highest correlation with final grain protein content.

*Outreach and Training*

Outreach activities in the form of field meetings and workgroup discussions were conducted to extend information on the costs and benefits associated with anthesis-time nitrogen management for grain protein improvement in wheat to growers, farm advisors and other interested parties. In the first year (2000) Ray Wennig led a discussion of the project at the meeting of the Small Grain Workgroup on May 16. Participating in the discussion were the project leader, project cooperators, and UC farm advisors and faculty from throughout the state. Ray Wennig also gave a presentation about the project during the Annual Small Grain and Alfalfa Field Day at UC Davis on May 17. Attendance at the Field Day was about 120 (growers, seed producers, grain industry personnel, farm advisors, PCA's, UC and USDA researchers, etc.). Discussions of the 1st year results and plans for the 2nd year experiments were conducted at training meetings held for San Joaquin Valley small grain farm advisors on September 15 and for Sacramento Valley small grain farm advisors on September 22. For the 2000/2001 season Project Leader Lee Jackson discussed the project's goals and progress at the Kings County Cereal Field Day at the Kings site (on April 23, 2001) and at the Annual Small Grain and Alfalfa Field Day at UC Davis (on May 16, 2001). Attendance at the Kings County Cereal Field Day was about 30 growers, PCA's, and students of Steve Wright's Fresno State University agronomy class. Attendance at the Annual Small Grain and Alfalfa Field Day at UC Davis was about 80 (growers, seed producers, grain industry personnel, farm advisors, PCA's, UC and USDA researchers, etc.). Further discussions are planned for a training meeting for farm advisors with responsibility for small grains that will be held in January, 2002.

**Budget Summary from January-June, 2000**

| | |
|---|---|
| Personnel | |
| SRA, Dept Agronomy and Range Science, UC Davis | |
| Wage labor for sample collection | |
| Operating Expenses | |
| Equipment (Minolta SPAD-502 Chlorophyll Meter, Data Port and Software) | |
| Materials and supplies | |
| Travel to research sites | |
| **Total Expenditures January-June, 2000** | **$ 8,837.00** |

**Budget Summary from July-December, 2000**

| | |
|---|---|
| Personnel | |
| SRA, Dept Agronomy and Range Science, UC Davis | |
| Wage labor for sample collection | |
| Operating Expenses | |
| Materials and supplies | |
| Travel to research sites | |
| Soil and Tissue sample analyses (DANR Diagnostic lab) | |
| **Total Expenditures from July-December, 2000** | **$ 8,837.00** |
| | |
| **Total Expenditures for 1st Year of Project, 2000** | **$17,674.00** |

**Budget Summary (charges, amounts) January 1, 2001 to June 30, 2001**

| | |
|---|---|
| Personnel | |
| Steve Scardaci, SRA, Dept Agronomy and Range Science, UC Davis | |
| (20%time + benefits for January – June, 2001) | |
| Wage labor for sample collection and processing (12 days @ $10/hr) | |

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| | |
|---|---|
| Operating Expenses | |
| Materials and supplies | |
| Analysis of samples | |
| Travel to research sites | |
| **Total Expenditures January 1, 2001 to June 30, 2001** | **$8041.00** |
| **Budget Summary from July-December, 2001** | |
| Personnel | |
| SRA, Steve Scardaci/Don Stewart, Dept Agronomy and Range Science, UC Davis | |
| Wage labor for sample collection | |
| Operating Expenses | |
| Materials and supplies | |
| Travel to research sites | |
| Soil and Tissue sample analyses (DANR Diagnostic lab) | |
| **Total Expenditures from July-December, 2001** | **$ 8,040.00** |
| **Total Expenditures for 2ndYear of Project, 2001** | **$16,081.00** |

Table 1. Preplant and Anthesis Soil Nitrogen Content, Anthesis-N Test Sites

| Site | 1999/2000 | | 2000/2001 | |
|---|---|---|---|---|
| | $NO_3$-N ppm | $NH_4$-N ppm | $NO_3$-N ppm | $NH_4$-N ppm |
| Preplant Samples - Kern Wheat Tests | | | | |
| Butte Co | 21.3 | 25.4 | 35.0 | 4.8 |
| Colusa Co | 28.9 | 10.5 | 34.5 | 24.1 |
| UC Davis | 16.3 | 11.4 | 53.7 | 4.5 |
| Anthesis Time Samples - Kern Wheat Tests | | | | |
| Butte Co | 1.0 | 16.0 | 4.4 | 6.5 |
| Colusa Co | 0.9 | 6.8 | 4.2 | 6.8 |
| UC Davis | 2.1 | 7.4 | 3.9 | 4.8 |
| Preplant Samples - Kronos Durum Wheat Tests | | | | |
| Madera Co | 42.4 | 44.0 | 21.6 | 19.2 |
| Kings Co | 23.9 | 37.4 | 23.8 | 35.4 |
| Kern Co. | 24.3 | 5.8 | 6.4 | 19.1 |
| Anthesis Time Samples - Kronos Durum Wheat Tests | | | | |
| Madera Co | 0.6 | 2.8 | 5.8 | 2.2 |
| Kings Co | 5.6 | 6.5 | 5.9 | 20.6 |
| Kern Co. | 5.0 | 22.3 | 4.0 | 8.0 |

Sacramento Valley sites:

Chico State University Farm, Butte Co
Erdman Ranch, Colusa Co
UC Davis Agronomy Farm, Yolo Co

San Joaquin Valley sites:

Dupont Research Facility, Madera Co
J.G. Boswell, Corcoran, Kings Co
J.G. Boswell Kern Lake, Kern Co

Table 2. Effects of Anthesis-Time Nitrogen Applications on Yield and Agronomic Characters of "Kern" Wheat
Sacramento Valley: Chico State University Farm, Butte Co; Erdman Ranch, Colusa Co; and UC Davis Agronomy Farm, Yolo Co

| | | 1999/2000 | | | | | 2000/2001 | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Site | Anthesis-N Rate (lb/acre) | Yield (lb/acre) | Test Wt (lb/bu) | 1000 Kernel Wt (g) | Plant Ht (in) | Lodging (harvest) | Yield (lb/acre) | Test Wt (lb/bu) | 1000 Kernel Wt (g) | Plant Ht (in) |
| Butte Co | | | | | | | | | | |
| | 0 | 5800 (02) | 64.5 | 44.7 | 33 | - | 5060 (4) | 63.4 | 46.9 | 35 |
| | 30 (as $NH_4NO_3$) | 5540 (03) | 64.4 | 43.8 | 33 | - | 5180 (3) | 63.6 | 48.0 | 35 |
| | 60 (as $NH_4NO_3$) | 5910 (01) | 64.7 | 46.3 | 34 | - | 5410 (1) | 63.6 | 48.3 | 36 |
| | 30 (as Foliar Urea) | 5490 (04) | 64.6 | 45.2 | 35 | - | 5220 (2) | 63.5 | 47.2 | 36 |
| | CV (%) | 4.6 | 0.2 | 2.9 | 5.4 | | 6.9 | 0.3 | 1.2 | 1.9 |
| | LSD (.05) | ns | ns | ns | ns | | ns | ns | 0.9 | 1 |
| Colusa Co | | | | | | | | | | |
| | 0 | 5240 (04) | 62.3 | 49.8 | - | 1.3 | 5850 (2) | 65.2 | 45.6 | 34 |
| | 30 (as $NH_4NO_3$) | 5470 (01) | 62.5 | 49.7 | - | 1.5 | 5830 (3) | 65.1 | 45.7 | 34 |
| | 60 (as $NH_4NO_3$) | 5310 (03) | 62.7 | 50.8 | - | 1.5 | 5720 (4) | 64.9 | 45.7 | 34 |
| | 30 (as Foliar Urea) | 5460 (02) | 63.1 | 49.9 | - | 1.3 | 6030 (1) | 65.2 | 45.1 | 34 |
| | CV (%) | 5.0 | 0.2 | 0.9 | | 36.4 | 4.9 | 0.2 | 2.3 | 2.9 |
| | LSD (.05) | ns | 0.5 | ns | | ns | ns | 0.2 | ns | ns |
| UC Davis | | | | | | | | | | |
| | 0 | 5560 (01) | 64.9 | 46.7 | 35 | 1.8 | 6140 (3) | 63.8 | 43.9 | 40 |
| | 30 (as $NH_4NO_3$) | 5430 (04) | 64.6 | 48.2 | 34 | 1.8 | 6120 (4) | 63.3 | 43.5 | 37 |
| | 60 (as $NH_4NO_3$) | 5530 (02) | 64.4 | 47.3 | 34 | 1.5 | 6430 (1) | 62.9 | 42.9 | 37 |
| | 30 (as Foliar Urea) | 5490 (03) | 64.8 | 46.2 | 36 | 1.8 | 6430 (2) | 63.5 | 44.3 | 39 |
| | CV (%) | 5.6 | 0.2 | 1.6 | 2.9 | 31.6 | 6.4 | 0.4 | 2.0 | 4.7 |
| | LSD (.05) | ns | ns | ns | ns | ns | ns | 0.4 | ns | ns |
| 3-Location Summary (1999/2000) | | | | | | | | | | |
| | 0 | 5530 (02) | - | - | - | - | - | - | - | - |
| | 30 (as $NH_4NO_3$) | 5480 (04) | - | - | - | - | - | - | - | - |
| | 60 (as $NH_4NO_3$) | 5580 (01) | - | - | - | - | - | - | - | - |
| | 30 (as Foliar Urea) | 5480 (03) | - | - | - | - | - | - | - | - |
| | CV (%) | 5.1 | | | | | | | | |
| | LSD (.05) | ns | | | | | | | | |

Rating scale for lodging: 1=0-3%, 2=4-14%, 3=15-29%, 4=30-49%, 5=50-69%, 6=70-84%, 7=85-95%, 8=96-100
Numbers in parentheses indicate relative rank in column.

Table 3. Effects of Anthesis-Time Nitrogen Applications on Yield and Agronomic Characters of "Kronos" Durum Wheat
San Joaquin Valley: Dupont Research Facility, Madera Co; J.G. Boswell, Corcoran, Kings Co;and J.G. Boswell Kern Lake, Kern Co

| | | 1999/2000 | | | | | 2000/2001 | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Site | Anthesis-N Rate (lb/acre) | Yield (lb/acre) | Test Wt (lb/bu) | 1000 Kernel Wt (g) | Plant Ht (in) | Lodging (harvest) | Yield (lb/acre) | Test Wt (lb/bu) | 1000 Kernel Wt (g) | Plant Ht (in) |
| Madera Co | | | | | | | | | | |
| | 0 | 5650 (03) | 63.4 | 64.5 | 38 | 1.0 | 4280 (2) | 61.2 | 60.8 | 34 |
| | 30 (as $NH_4NO_3$) | 6000 (01) | 63.3 | 64.9 | 36 | 1.0 | 4330 (1) | 61.4 | 60.7 | 33 |
| | 60 (as $NH_4NO_3$) | 5910 (02) | 63.0 | 66.1 | 36 | 1.3 | 4070 (4) | 61.5 | 62.2 | 33 |
| | 30 (as Foliar Urea) | 5580 (04) | 63.4 | 63.1 | 36 | 1.3 | 4270 (3) | 61.4 | 60.8 | 32 |
| | CV (%) | 11.4 | 0.4 | 5.3 | 1.6 | 33.1 | 11.3 | 0.4 | 3.3 | 3.7 |
| | LSD (.05) | ns | ns | ns | ns | ns | ns | ns | ns | ns |
| Kings Co | | | | | | | | | | |
| | 0 | 6390 (02) | 62.6 | 63.9 | 35 | 6.5 | 5120 (1) | 60.3 | 53.7 | 42 |
| | 30 (as $NH_4NO_3$) | 6340 (03) | 62.4 | 61.7 | 35 | 6.5 | 5050 (2) | 60.4 | 53.0 | 41 |
| | 60 (as $NH_4NO_3$) | 6510 (01) | 62.4 | 62.9 | 34 | 6.5 | 4870 (4) | 60.1 | 53.3 | 41 |
| | 30 (as Foliar Urea) | 6250 (04) | 62.3 | 63.4 | 35 | 6.5 | 4950 (3) | 60.7 | 54.0 | 42 |
| | CV (%) | 7.5 | 0.7 | 3.7 | 1.7 | 6.3 | 7.2 | 0.7 | 2.7 | 1.4 |
| | LSD (.05) | ns | ns | ns | ns | ns | ns | ns | ns | ns |
| Kern Co | | | | | | | | | | |
| | 0 | 4110 (03) | 58.1 | 49.0 | - | 8.0 | 6200 (2) | 62.1 | 56.5 | 41 |
| | 30 (as $NH_4NO_3$) | 4570 (01) | 57.6 | 48.3 | - | 8.0 | 6040 (4) | 61.9 | 56.4 | 41 |
| | 60 (as $NH_4NO_3$) | 3780 (04) | 58.0 | 46.5 | - | 8.0 | 6050 (3) | 61.8 | 56.8 | 41 |
| | 30 (as Foliar Urea) | 4310 (02) | 57.7 | 47.8 | - | 8.0 | 6270 (1) | 62.0 | 57.1 | 41 |
| | CV (%) | 16.7 | 1.4 | 3 | | | 3.7 | 0.4 | 2.5 | 1.8 |
| | LSD (.05) | ns | ns | ns | | | ns | ns | ns | ns |
| 3-Location Summary (1999/2000) | | | | | | | | | | |
| | 0 | 5380 (03) | - | - | - | - | - | - | - | - |
| | 30 (as $NH_4NO_3$) | 5640 (01) | - | - | - | - | - | - | - | - |
| | 60 (as $NH_4NO_3$) | 5400 (02) | - | - | - | - | - | - | - | - |
| | 30 (as Foliar Urea) | 5380 (04) | - | - | - | - | - | - | - | - |
| | CV (%) | 11.4 | | | | | | | | |
| | LSD (.05) | ns | | | | | | | | |

Rating scale for lodging: 1=0-3%, 2=4-14%, 3=15-29%, 4=30-49%, 5=50-69%, 6=70-84%, 7=85-95%, 8=96-100.
Numbers in parentheses indicate relative rank in column.

Table 4. Effects of Anthesis-Time Nitrogen Applications on N-Tissue Content, Biomass, and Grain Protein of "Kern" Wheat
Sacramento Valley: Chico State University Farm, Butte Co; Erdman Ranch, Colusa Co; and UC Davis Agronomy Farm, Yolo Co

| | Anthesis | | | | 14 Days Post Anthesis | | | | Harvest | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Anthesis-N Rate (lb/acre) | Flag Leaf SPAD | Flag Leaf N (%) | Stem N % | Biomass (g) (m-row) | Flag Leaf SPAD | Flag Leaf N (%) | Stem N % | Biomass (g) (m-row) | Flag Leaf N (%) | Stem N % | Biomass (g) (m-row) | Grain Pro % (12% mb) |
| Butte, 1999/2000 | | | | | | | | | | | | |
| 0 | 40.3 | 3.4 | 1.4 | 217 | 42.5 | 3.1 | 1.2 | 212 | 0.9 | 0.8 | 280 | 10.0 |
| 30 (as NH4NO3) | 40.7 | 3.5 | 1.5 | 218 | 43.8 | 3.4 | 1.5 | 217 | 1.0 | 0.8 | 274 | 10.8 |
| 60 (as NH4NO3) | 40.4 | 3.5 | 1.5 | 216 | 43.8 | 3.3 | 1.4 | 187 | 1.3 | 0.8 | 286 | 11.6 |
| 30 (as Foliar Urea) | 42.0 | 3.7 | 1.5 | 212 | 41.4 | 3.2 | 1.3 | 209 | 1.3 | 0.8 | 229 | 10.8 |
| CV (%) | 3.39 | 7.5 | 6.4 | 7.6 | 4.4 | 8.0 | 12.4 | 13.5 | 15.6 | 8.5 | 13.9 | 4.6 |
| LSD (.05) | ns | ns | ns | ns | 3.1 | 0.4 | 0.3 | 45 | 0.3 | 0.1 | 59 | 0.8 |
| Butte, 2000/2001 | | | | | | | | | | | | |
| 0 | 40.0 | 3.3 | 1.5 | 157 | 41.6 | 2.9 | 1.2 | 193 | 0.76 | 0.48 | 201 | 9.6 |
| 30 (as NH4NO3) | 37.7 | 2.9 | 1.3 | 148 | 42.5 | 3.1 | 1.3 | 186 | 0.87 | 0.57 | 275 | 11.1 |
| 60 (as NH4NO3) | 39.5 | 3.3 | 1.5 | 147 | 45.0 | 3.4 | 1.6 | 165 | 0.96 | 0.54 | 260 | 11.9 |
| 30 (as Foliar Urea) | 40.8 | 3.4 | 1.5 | 180 | 42.0 | 3.0 | 1.3 | 176 | 0.79 | 0.33 | 231 | 9.8 |
| CV (%) | 4.2 | 6.4 | 4.9 | 11.1 | 3.1 | 3.5 | 6.1 | 11.2 | | | 23.4 | |
| LSD (.05) | ns | 0.3 | 0.1 | ns | 2.1 | 0.2 | 0.1 | ns | | | ns | |
| Colusa Co, 1999/2000 | | | | | | | | | | | | |
| 0 | 43.8 | 3.7 | 1.5 | 183 | 42.7 | 3.1 | 1.2 | 256 | 1.2 | 0.9 | 306 | 9.9 |
| 30 (as NH4NO3) | 45.1 | 3.7 | 1.5 | 222 | 44.6 | 3.4 | 1.3 | 251 | 1.5 | 0.9 | 325 | 11.0 |
| 60 (as NH4NO3) | 44.4 | 3.7 | 1.5 | 173 | 44.3 | 3.4 | 1.3 | 208 | 1.7 | 1.0 | 296 | 11.8 |
| 30 (as Foliar Urea) | 44.2 | 3.8 | 1.6 | 194 | 45.8 | 3.6 | 1.3 | 241 | 1.3 | 0.9 | 328 | 10.7 |
| CV (%) | 4.19 | 5.7 | 7.5 | 19.0 | 3.5 | 6.0 | 5.7 | 13.6 | 9.4 | 10.2 | 16.2 | 6.4 |
| LSD (.05) | ns | ns | ns | ns | 2.5 | 0.3 | 0.1 | 52 | 0.2 | 0.2 | 81 | 1.1 |
| Colusa Co, 2000/2001 | | | | | | | | | | | | |
| 0 | 39.3 | 3.3 | 1.3 | 134 | 38.3 | 2.5 | 1.1 | 157 | 0.98 | 0.49 | 225 | 9.6 |
| 30 (as NH4NO3) | 39.6 | 3.4 | 1.3 | 138 | 39.4 | 2.8 | 1.2 | 171 | 1.02 | 0.52 | 204 | 10.6 |
| 60 (as NH4NO3) | 39.7 | 3.3 | 1.3 | 121 | 40.0 | 3.0 | 1.2 | 164 | 1.05 | 0.55 | 219 | 11.3 |
| 30 (as Foliar Urea) | 40.9 | 3.6 | 1.3 | 129 | 39.8 | 3.0 | 1.2 | 142 | 1.19 | 0.50 | 225 | 10.7 |
| CV (%) | 3.1 | 6.8 | 5.6 | 12.9 | 4.1 | 7.8 | 6.9 | 13.5 | | | 14.4 | |
| LSD (.05) | ns | ns | ns | ns | ns | 0.4 | ns | ns | | | ns | |
| UC Davis, 1999/2000 | | | | | | | | | | | | |
| 0 | 43.4 | 3.6 | 1.5 | 195 | 42.6 | 2.9 | 1.1 | 207 | 1.2 | 0.8 | 329 | 10.7 |
| 30 (as NH4NO3) | 42.4 | 3.3 | 1.4 | 173 | 44.6 | 3.5 | 1.2 | 195 | 1.2 | 0.9 | 323 | 11.6 |
| 60 (as NH4NO3) | 41.7 | 3.2 | 1.4 | 176 | 43.9 | 3.4 | 1.2 | 230 | 1.3 | 0.9 | 288 | 12.2 |
| 30 (as Foliar Urea) | 42.6 | 3.1 | 1.4 | 176 | 42.3 | 3.1 | 1.1 | 193 | 1.2 | 0.8 | 304 | 10.8 |
| CV (%) | 4.81 | 6.7 | 5.6 | 15.5 | 2.9 | 4.0 | 5.8 | 10.2 | 11.6 | 6.7 | 13.2 | 5 |
| LSD (.05) | ns | 0.4 | ns | ns | 1.6 | 0.2 | 0.1 | 34 | 0.2 | 0.1 | 65 | 0.9 |
| UC Davis, 2000/2001 | | | | | | | | | | | | |
| 0 | 43.9 | 3.6 | 1.6 | 138 | 43.5 | 3.4 | 1.5 | 174 | 1.32 | 0.53 | 293 | 11.3 |
| 30 (as NH4NO3) | 43.4 | 3.6 | 1.5 | 127 | 44.2 | 3.6 | 1.6 | 170 | 1.56 | 0.57 | 266 | 12.0 |
| 60 (as NH4NO3) | 43.4 | 3.6 | 1.5 | 129 | 43.7 | 3.5 | 1.7 | 158 | 1.87 | 0.72 | 300 | 12.7 |
| 30 (as Foliar Urea) | 43.1 | 3.5 | 1.5 | 135 | 45.0 | 3.3 | 1.6 | 143 | 1.41 | 0.60 | 254 | 11.5 |
| CV (%) | 1.9 | 2.8 | 4.8 | 7.2 | 3.1 | 5.5 | 6.5 | 17.5 | | | 12.5 | |
| LSD (.05) | ns | ns | ns | ns | ns | ns | ns | ns | | | ns | |

SPAD: Minolta SPAD-502 Chlorophyll Meter readings.

Table 5. Effects of Anthesis-Time Nitrogen Applications on N-Tissue Content, Biomass, and Grain Protein of "Kronos" Durum Wheat San Joaquin Valley: Dupont Research Facility, Madera Co; J.G. Boswell, Corcoran, Kings Co;and J.G. Boswell Kern Lake, Kern Co

| | Anthesis | | | | 14 Days Post Anthesis | | | | Harvest | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Anthesis-N Rate (lb/acre) | Flag Leaf SPAD | Flag Leaf N (%) | Stem N % | Biomass (g) (m-row) | Flag Leaf SPAD | Flag Leaf N (%) | Stem N % | Biomass (g) (m-row) | Flag Leaf N (%) | Stem N % | Biomass (g) (m-row) | Grain Pro % (12% mb) |
| Madera Co, 1999/2000 | | | | | | | | | | | | |
| 0 | 49.2 | 3.4 | 1.4 | 176 | 50.0 | 3.0 | 0.9 | 256 | 0.7 | 0.4 | 296 | 9.2 |
| 30 (as NH4NO3) | 48.8 | 3.3 | 1.4 | 173 | 51.1 | 3.1 | 1.0 | 244 | 0.9 | 0.5 | 304 | 11.3 |
| 60 (as NH4NO3) | 50.0 | 3.3 | 1.4 | 188 | 52.4 | 3.7 | 1.1 | 244 | 1.1 | 0.6 | 319 | 13.6 |
| 30 (as Foliar Urea) | 45.5 | 3.1 | 1.2 | 171 | 50.5 | 3.4 | 1.1 | 238 | 0.9 | 0.5 | 290 | 10.5 |
| CV (%) | 5.14 | 10.1 | 8.3 | 12.9 | 6.4 | 12.2 | 13.9 | 12.7 | 19.4 | 21.8 | 13.2 | 9.1 |
| LSD (.05) | ns | ns | ns | ns | 5.2 | 0.7 | 0.2 | 50 | 0.3 | 0.2 | 64 | 1.6 |
| Madera Co, 2000/2001 | | | | | | | | | | | | |
| 0 | 57.3 | 4.2 | 1.6 | 118 | 57.1 | 3.1 | 1.2 | 152 | 1.11 | 0.51 | 209 | 13.8 |
| 30 (as NH4NO3) | 57.6 | 4.2 | 1.5 | 130 | 58.4 | 3.9 | 1.5 | 138 | 1.28 | 0.55 | 186 | 15.0 |
| 60 (as NH4NO3) | 57.0 | 4.1 | 1.5 | 103 | 58.1 | 3.8 | 1.7 | 120 | 1.54 | 0.56 | 192 | 15.6 |
| 30 (as Foliar Urea) | 57.9 | 4.4 | 1.6 | 130 | 57.1 | 3.4 | 1.4 | 141 | 1.16 | 0.49 | 219 | 13.7 |
| CV (%) | 4.1 | 7.6 | 4.7 | 20.2 | 4.2 | 8.7 | 10.0 | 26.5 | | | 13.4 | |
| LSD (.05) | ns | ns | ns | ns | ns | 0.5 | 0.2 | ns | | | ns | |
| Kings Co, 1999/2000 | | | | | | | | | | | | |
| 0 | 53.6 | 3.9 | 1.5 | 222 | 52.0 | 3.3 | 1.0 | 268 | 1.0 | 0.6 | 331 | 12.6 |
| 30 (as NH4NO3) | 54.7 | 3.9 | 1.6 | 253 | 52.9 | 3.7 | 1.2 | 242 | 1.1 | 0.6 | 345 | 13.3 |
| 60 (as NH4NO3) | 53.0 | 3.8 | 1.5 | 257 | 53.9 | 3.7 | 1.2 | 295 | 1.0 | 0.6 | 338 | 13.5 |
| 30 (as Foliar Urea) | 54.0 | 3.7 | 1.6 | 237 | 52.7 | 3.6 | 1.1 | 278 | 1.3 | 0.6 | 357 | 13.2 |
| CV (%) | 2.43 | 5.1 | 5.2 | 10.9 | 1.8 | 6.6 | 16.1 | 14.4 | 12.2 | 11.7 | 17.7 | 4.8 |
| LSD (.05) | ns | ns | ns | ns | 1.6 | 0.4 | 0.3 | 62 | 0.2 | 0.1 | 97 | 1.0 |
| Kings Co, 2000/2001 | | | | | | | | | | | | |
| 0 | 46.6 | 3.4 | 1.4 | 116 | 51.4 | 2.7 | 1.0 | 200 | 0.77 | 0.41 | 342 | 12.7 |
| 30 (as NH4NO3) | 48.1 | 3.4 | 1.4 | 196 | 52.7 | 3.0 | 1.1 | 224 | 0.82 | 0.40 | 339 | 13.1 |
| 60 (as NH4NO3) | 48.2 | 3.5 | 1.5 | 94 | 51.1 | 2.8 | 1.3 | 188 | 0.93 | 0.41 | 402 | 14.2 |
| 30 (as Foliar Urea) | 51.7 | 3.7 | 1.6 | 163 | 53.3 | 3.2 | 1.4 | 170 | 0.86 | 0.41 | 291 | 12.9 |
| CV (%) | 2.5 | 4.6 | 4.3 | 29.4 | 2.9 | 8.7 | 7.2 | 36.3 | | | 28.3 | |
| LSD (.05) | ns | ns | ns | ns | ns | ns | 0.1 | ns | | | ns | |
| Kern Co, 1999/2000 | | | | | | | | | | | | |
| 0 | 51.2 | 3.9 | 1.4 | 244 | 46.6 | 3.2 | 1.3 | 265.5 | 1.4 | 1.1 | 336 | 13.0 |
| 30 (as NH4NO3) | 51.3 | 3.8 | 1.5 | 238 | 45.8 | 3.1 | 1.4 | 302.8 | 2.1 | 1.2 | 354 | 13.5 |
| 60 (as NH4NO3) | 49.0 | 3.8 | 1.5 | 220 | 45.6 | 3.4 | 1.3 | 258.0 | 2.7 | 1.2 | 347 | 14.1 |
| 30 (as Foliar Urea) | 50.8 | 3.8 | 1.4 | 239 | 48.0 | 3.4 | 1.3 | 312.2 | 1.6 | 1.0 | 373 | 14.1 |
| CV (%) | 4.57 | 5.0 | 8.1 | 11.7 | 4.6 | 6.7 | 9.6 | 15.0 | 23.0 | 11.5 | 15.5 | 4.8 |
| LSD (.05) | ns | ns | ns | ns | 3.4 | 0.4 | 0.2 | 68.5 | 0.7 | 0.2 | 88 | 1.1 |
| Kern Co, 2000/2001 | | | | | | | | | | | | |
| 0 | 53.3 | 3.6 | 1.3 | 182 | 48.6 | 2.2 | 1.0 | 226 | 0.87 | 0.51 | 415 | 12.9 |
| 30 (as NH4NO3) | 53.3 | 3.5 | 1.3 | 182 | 50.9 | 2.5 | 1.0 | 287 | 1.10 | 0.59 | 412 | 14.0 |
| 60 (as NH4NO3) | 51.9 | 3.6 | 1.3 | 165 | 51.3 | 2.5 | 1.1 | 279 | 1.12 | 0.63 | 464 | 14.2 |
| 30 (as Foliar Urea) | 53.6 | 3.7 | 1.4 | 183 | 50.5 | 2.4 | 1.1 | 316 | 0.93 | 0.55 | 447 | 13.4 |
| CV (%) | 2.8 | 2.5 | 5.1 | 26.1 | 4 | 7.6 | 8.5 | 23.8 | | | 8.3 | |
| LSD (.05) | ns | ns | ns | ns | ns | ns | ns | ns | | | ns | |

SPAD: Minolta SPAD-502 Chlorophyll Meter readings.