COMPREHENSIVE RESEARCH ON RICE
ANNUAL REPORT

January 1, 1982 - December 31, 1982

PROJECT TITLE: Problems in the development and ripening of rice grain affecting yield and milling quality

PROJECT LEADER AND PRICIPAL UC INVESTIGATORS: D.S. Mikkelsen, Professor of Agronomy, A.A.R. Hafez, Staff Research Associate. G.P. Deo, G. McKiernan, D. Chamberlain, T. Alexander, Student Assistants; J.E. Hill, C. Wick, S. Scardaci, J. Williams cooperating.

LEVEL OF 1982 FUNDING: Equipment $10,095 and Support $21,388

OBJECTIVES AND EXPERIMENTS CONDUCTED BY LOCATIONS TO ACCOMPLISH OBJECTIVES:

Objective I. To determine how environmental factors, both natural and and management controlled affect the development and ripening of California rice varieties, their yield components and milling quality.

a. Rice grain samples were collected from 8 varieties at 8 production locations for studies of the physical properties of California rice varieties.

b. Field experiments were conducted in Colusa, Glenn, Butte, Sutter, Sacramento Co. and the University Rice Facility to determine the effect of variety and location on the yield and milling quality of very early, early and late maturing rice varieties.

c. Controlled growth environment experiments were conducted to determine the effect of temperature on the filling, maturation and milling quality of a California rice variety.

Objective II. Evaluation of crop management practices which can be controlled to improve rice yield components and milling quality.

a. Field experiments were conducted at the University Rice Facility and Butte Co. (Carl Wick, Coop.) to study variety X nitrogen effects on rice yield and quality.

b. A yield experiment was conducted at the University Rice Facility to study the effect of nitrogen fertilization and time of drainage on rice filling, maturation, yield and quality.

Objective III To determine by analysis of statewide records available from California rice mills, some factors associated with head and total milling yield.

a. This project was undertaken by Dr. Shu Geng in cooperation with J.E. Hill and J. Williams and will be reported separately.

SUMMARY OF 1982 RESEARCH (MAJOR ACCOMPLISHMENTS) BY OBJECTIVE:

Objective I.

Relationships of variety, nitrogen fertilization rates and environmental location on the ripening of rice and their implications on grain yield and quality.

Rice varieties grown in California have growth periods varying from about 140 to 160 days. The growth cycle of California rice is logically divided into three main phases:

(1) Vegetative growht phase, 60-80 days depending upon variety.

(2) Reproductive phase, about 30-35 days, and

(3) Ripening phase, 40 to 60 days. The ripening phase is the most important with reference to rice milling quality, although both yield and quality are influenced by the cultural practices and environment preceeding grain filling and ripening. Ripening occurs over a period of 40 to 60 days in California depending upon the time of planting, variety and climatic conditions prevailing during ripening. The ripening grain undergoes three progressive developmental stages: (1) the milk stage, in which the starchy portion of the kernel changes from a watery fluid to a milky consistency; (2) the dough stage, in which the milky caryopsis turns to a soft dough, (3) the maturation stage in which the caryopsis of each individual kernel becomes fully developed, being hard, clear and free of chlorophyll pigmentation.

The maturation process of grain is identified with an increase in dry matter and a decrease in moisture content. The rate of grain growth is determined by the variety, cultural practices and the climatic conditions which prevail during ripening. California based observations were made on the differences in grain filling period and duration of filling under field conditions in California at locations in Davis (University Rice Facility), Glenn Co. (Wylie Ranch), and Butte Co. (Skinner Ranch). A purpose for the grain filling studies on the varieties California Pearl, M9, S6,S201, M101, M201,M302,M401, CALROSE 76, M7, L201, and California Belle was to determine if filling rates were related to yield and ultimately grain quality. The changes in moisture content at 2 or 3 levels of nitrogen fertilization (depending upon location) and dry matter increase at three locations over 6 harvest periods are shown in figures 1,2, and 3.

Temperature data, taken from the air, water and soil were recorded for each variety. The relationship between grain filling rates, nitrogen levels, climatic conditions and grain yield will be correlated as soon as the data can be tabulated.

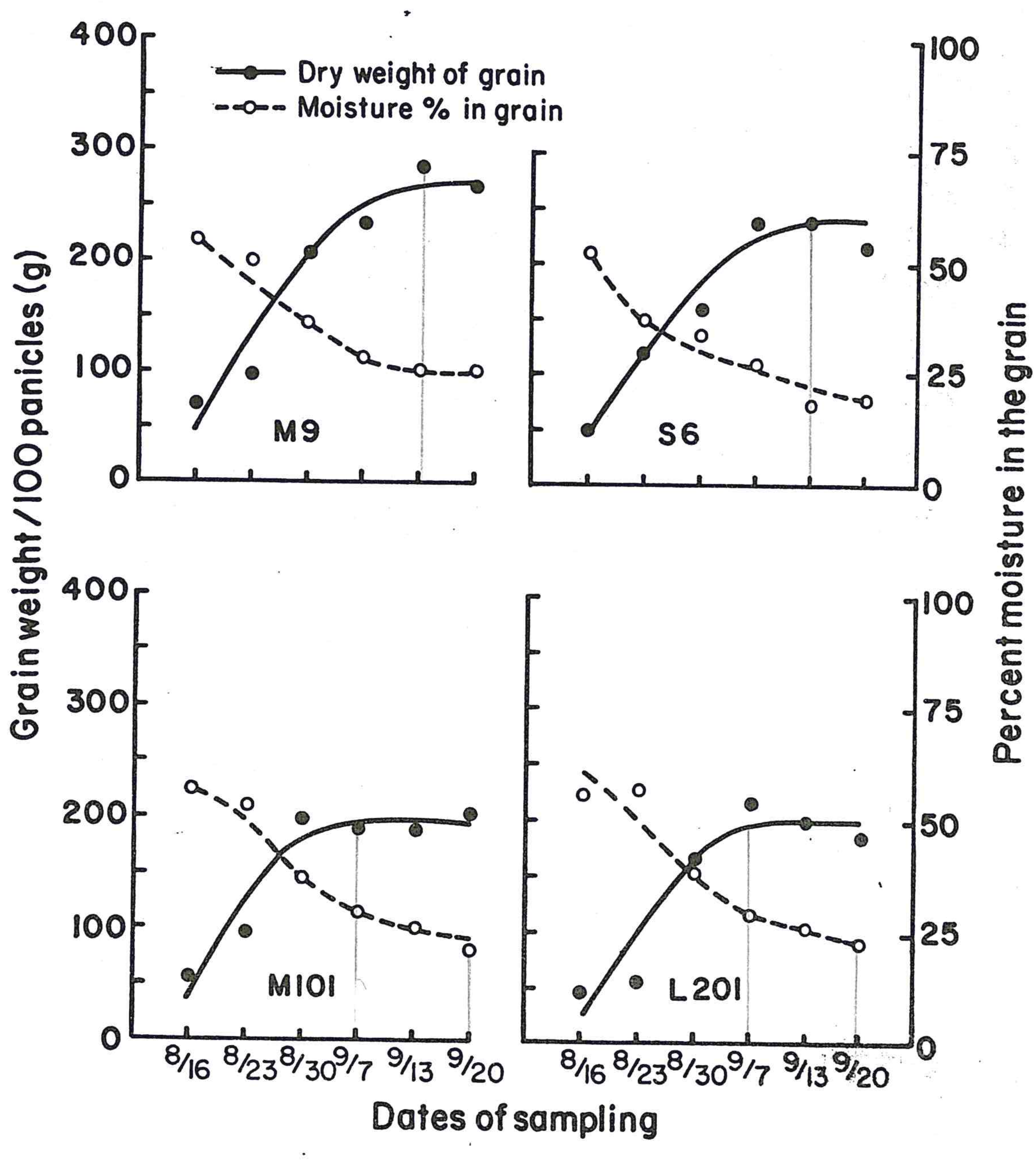


Figure 1. Time of grain filling and moisture content of 8 early maturing rice varieties. (Wylie Ranch, Glenn Co., 1982)

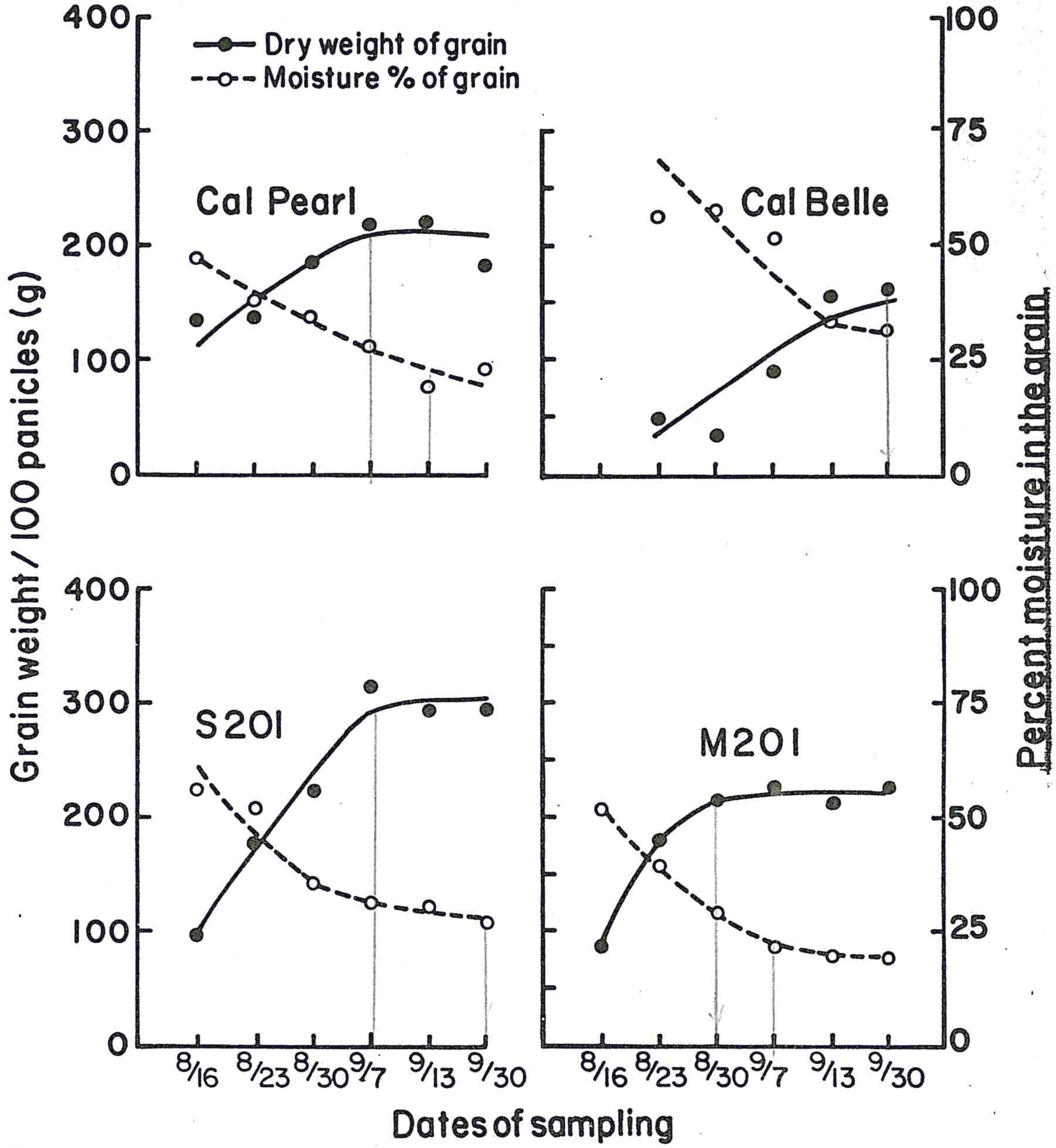


Figure 1 (cont.). Time of grain filling and moisture content of 8 early maturing rice varieties. (Wylie Ranch, Glenn Co., 1982)

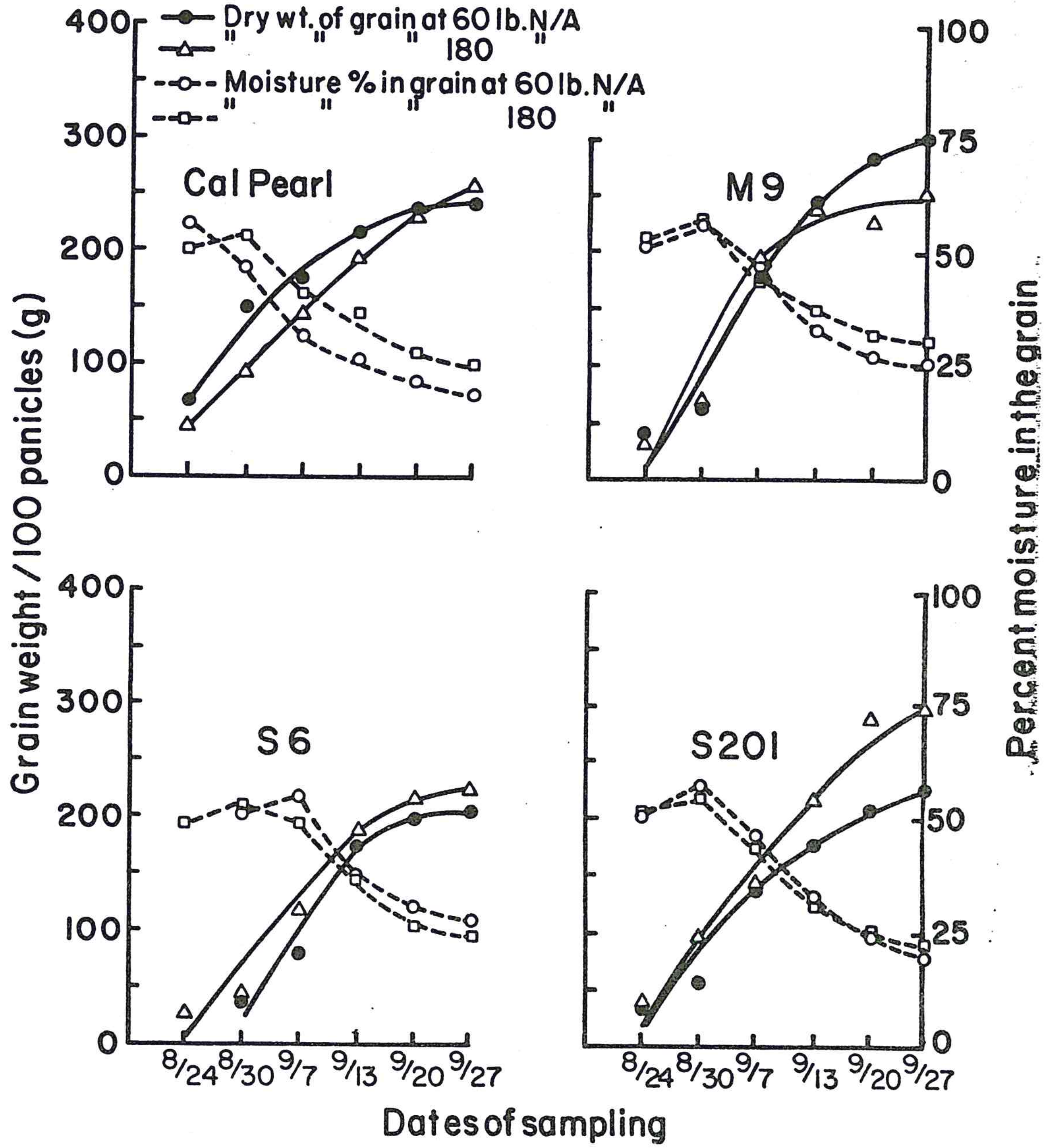


Figure 2. Time of grain filling and moisture content of 8 early maturing rice varieties. (U.C. Davis, Yolo Co., 1982)

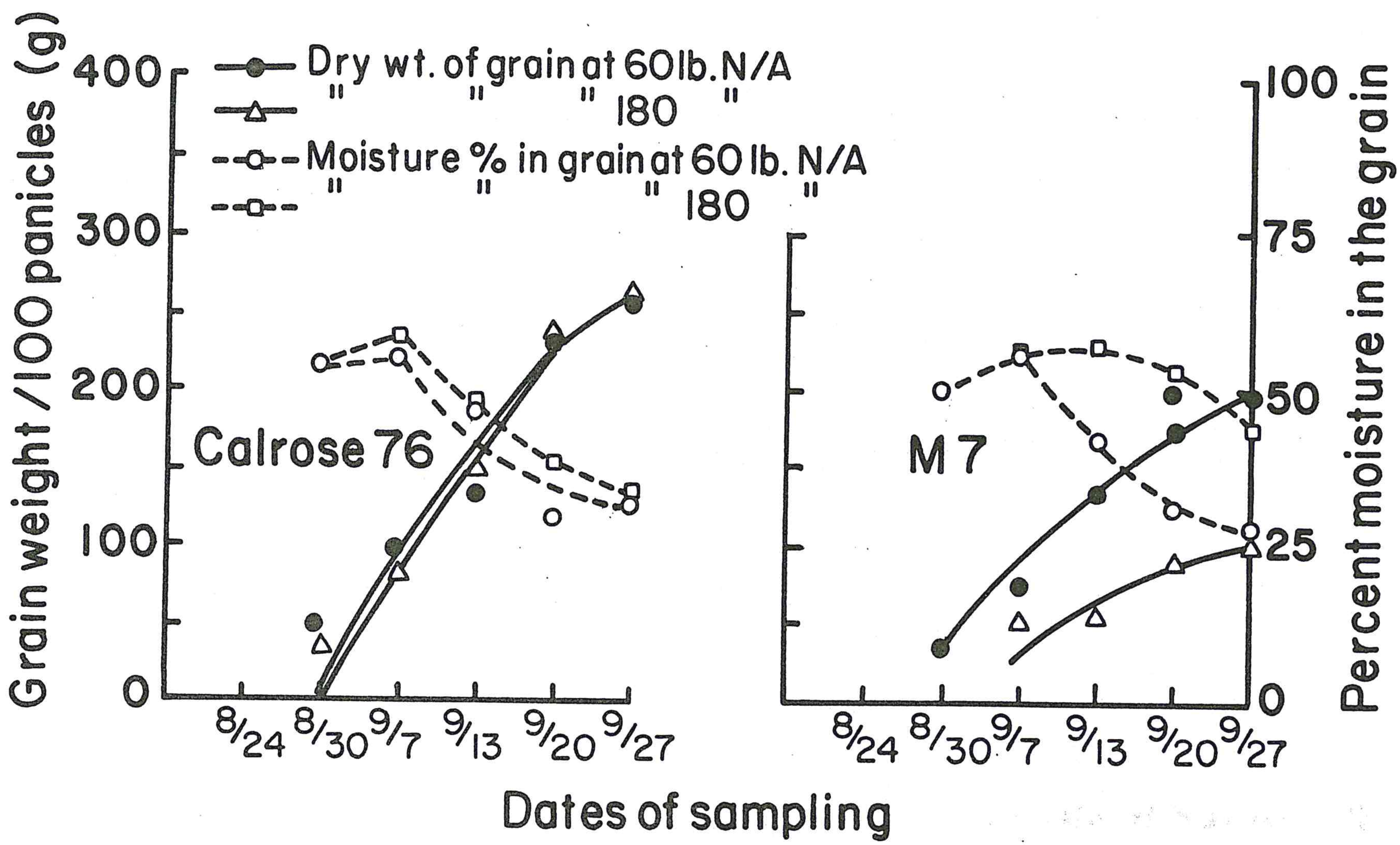


Figure 2 (cont.). Time of grain filling and moisture content of 8 early maturing rice varieties. (U.C. Davis, Yolo Co., 1982)

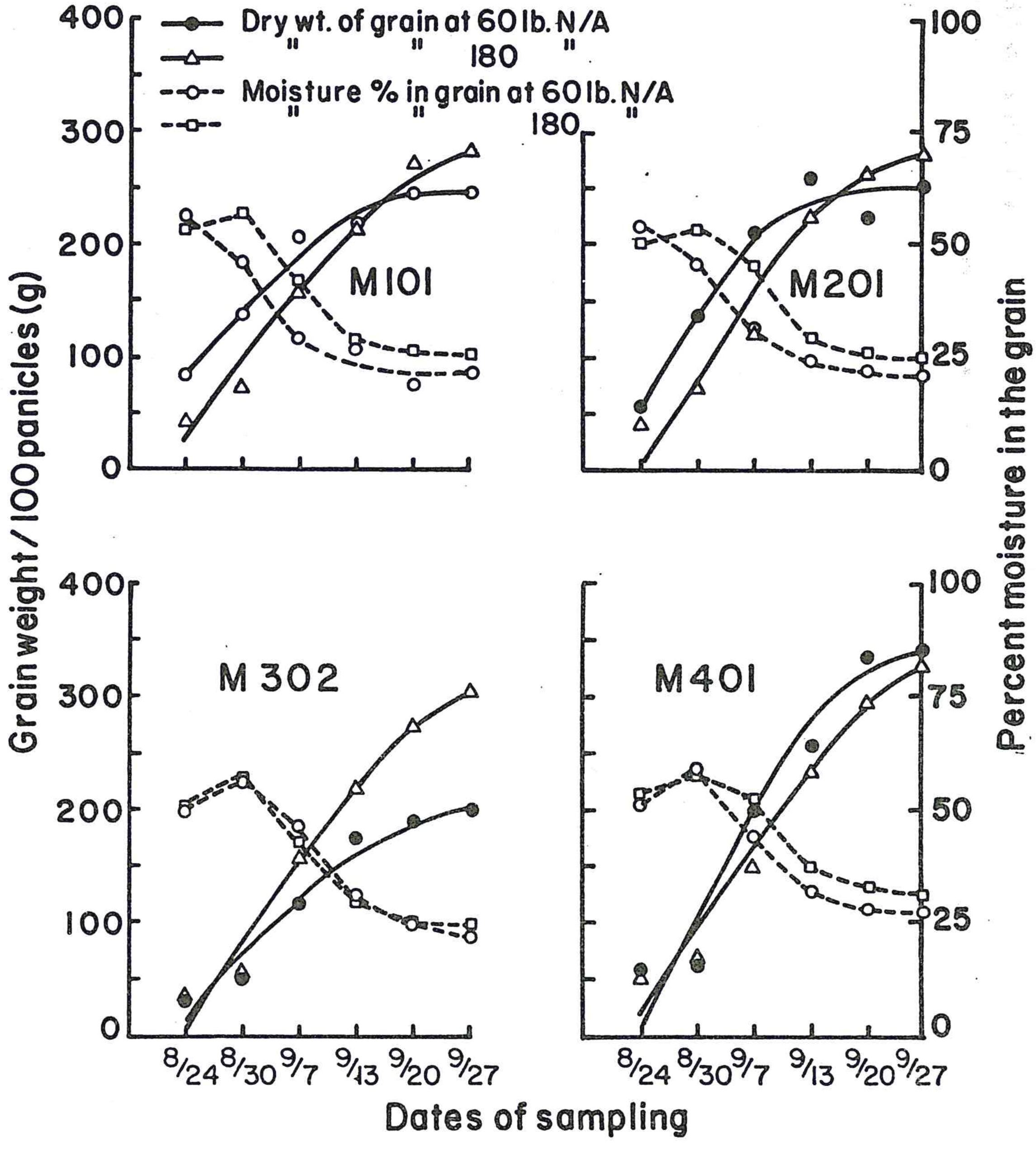


Figure 2 (cont.). Time of grain filling and moisture content of 8 early maturing rice varieties. (U.C. Davis, Yolo Co., 1982)

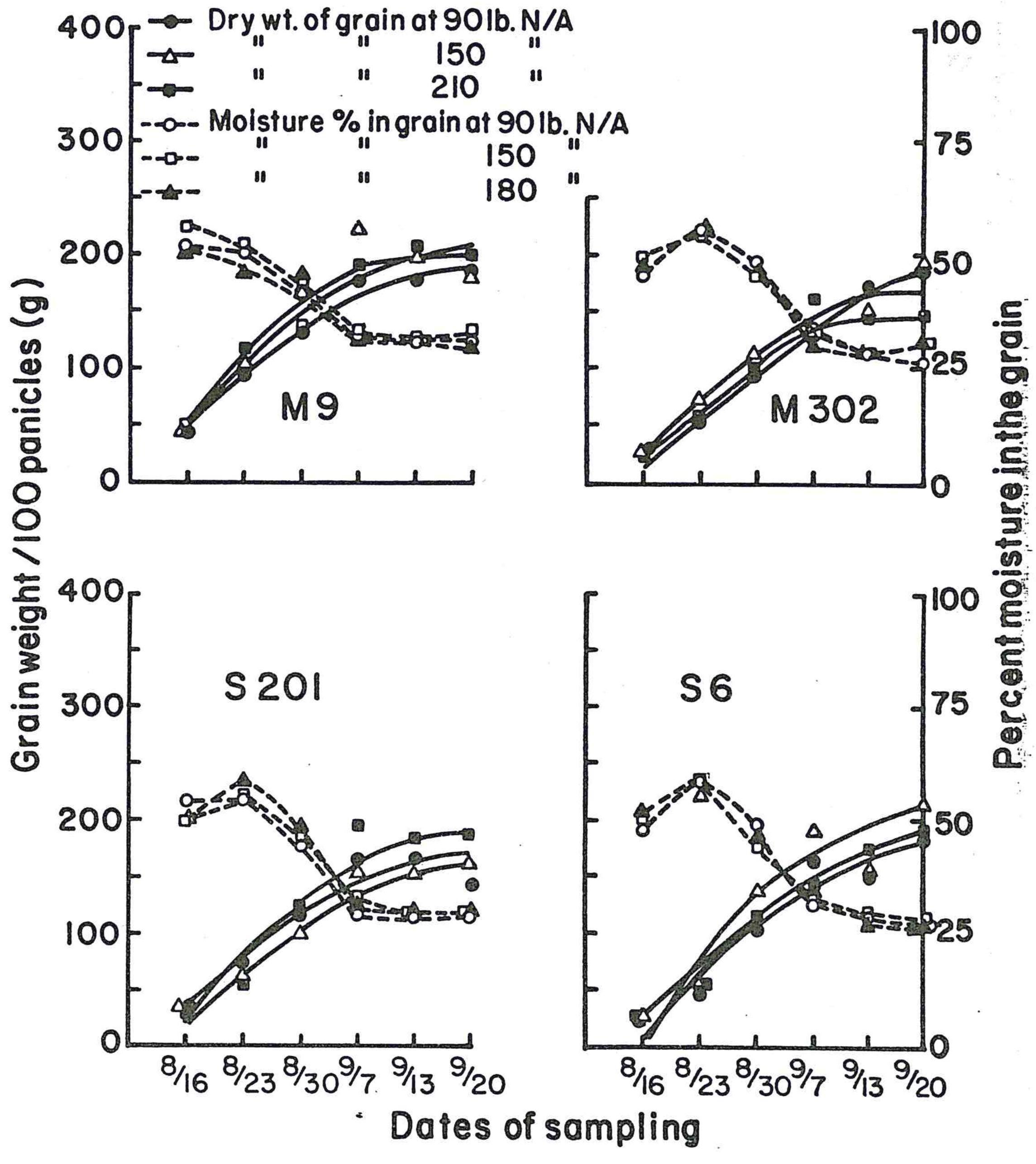


Figure 3. Time of grain filling and moisture content as affected by nitrogen fertilization of 4 early maturing rice varieties. (Skinner Ranch, Colusa Co., 1982)

Objective I (Continued)

Physical Properties of California Rice Varieties Related to Pre-Harvest and Post-Harvest Rice Quality

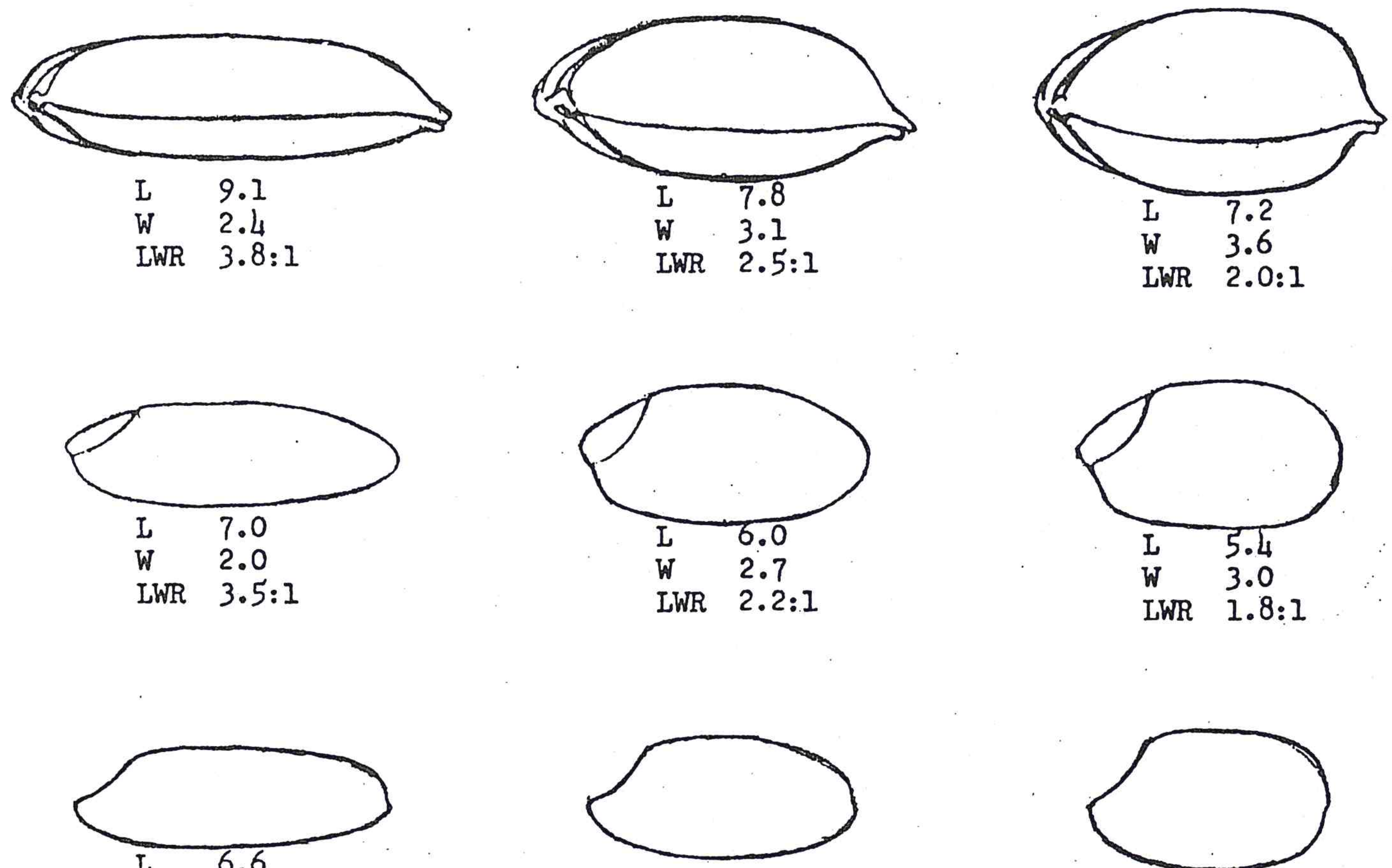
The rice grain is composed mainly of the hull, pericarp, endosperm, and embryo. By proportion of the total kernel weight, the hull composes 15-22%, the pericarp 4-5%, the aleurone layer 12-14%, the embryo 2-3% and the endosperm 65-67% depending upon variety. In post-harvest operations, the grain must be cleaned, dried, stored and ultimately milled for consumer use. These operations subject the rice to various mechanical factors and heat during drying. As a consequence the chemical and physical properties of rough rice may be changed. These various post-harvest treatments must be maintained below a critical level in order to maintain grain quality. For this reason and concerns which exist to properly mill rice, the physical properties of the California rice grain varieties and types must be understood. In California grain properties are important since it is standard practice to co-mingle rice varieties of the same grain type (short-medium) to ease storage problems and to facilitate milling.

One of the more important and practical ways to identify rice physically is by the kernel dimensions of length, width, and thickness. Other grain properties are also important which concern their bulk densities, flow characteristics, presence of awns or pubescence, water sorption, thermal characteristics and potential deformation under various wetting and drying and mechanical forces which stress the grain during harvest.

The grading of rough and milled rice is based directly on the dimensions of grain length, width, and thickness. Rough and milled rice are broadly classified as long, medium and short-grain varieties based on USDA standards. The approximate length, width, and length/width ratios for the various grain types are shown in Figure 4. The dimensions and shape of the rice grain are essential for proper design and adjustment of processing equipment. Cleaning grain, husking and milling function effeciently only if adjusted to the size of the kernel. Uniform size of kernels within a variety is thus very important. It is also important that varieties with different seed sizes, within the same grain type, not be co-mingled if such a procedure reduces total milling yields and head yield.

To evaluate the range of physical differences in the seed of different California rice varieties and grain types, Mr. Ray Porter (Rice Growers Association) provided rough rice samples of 8 varieties of medium and short grain rice types grown in 8 different rice growing areas of California. The varieties sampled included CALROSE, CALROSE 76, M7, M9, M101,M301,S6, and S201 from locations in Willows, Sutter Basin, Williams, District 10, Natomas, Richvale, Sutter Co. and Galt. The samples provided were measured for kernel dimensions of width and length in the rough rice, hulled rice and milled rice forms. Quality data is being developed from the samples to correlate rice physical dimensions with milling quality.

Figure 4. Approximate Length (L) and Width (W) in millimeters and Length/Width Ratio (LWR) for Kernels of Rice



	Long Grain	Medium Grain	Short Grain
Paddy Kernels	L 9.1 W 2.4 LWR 3.8:1	L 7.8 W 3.1 LWR 2.5:1	L 7.2 W 3.6 LWR 2.0:1
Brown Rice Kernels	L 7.0 W 2.0 LWR 3.5:1	L 6.0 W 2.7 LWR 2.2:1	L 5.4 W 3.0 LWR 1.8:1
Milled Rice Kernels	L 6.6 W 1.9 LWR 3.4:1	L 5.6 W 2.4 LWR 2.3:1	L 5.0 W 2.8 LWR 1.8:1

A summary of the physical characteristics of rough rice, hulled rice and milled rice for the 8 varieties and 8 locations are shown in Table 1, 2 and 3. A complete analysis of these data will be made as further statistical computer data becomes available.

Effect of Day and Night Temperature on Grain Filling

The effect of day and night temperatures, 20° C, 25° C, and 30° C daytime temperature and a constant 25° C night temperature on the growth of grain of Var M101 was studied in a controlled environment growth chamber. Fig. 5. The growth rate of individual grains at these temperatures was determined during a period of 50 days after flowering (50%). From preliminary data it can be seen that the rate of grain size development occurred faster and the grain filling period shorter as day time temperatures increased. At the 30° C daytime temperature filling was completed in about 25 days, while at 25° C an additional 10 days was required for the grain to reach maximum weight. With daytime temperatures of 20° C an additional 10 days was required for the grain to reach maximum weight. With daytime temperatures of 20° C ripening was greatly delayed, requiring about 40 days for attaining maximum seed weight. It is anticipated that under field conditions that the growth rate of the entire crop will occur later because of different rates of tiller development, and time of heading and anthesis. Additional studies are required to relate filling time of different varieties and growth responses affecting grain quality. Past experience dictates that rapid grain formation and filling, associated with high temperature adversely affects both grain yield and quality.

Objective II

Evaluation of crop management practices which can be controlled to improve rice yield components and milling quality.

Good agronomic practices not only increase grain yields, but also improve the quality of the grain as a result of more uniform maturity. The following agronomic practices contribute to rice yields and quality in California rice culture:

1. Varietal Characteristics

   A. Physical and Chemical Characteristics of Grain

   B. Water Sorption and Desorption Characteristics of Grain

   C. Time of Maturity (See Environmental Conditions)

   D. Uniformity of Ripening (Immature Grain)

   E. Response to Adverse Climatic Conditions during Ripening.

      (1) High and Low Temperature Effects, Winds, Humidity, Day/Night Temperature Variations, Solar Radiation

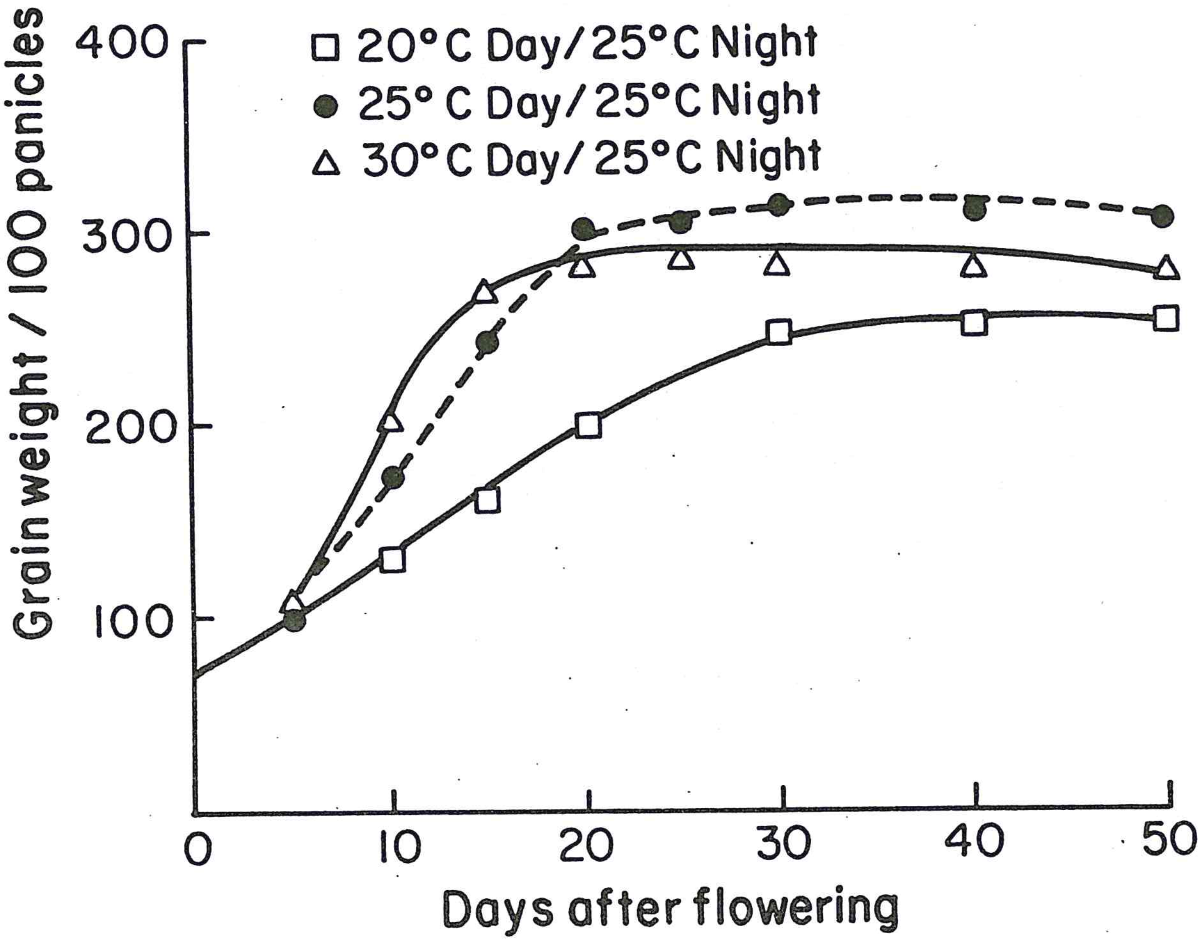


Figure 5. Growth of rice grain (var. M101) at different day/night temperatures in a controlled-climate chamber. (UC-Davis)

2. Time of Planting

A. Grain ripening during periods of wide day/night temperatures or high day temperatures does not favor high head yields

B. Grain quality may deterirate while crop ripens (i.e.) fungi, insects, rodents, birds, lodging, weathering

3. Seeding Rates and Plant Populations

A. High plant populations increase mutual shading effects, nitrogen fertilizer management and possibly increase disease incidence

B. Low plant populations cause increased tillering and create more variation in panicle maturity

(a) non-synchronous heading

4. Nitrogen Fertilization

A. May stimulate late tillering and production of immature panicles, incease panicle sterility

B. May increase incidence of certain foliar diseases

C. Number of spikelets/panicle and percent of filled grains decrease with high nitrogen and mutual shading

5. Source Rate and Timing of Herbicides

Herbicides may modify plant development, tiller production, or cause root pruning contributing to adverse rice quality

6. Timeliness of Pest Control

Disease or insect attack may alter plant growth and influence grain yield and quality

7. Environmental Conditions during Filling and Maturation Stage

A. High temperatures increase respiratory loss and a reduction in supply of plant carbohydrates, causing poor filling and chalky grain

B. Reduced solar radiation (or mutual shading) reduces yield and grain quality

C. Wide day/night temperatures cause chalkiness.

D. High temperatures cause accelerated ripening leading to "sun checking"

E. Dews and rain showers allow dry kernels to re-absorb moisture causing checking

F. Low humidity and desiccating winds cause kernels to dry too rapidly, causing cracks to develop in grain

8. Field Drainage Prior to Harvest

A. Too early removal of water prevents normal ripening, causing formation of shriveled and pinched grain with subsequently increased breakage.

B. Delayed drainage may prohibit harvest at optimum grain moisture content for high head yields.

9. Harvesting at Proper Grain Moisture Percentage

A. Harvesting rice between 20-24% moisture gives highest head yields

B. Use proper combine cutting height to minimize mechanical damage to kernels during harvest

C. Proper combine settings and cylinder speeds reduce mechanical damage.

10. Conditions of Drying, Tempering and Storage

A. Rate of drying and tempering of grain affects "checking"

B. Reabsorption of moisture during storage affects milling quality

11. Milling and Processing Conditions

A. Moisture percentage during milling affects quality

B. Uniform seed size essential to proper milling

C. Quality affected by degree of rice milling and milling equipment

D. Seed movement prior to milling may cause damage

E. Effect of pre-milling storage time and storage conditions influences quality

F. Head yield improves with long storage-volume expansion and water absorption increases

G. Chemical changes in seed protein, starch, and oil affect quality

During the 1982 season field experiments were conducted on the following management factors which can influence rice quality:

1. Variety X Nitrogen fertilization - Butte Co.

2. Variety X Nitrogen fertilization - UC-Rice Facility

3. Variety X Time of Field Drainage - UC-Rice Facility

4. Air temperature effects during grain maturation - UC-Davis Controlled Environment Chambers

5. Variety X Moisture Content at Harvest. Glenn Co., Colusa Co., Butte Co., Sutter Co., Sacramento Co, and University Rice Facility

Data on milling tests from the above trials have not been completed at the time of this report. The data will be reported as soon as data can be tabulated and analyzed. Yield data from variety X location tests are shown in Table 4.

Objective III. To determine by analysis of statewide records available from California rice mills, some factors associated with head and total milling yields.

This portion of the project has been undertaken by S. Geng, J.E. Hill, and J. Williams and will be reported separately.

Table 1 Summary of Physical Characteristics of Rice Varieties

(A) Unhulled Grain (Rough Rice)

S.No. (1)	Variety (2)	Description (3)	No. of Grain Measured (4)	Length (mm) Range (5)	Length (mm) Mean (6)	Length (mm) S.Dev (7)	Pop S.Dev (8)	Width (mm) Range (9)	Width (mm) Mean (10)	Width (mm) S.Dev. (11)	Pop S.Dev (12)
1	Calrose	Sutter,Lot-1088 Can 1287	20	7.12-9.09	8.35	0.52	0.51	2.92-3.33	3.19	0.12	0.12
2	Calrose	Natomas,Lot 1456,Can 1129	20	7.18-9.15	8.05	0.53	0.51	2.94-3.51	3.20	0.15 N_S	0.14
3	Calrose	Williams, Lot 1240 Can 1535	20	7.69-9.72	8.34	0.56	0.55	3.00-3.33	3.18	0.09	0.09
MEAN			20	7.12-9.72	8.25	0.54	0.52	2.92-3.51	3.19	0.12	0.12
1	Calrose 76	Sutter,Lot 1113 Can 1289	20	7.32-9.09	8.26	0.44	0.43	3.00-3.39	3.23	0.09	0.08
2	Calrose 76	Natomas,Lot 1559 Can 1245	20	7.41-8.91	8.21 *	0.44	0.43	3.14-3.48	3.30 *	0.09	0.09
3	Calrose 76	Willows,Lot 906 Can 1723	20	7.53-9.68	8.64	0.60	0.59	3.03-3.39	3.22	0.11	0.11
MEAN			20	7.41-9.68	8.37	0.49	0.48	3.00-3.48	3.25	0.10	0.09
1	Earli-Rose	Galt-Herald Lot 890, Can 1346	20	7.33-9.74	8.31	0.49	0.48	2.85-3.53	3.19	0.17	0.17
2	Earli-Rose	Natomas,Lot 1344 Can 1471	20	7.57-8.97	8.14	0.14	0.40	2.90-3.61	3.27	0.18	0.18
MEAN			20	7.33-9.74	8.28	0.46	0.45	2.85-3.61	3.24	0.15	0.15

Table 1 (Continued)

S.No.	Variety	Description	No. of Grain Measured	Length (mm) Range	Length (mm) Mean	S.Dev	Pop S.Dev	Width (mm) Range	Width (mm) Mean	S.Dev.	Pop S.Dev
1	M7	Williams,Lot 1364, Can 1242	20	7.65-9.48	8.40	0.50	0.49	3.03-3.50	3.18	0.12	0.12
2	M7	Richvale,Lot 1354,Can 1413	20	7.69-9.27	8.26	0.44	0.43	3.00-3.35	3.17	0.09	0.09
3	M7	Sutter, Lot 1238, Can 2117	20	7.55-9.54	8.32 N_S	0.50	0.49	3.03-3.29	3.16	0.09 *	0.08
4	M7	Sutter Basin Lot 1314, Can 1284	20	7.21-8.67	8.07	0.52	0.51	2.90-3.27	3.10	0.10	0.10
5	M7	Willows, Lot 945 Can 1941	20	7.45-8.73	8.28	0.36	0.35	2.87-3.35	3.09	0.12	0.12
MEAN			20	7.21-9.54	8.27	0.46	0.45	2.87-3.50	3.14	0.10	0.08
1	M9	Willows, Lot 630 Can 2089	20	7.73-9.70	8.97	0.45	0.44	2.94-3.40	3.22	0.10	0.10
2	M9	Sutter Basin,Lot 615, Can 2172	20	7.33-9.13 **	8.36	0.48	0.47	3.00-3.44	3.22 N_S	0.11	0.10
3	M9	Williams, Lot 1011,Can 1383	20	7.71-9.11	8.61	0.36	0.35	3.09-3.57	3.25	0.12	0.12
4	M9	D-10, Lot 1241 Can 1668	20	7.83-9.27	8.64	0.43	0.41	3.05-3.48	3.23	0.11	0.11
5	M9	Natomas, Los 1036, Can 4158	20	7-89-9.76	8.65	0.43	0.42	3.09-3.42	3.26	0.09	0.09

Table 1 (Continued)

S.No.	Variety	Description	No. of Grain Measured	Length (mm)				Width (mm)			
				Range	Mean	S.Dev	Pop S.Dev	Range	Mean	S.Dev	Pop S.Dev
6	M9	Richvale,Lot 813, Can 2048	20	8.04-10.35	8.71	0.62	0.60	3.09-3.57	3.27	0.13	0.13
7	M9	Sutter, Lot 761 Can 1138	20	8.20-9.96	9.16	0.39	0.38	3.09-3.48	3.27	0.11	0.11
MEAN			20	7.33-10.35	8.73	0.45	0.44	2.94-3.57	3.25	0.11	0.11
1	M101	D-10, Lot 1173 Can 1570	20	8.20-9.54	8.85	0.34	0.33	3.14-3.61	3.30	0.13	0.13
2	M101	Sutter Basin Lot 799,Can 1871	20	7.87-9.11	8.55	0.39	0.38	3.05-3.59	3.26	0.15	0.15
3	M101	Natomas, Lot 525 Can 4154	20	7.47-8.73	** 8.16	0.44	0.43	2.96-3.33	3.20 **	0.09	0.09
4	M101	Williams, Lot 1401, Can 1485	20	7.89-9.68	8.76	0.53	0.51	3.03-3.50	3.23	0.12	0.12
5	M101	Galt-Herald, Lot 1381, Can 1226	20	7.45-9.19	8.21	0.56	0.54	2.81-3.27	3.12	0.13	0.13
MEAN			20	7.45-9.68	8.51	0.45	0.44	2.81-3.61	3.22	0.12	0.12
1	M301	Willows, Lot 1590, Can 1469	20	7.04-8.85	8.08	0.48	0.47	2.83-3.24	3.10	0.09	0.09
1	S6	Sutter Basin, Lot 232, Can 625	20	6.74-8.30	7.62	0.44	0.43	3.14-3.53	3.33	0.11	0.11
2	S6	Willows, Lot 272 Can 750	20	7.55-8.61	8.00	0.29	0.29	3.14-3.55	3.39	0.11	0.11
3	S6	Richvale, Lot 423, Can 830	20	6.90-8.61	7.72	0.50	0.49	3.09-3.55	3.36	0.12	0.12

Table 1 (Continued)

S. No.	Variety	Description	No. of Grain Measured	Length (mm) Range	Mean	S.Dev	Pop S. Dev	Width (mm) Range	Mean	S.Dev	Pop S.Dev
4	S6	Williams, Lot 60, Can 439	20	7.41-8.77	8.06	0.40	0.39	3.26-3.74	3.47	0.15	0.15
5	S6	Natomas, Lot 297, Can 702	20	7.31-0.09	8.01	0.45	0.44	3.22-3.59	3.40	0.10	0.10
MEAN			20	6.74-9.09	7.88	0.42	0.41	3.09-3.74	3.39	0.12	0.12
1	S201	Natomas,Lot 362 Can 785	20	7.65-8.97	8.30	0.39	0.38	3.35-3.72	3.58	0.10	0.09
2	S201	Williams, Lot 57, Can 403	20	6.84-7.96	7.48	0.35	0.34	3.27-3.68	3.50	0.11	0.11
3	S201	Sutter, Lot 224 Can 654	20	7.35-8.85	7.85	0.37	0.36	3.31-3.72	3.55	0.12	0.12
4	S201	Willows, Lot 18 Can 822	20	6-86-8.46	7.71 **	0.37	0.36	3.37-3.66	3.46 **	0.09	0.08
5	S201	Sutter Basin Lot 68, Can 803	20	7.45-8.54	7.90	0.34	0.33	3.33-3.72	3.53	0.10	0.10
6	S201	D-10, Lot 144 Can 754	20	7.49-8.73	7.93	0.35	0.34	3.29-3.74	3.59	0.12	0.11
7	S201	Richvale Area Lot 237, Can 446	20	6.77-8.34	7.79	0.41	0.40	3.27-3.68	3.52	0.11	0.11
MEAN			20	6.77-8.97	7.85	0.37	0.36	3.27-3.74	3.53	0.11	0.10

Table 2 Summary of Physical Characteristics of Rice Varieties

(B) Hulled Grain

S.No.	Variety	Description	No. of Grain Measured	Length (mm) Range	Mean	S.Dev	Pop S.Dev	Width (mm) Range	Mean	S.Dev	Pop S.Dev
1	Calrose	Sutter, Lot 1088, Can 1287	20	4.70-5.89	5.25	0.33	0.31	2.61-2.83	2.72	0.08	0.08
2	Calrose	Natomas, Lot 1456, Can 1129	19	4.60-5.50	4.99	0.23	0.22	2.55-2.82	2.72	0.08	0.07
3	Calrose	Williams, Lot 1240, Can 1525	20	4.72-5.81	5.25	0.29	0.28	2.62-2.89	2.73	0.07	0.07
MEAN			19.7	4.60-5.89	5.17	0.28	0.27	2.55-2.89	2.72	0.08	0.07
1	Calrose	Sutter, Lot 1113 Can 1289	20	4.74-5.54	5.09	0.19	0.18	2.57-3.01	2.70	0.09	0.09
2	Calrose	Natomas, Lot 1559, Can 1245	19	4.37-5.42	4.94	0.33	0.32	2.59-3.06	2.77	0.10	0.10
3	Calrose	Willows, Lot 906 Can 1723	20	4.54-5.58	5.18	0.26	0.26	2.64-2.97	2.73	0.08	0.08
MEAN			19.7	4.37-5.58	5.07	0.26	0.25	2.57-3.06	2.73	0.09	0.09
1	Earli-rose	Galt-Herald, Lot 870, Can 1346	16	4.99-6.16	5.32	0.31	0.30	2.50-2.87	2.73	0.10	0.09
2	Earli-rose	Natomas, Lot 1344 Can 1471	16	4.85-5.69	5.24	0.28	0.27	2.54-2.94	2.77	0.11	0.11
MEAN			16	4.85-6.16	5.28	0.30	0.29	2.50-2.94	2.75	0.11	0.10

Table 2 (Continued)

S. No.	Variety	Description	No. of Grain Measured	Length (mm) Range	Mean	S.Dev	Pop S.Dev	Width (mm) Range	Mean	S.Dev	Pop S.Dev
1	M7	William, Lot 1364, Can 1242	16	5.11-5.71	5.43	0.19	0.18	2.68-2.83	2.76	0.06	0.06
2	M7	Richvale, Lot 1359, Can 1413	19	4.91-5.81	5.39	0.24	0.23	2.61-2.92	2.75	0.07	0.07
3	M7	Sutter, Lot 1238 Can 2117	19	4.60-5.63	5.13	0.26	0.26	2.61-2.85	2.73	0.07	0.07
			**						**		
4	M7	Sutter Basin Lot 1314,Can 1284	17	4.68-5.67	5.12	0.26	0.26	2.45-2.87	2.69	0.10	0.10
5	M7	Willows, Lot 945 Can 1941	19	4.99-5.50	5.27	0.13	0.13	2.55-2.83	2.68	0.07	0.07
MEAN			18	4.60-5.81	5.27	0.22	0.21	2.45-2.92	2.72	0.07	0.07
1	M9	Willows, Lot 630 Can 2089	20	5.07-6.30	5.81	0.30	0.29	2.55-3.18	2.77	0.13	0.13
2	M9	Sutter Basin Lot 615, Can 2172	19	5.34-5.99	5.61	0.20	0.20	2.64-2.94	2.80	0.10	0.09
3	M9	Williams, Lot 1010 Can 1383	15	5.73-6.47	6.09	0.25	0.24	2.69-2.94	2.84	0.07	0.07
4	M9	D-10, Lot 1241 Can 1668	20	5.44-6.43	5.85	0.27	0.26	2.66-2.96	2.82	0.09	0.08
5	M9	Natomas, Lot 1036 Can 4158	16	4.89-5.99	5.45	0.31	0.30	2.69-2.90	2.80	0.07	0.07

Table 2 (Continued)

S.No.	Variety	Description	No. of Grain Measured	Length (mm) Range	Mean	S. Dev	Pop S. Dev	Width (mm) Range	Mean	S. DEV	Pop S. Dev
6	M9	Richvale, Lot 813, Can 2048	17	5.05-5.95	5.54	0.25	0.25	2.59-2.99	2.83	0.11	0.11
7	M9	Sutter, Lot 761 Can 1138	18	4.74-5.95	5.58	0.34	0.33	2.66-3.01	2.80	0.11	0.10
MEAN			17.9	4.74-6.47	5.70	0.27	0.27	2.55-3.18	2.81	0.10	0.09
1	M101	D-10, Lot 1173 Can 1570	19	4.97-5.83	5.25	0.20	0.19	2.55-2.78	2.68	0.07	0.07
2	M101	Sutter Basin Lot 799, Can 1871	20	5.11-5.85	5.61	0.23	0.23	2.61-2.94	2.78	0.09	0.09
3	M101	Natomas, Lot 525 Can 4154	15	4.62-5.42	5.12 **	0.23	0.22	2.61-2.83	2.74 **	0.06	0.06
4	M101	Williams, Lot 1401, Can 1485	15	4.97-5.81	5.44	0.22	0.22	2.52-2.83	2.72	0.09	0.08
5	M101	Galt-Herald, Lot 1381, Can 1226	16	4.76-5.97	5.21	0.32	0.31	2.50-2.85	2.72	0.11	0.11
MEAN			17	4.62-5.97	5.31	0.24	0.23	2.50-2.94	2.75	0.08	0.08
1	M301	Willows, Lot 1590,Can 1469	18	4.68-5.56	5.18	0.24	0.23	2.57-2.83	2.70	0.06	0.06
1	S6	Sutter Basin,Lot 232, Can 625	20	4.19-5.30	4.92	0.30	0.29	1.94-3.11	2.89	0.25	0.25
2	S6	Willows, Lot 273 Can 750	20	4-62-5.30	4.99	0.18	0.17	2.90-3.13	2.97	0.07	0.07
3	S6	Richvale, Lot 423 Can 830	17	4.21-5.21	4.84	0.24	0.23	2.69-3.13	2.92	0.10	0.10

Table 2 (Continued)

S. No.	Variety	Description	No. of Grain Measured	Length (mm)				Width (mm)			
				Range	Mean	S.Dev	Pop S.Dev	Range	Mean	S.Dev	Pop S.Dev
4	S6	Williams, Lot 60, Can 439	20	4.21-5.44	4.85	0.24	0.24	2.76-3.20	2.98	0.13	0.13
5	S6	Natomas, Lot 297 Can 702	20	4.60-5.44	4.99	0.21	0.21	2.71-3.13	2.99	0.10	0.09
MEAN			19.4	4.19-5.44	4.92	0.21	0.21	1.94-3.20	2.95	0.13	0.13
1	S201	Natomas, Lot 362 Can 785	20	4.78-5.99	5.20	0.24	0.23	2.62-3.15	2.98	0.13	0.13
2	S201	Williams, Lot 57 Can 403	20	4.68-5.19	4.94	0.18	0.18	2.62-3.17	3.02	0.14	0.14
3	S201	Sutter, Lot 224 Can 654	17	4.60-4.91	4.78	0.15	0.14	2.82-3.15	3.05	0.11	0.11
4	S201	Willows, Lot 18 Can 822	19	4.34-5.13	4.77	0.21	0.21	2.89-3.18	3.04	0.08	0.08
5	S201	Sutter Basin,Lot 68, Can 803	18	4.41-5.07	4.75	0.16	0.16	2.78-3.20	3.03	0.11	0.11
6	S201	D-10, Lot 144 Can 754	18	4.46-5.21	4.75	0.22	0.21	2.76-3.18	3.07	0.11	0.11
7	S201	Richvale Area Lot 237, Can 446	20	4.23-5.19	4.76	0.22	0.22	2.90-3.15	3.07	0.07	0.07
MEAN			18,9	4.23-5.99	4.85	0.20	0.19	2.62-3.20	3.04	0.11	0.11

Table 3. Milled Rice Grain (20 grains ave.)

S. No.	Variety	Description	Length (mm) Range	Length (mm) Mean	Length (mm) S.Dev	Length (mm) Pop S.Dev	Width (mm) Range	Width (mm) Mean	Width (mm) S.Dev	Width (mm) Pop S. Dev
1	Calrose	Williams, Lot 1240, Can 1535	4.79-5.74	5.31	0.258	0.251	2.54-2.86	2.66	0.085	0.083
2	Calrose	Sutter, Lot 1088, Can 1287	4.64-5.86	5.17	0.300	0.293 N_S	2.45-2.82	2.61 N_S	0.093	0.091
3	Calrose	Natomas, Lot 1456, Can 1129	4.56-5.54	5.10	0.291	0.283	2.52-2.78	2.66	0.083	0.081
MEAN			4.56-5.86	5.19	0.283	0.276	2.45-2.86	2.64	0.087	0.085
1	Calrose 76	Willows, Lot 906, Can 1723	4.52-5.66	5.13	0.329	0.320	2.51-2.88	2.64	0.080	0.078
2	Calrose 76	Sutter, Lot 1113, Can 1289	4.48-5.44	5.01 N_S	0.304	0.296	2.43-2.88	2.60 *	0.093	0.091
3	Calrose 76	Natomas, Lot 1559, Can 1245	4.62-5.39	4.95	0.269	0.262	2.51-2.80	2.67	0.090	0.088
MEAN			4.48-5.66	5.03	0.301	0.293	2.43-2.88	2.64	0.088	0.086
1	Earli-rose	Natomas, Lot 1344, Can 1471	4.62-5.84	5.28	0.345	0.337	2.45-2.86	2.70	0.099	0.097
2	Earli-rose	Galt Herald Lot 890, Can 1346	4.50-5.72	5.16	0.400	0.390	2.41-2.86	2.67	0.112	0.110
MEAN			4.50-5.84	5.22	0.372	0.364	2.41-2.86	2.69	0.105	0.103

Table 3 (Continued)

S. No.	Variety	Description	Length (mm) Range	Mean	S. Dev	Pop S. Dev	Width (mm) Range	Mean	S. Dev	Pop S. Dev
1	M7	Sutter, Lot 1238, Can 2117	4.58-5.48	5.06	0.286	0.276	2.52-2.84	2.68	0.089	0.087
2	M7	Williams, Lot 1364, Can 1242	4.77-5.76	5.21	0.296	0.289	2.54-2.80	2.69	0.069	0.067
3	M7	Sutter Basin, Lot 1314, Can 1284	4.46-5.68	5.17	0.363	0.353	2.39-2.84	2.62	0.097	0.095
			N_S					N_S		
4	M7	Richvale, Lot 1359, Can 1413	4.56-5.74	5.11	0.327	0.319	2.56-2.86	2.66	0.079	0.077
5	M7	Willows, Lot 945, Can 1941	4.72-5.62	5.27	0.227	0.221	2.47-2.75	2.61	0.076	0.074
MEAN			4.46-5.78	5.18	0.300	0.292	2.47-2.86	2.65	0.082	0.080
1	M9	Richvale, Lot 813, Can 2048	4.54-6.37	5.42	0.449	0.437	2.45-2.93	2.74	0.133	0.130
2	M9	Sutter, Lot 761, Can 1138	4.28-5.96	5.25	0.438	0.427	2.58-2.86	2.72	0.090	0.087
3	M9	Willows, Lot 630, Can 2089	4.66-5.84	5.31	0.378	0.368	2.49-3.08	2.71	0.123	0.120
4	M9	Sutter Basin Lot 615,Can 2172	4.60-5.72	5.12	0.372	0.363	2.52-2.78	2.66	0.087	0.085

Table 3 (Continued)

S. No.	Variety	Description	Length (mm) Range	Mean	S. Dev	Pop S. Dev	Width (mm) Range	Mean	S. Dev	Pop S. Dev
5	M9	Richvale, Lot 1010, Can 1383	4.75-6.08	5.46	0.333	0.325	2.44-3.01	2.74	0.116	0.113
6	M9	D-10, Lot 1241 Can 1668	4.48-6.04	5.26	0.418	0.408	2.51-2.84	2.68	0.077	0.075
7	M9	Natomas, Lot 1036, Can 4158	4.70-6.17	5.44	0.396	0.386	2.56-2.86	2.74	0.076	0.074
MEAN			4.28-6.37	5.32	0.398	0.388	2.45-3.01	2.71	0.100	0.098
1	M101	Williams, Lot 1401, Can 1485	4.04-6.04	5.15	0.738	0.719	2.62-2.93	2.77	0.099	0.096
2	M101	Galt-Herald, Lot 1381, Can 1226	5.21-6.10	5.60	0.290	0.283	2.49-2.47	2.75	0.135	0.131
3	M101	D-10,Lot 1173, Can 1570	4.95-5.78	5.36	0.240	0.234	2.56-3.19	2.73	0.154	0.150
				**				**		
4	M101	Sutter Basin, Lot 799, Can 1871	5.33-6.39	5.75	0.291	0.284	2.64-3.03	2.84	0.133	0.130
5	M101	Natomas, Lot 525, Can 4154	4.97-5.98	5.53	0.263	0.256	2.65-3.06	2.81	0.103	0.100
MEAN			4.04-6.39	5.48	0.364 (0.271)	0.355 (0.264)	2.49-3.19	2.78	0.125	0.121
1	M301	Willows, Lot 1590, Can 1469	4.54-5.62	5.11	0.302	0.294	2.52-2.78	2.62	0.066	0.65
1	S6	Williams, Lot 60, Can 439	4.64-5.54	5.04	0.318	0.310	2.71-3.21	3.00	0.144	0.140

Table 3 (Continued)

S. No.	Variety	Description	Length (mm) Range	Mean	S. Dev	Pop S. Dev	Width (mm) Range	Mean	S. Dev	Pop S. Dev
2	S6	Natomas, Lot 247, Can 702	4.64-5.58	5.09	0.224	0.218	2.91-3.19	3.01	0.109	0.107
3	S6	Richvale, Lot 423, Can 830	4.72-5.46	5.00	0.257	0.251	2.75-3.15	2.96	0.107	0.104
4	S6	Sutter Basin, Lot 232,Can 625	4.62-5.58	5.08	N_S 0.259	0.253	2.78-3.28	3.04	N_S 0.140	0.136
5	S6	Willows, Lot 273,Can 750	4.73-5.37	5.11	0.187	0.182	2.82-3.19	3.01	0.095	0.092
MEAN			4.62-5.58	5.06	0.249	0.243	2.71-3.28	3.00	0.119	0.116
1	S201	Sutter Basin Lot 68, Can 803	4.73-5.44	5.05	0.195	0.190	2.88-3.28	3.11	0.113	0.110
2	S201	Natomas, Lot 362,Can 785	4.68-5.41	5.05	0.225	0.220	2.77-3.21	3.06	0.125	0.122
3	S201	Williams, Lot 57, Can 403	4.66-5.43	5.03	0.204	0.199	2.90-3.28	3.08	0.110	0.108
4	S201	D-10, Lot 144, Can 754	4.66-5.41	5.04	0.220	0.215	2.88-3.27	3.13	0.086	0.084
5	S201	Richvale Area, Lot 237,Can 446	4.62-5.37	4.92	0.219	0.214	2.93-3.23	3.11	0.084	0.082
6	S201	Sutter, Lot 224, Can 654	4.66-5.50	5.00	0.261	0.254	2.86-3.43	3.08	0.139	0.136
7	S201	Willows, Lot 18, Can 822	4.87-5.35	5.04	0.133	0.130	2.97-3.25	3.09	0.102	0.099
MEAN			4.62-5.50	5.02	0.208	0.203	2.77-3.43	3.09	0.108	0.106

Table 4.. Rice yield data from four test locations sampled during 1982

RICE YIELD-QUALITY TRIALS - 1982

Variety	District 10 Sutter Co.	Wiley Ranch Glenn Co.	Lauppe Range Sacramento Co.	Dennis Ranch Colusa Co.
	Grain Yields - Pounds/Acre at 14% Moisture			
M101	8766	9303	8987	--
M9	10034	8410	10114	--
M201	10213	9552	8877	--
S201	10151	9141	9931	--
L201	8945	8339	9620	--
S6	8946	8441	8822	--
Cal Pearl	10151	9972	10140	--
Cal Belle	--	6892	8430	--
M401	--	--	--	8099
M7	--	--	--	9453
M302	--	--	--	9599
Calrose 76	--	--	--	9677
LSD (0.5) Pounds/Acre	573	935	NSD	NSD

Rice Fertilization Experiments - 1982 (not funded by RRB)

Foliar Fertilization of Rice

It is well established that in most plants, including rice, that the period in plant growth from flowering to seed maturity is accompanied by a partial translocation of mineral nutrients from the vegetative plant parts to the reproductive organs. Research has suggested that the nutritional requirements of seeds often exceed the supplying capacity of the roots and that the dificit is partially made up by progressive catabolism of leaf proteins and leaf minerals. It is argued that this progressive removal of nutrients induces early leaf maturity and senescence with a corresponding decline in photosynthesis and ultimate loss of crop yield.

Various companies have had a renewed interest in foliar fertilization with reported success in applying multiple plant nutrients as foliar sprays. Investigations were underaken with rice to determine the effectiveness of such materials in affecting the yield and quality of California rice.

Table 5,6, and 7 report yield data of replicated foliar fertilization trials conducted at the Rice Research Facility, University of California, at the Geer Ranch, Colusa Co. and the Willey Ranch, Sacramento, Ca. with a commercial product Bayfolan-Plus. The material was applied according to label recommendations with 2 rates of application and at multiple stages of rice plant growth.

An additional foliar fertilization study was conducted with two additional foliar materials at the Rice Research Facility - U.C. Davis. Two commercial foliar fertilizers "NZn" (15-0-0-5 Zn) and "Balance" as (9-18-9) were applied at recommended rates and multiple rates at 3 different stages of rice plant development. Yield data obtained from this experiment are reported in Table 8.

In none of the 4 foliar fertilization trials conducted on rice during 1982 was there a statistically significant yield increase in rice grain yields from the use of foliar materials. These results are consistent with those obtained during the period of 1980-1982 in which foliar materials applied between the time of panicle initiation and 50% heading had no significant effect on increasing rice yields.

Table 5. Grain yield of rice (14 % moisture) as affected by Bayfolan-Plus treatments at Rice Facility, Davis (1982)

TREATMENT	TIMING	GRAIN YIELD (lbs/Acre)
Control		6867
1 Quart/Acre	Panicle Initiation	6438
2 Quarts/Acre	Panile Initiation	6128
1 Quart/Acre	Early Boot	6220
2 Quarts/Acre	Early Boot	6565
1 Quart/Acre	50% Heading	6365
2 Quarts/Acre	50% Heading	6448
1 Quart/Acre each	P.I. and Early Boot	6993
1 Quart/Acre each	P.I. and 50% Heading	6978
0.66 Quart/Acre Each	P.I. + Early Boot = 50% Heading	6978
MEAN		6599
F-Test		n.s.
CV %		4.8

Meyers cl
Fertilized with 120 N as Urea -Pre-flood

Table 6. Effects of different rates and forms of foliar nutrient-application on the rice yield (14% moisture) at Geer Ranch (1982)

TREATMENTS	TIMING	GRAIN/YIELD (lbs/Acre)
Control		10512
Bayfolan 1 Qt/Acre	P.I.	10058
Bayfolan 2 Qt/Acre	P.I.	10187
Bayfolan 1 Qt/Acre	E.B.	10406
Bayfolan 2 Qt/Acre	E.B.	10286
Bayfolan 1 Qt/Acre	50% Heading	9890
Bayfolan 2 Qt/Acre	50% Heading	9778
Bayfolan 1 Qt/Acre each	P.I.+ E.B.	10587
Bayfolan 1 Qt/Acre each	P.I.+50% Heading	10313
Complesal 2 Qts/Acre	P.I.	9899
Complesal 2 Qts/Acre	E.B.	10304
Composal 2 Qts/Acre	50% Heading	10574
MEAN		10234
F-Test		ns
CV%		2.85

VAR M101

(Cooperation with S. Scardaci)

Table 7 Effect of different levels of Bayfolan Foliar application at different stages of rice crop on the grain yield (14% moisture) of rice at Willey Ranch. (1982)

TREATMENTS	GRAIN YIELD AT 14% MOISTURE. (lbs/Acre)
Control	7666.2
1 Qt/Bayfolan at PI	8819.9
2 Qt Bayfolan at PI	8373.8
1 Qt Bayfolan at EB	8419.4
2 Qt Bayfolan at EB	8574.1
1 Qt Bayfolan at 50% H	7335.2
2 Qt Bayfolan at 50% H	8505.7
1 Qt Bayfolan at each PI + DB	8887.1
1 Qt Bayfolan at each PI + 50% H	8048.8
MEAN	8292.2
F-Test for treatment	ns
CV %	5.8
LSD 5%	--
LSD 1%	--

PI = Panicle initiation
EB = early booting
50% H = 50% heading
Variety. M7
Net Plot Size = 4'x4'

Cooperative with J. Williams

Table 8. Effect of fertilizers-foliar spray on the grain yield of rice (14% moisture) at Rice Facility, Davis (1982)

TREATMENTS	TIMING	GRAIN YIELD (lbs/acre)
Control		6942
N Zn 2 Quarts/Acre	P.I.	6845
N Zn 4 Quarts/Acre	P.I.	6694
N Zn 8 Quarts/Acre	P.I.	6249
N Zn 2 Quarts/Acre	50% Heading	6803
N Zn 4 Quarts/Acre	50% Heading	6857
N Zn 8 Quarts/Acre	50% Heading	6584
9-18-9 2 Gallons/Acre	P.I.	6662
9-18-9 4 Gallons/Acre	P.I.	6881
9-18-9 8 Gallons/Acre	P.I.	6536
9-18-9 2 Gallons/Acre	50% Heading	6966
9-18-9 4 Gallons/Acre	50% Heading	7270
9-18-9 8 Gallons/Acre	50% Heading	6845
N Zn 8 Quarts/Acre	Milk Stage	6110
9-18-9 8 Gallons/Acre	Milk Stage	6881
MEAN		6742
F-test		n.s.
CV %		3.5

Iron Content of Rice Plant in Relation to Growth

Although the critical nutrient concentration levels for both deficiency and toxicity of many elements in the rice plant have been quite well established, the critical concentration for iron toxicity is not yet clear. According to Tanaka et al. (1966), the critical toxic concentration of iron in rice shoots, when bronzing appeared, was about 300 ppm. Tadano (1976), however, indicated that the critical concentration of iron in the lower leaves on which bronzing appeared were 550 ppm and 1850 ppm, respectively, for the plants grown in 50 ppm and 200 ppm iron in culture solution. The critical concentration also seems to differ between varieties and according to leaf ages, i.e., the older the leaves, the more readily are the bronzing symptoms produced. Bronzing does not develop readily during the early growth stages even in plans grown with high levels of available iron and containing large amounts of total iron. Bronzing does not occur although plant growth is greatly reduced (Tanaka et al. 1966).

Thus the critical concentration levels for iron toxicity reported so far are of questionable realiability because of their inconsistent values, and the lack of physiological significances. The critical concentrations reported have simply been related to occurrence of bronzing symptoms rather than the effect on plant growth.

In our previous studies on the nutritional status of rice, plants were collected from all over . and analyzed for iron and various other elements (Lian 1976). The iron content in shots varied widely from 500 ppm to 2000 ppm and from 200 ppm to 1000 ppm, respectively, at the active tillering stage and at panicle initiation. However, it was difficult to judge if iron toxicity occurred since no bronzing was observed.

Since growth retardation, due to iron toxicity, occurs before bronzing symptoms develop, the relationship between the iron content of rice plants at specific growth stages and plant growth need to be examined.

Ten rice seedlings, two per pot, in the 3-4 leaf stage (cultivar M9) were transplanted to each 6-liter pot, and cultivated with culture solution at pH 4.5 with 2 ppm Fe as described by Yoshida et al. (1972). Graded levels of iron, i.e. 2, 10, 50, 100, and 200 ppm Fe were added to the solution in the form of $FeSO_4$ during the period from 17 to 25 days after transplanting (i.e., during the active tillering stage). Three replications of each iron treatment were used. The culture solutions were renewed weekly until the 17th day after transplanting, and every two days during the iron treatments. The pH's of the culture solutions were adjusted to the value of 4.5 once or twice every day during the treatment period.

The dry weights of individual hills of plants before iron treatment were estimated by obtaining the fresh weight of individual hills and the dry matter percentage of one harvested hill each from the pots before treatment. At 2 and 5 days after treatments, one hill at each date was harvested from each pot, while at 8 days after treatments two hills were harvested from each pot. These plants were oven dried and weighed. The plant growth of different iron treatments were compared at 2,5, and 8 days after treatment by the plant growth indicies which are the percentage ratios of plant weights after treatments to the respective plant weights before treatments.

The rates of potassium uptake in each pot were also tested at two day intervals by measuring the difference of potassium concentrations at and before the change of culture solutions. It was reported that the uptake of phosphorus, potassium and manganese was adversely affected by high level of iron in culture solution (Tanaka et al., 1966), but only the uptake of potassium was tested in this study.

The harvested plant samples were disected into shoot and roots. Only the shoot samples were ground, digested, and analyzed for iron by atomic absorption spectrophotometry. For the samples harvested at 8 days after treatment, the main culm from each hill were further disected into leaves of different positions, i.e., the new apical, the recently matured and the lower leaves. These were analyzed for iron content.

A similar experiment as descrived above, except using 20 liter pots was also conducted and graded levels of rin were added for 10 days during the period from 32 days after transplanting, i.e., approximately during the maximum tiller stage. Two hills from each pot were sampled at 4 and 10 days, respectively, after the treatments and the plant growth indices were determined as before. The rates of potassium uptake for each pot were also measured.

Despite frequent adjustments of pH and change of culture solution, the pH's of the culture solutions fluctuated between 4.5 and 3.7, and 4.5 and 3.1, respectively, under the low and high levels of iron treatments. Under the high level of iron, roots turned reddish brown due to a heavy deposit of ferric iron on the root surface.

1. Effect of iron levels on iron content

The iron content in shoot increased in accordance with the increase of iron level in the culture solution (Fig. 1 and 2). With 202 ppm iron in the culture solution during active tillering stage, the iron content in shoots increased from about 200 ppm to about 750 ppm within two days, and this level persisted for 6 days further with continuous treatment of 202 ppm iron.

The iron content did not increase as much during the maximum tiller number stage as during the active tillering stage in accordance with the increase of iron level in solution. This observation agreed with those reported in the literature, which is attributed to the difference in iron excluding power of roots at different stages of growth.

The iron content of leaves differed according to leaf ages (Fig. 3). In general, the content in the apical leaves was low, irrespective of different iron concentrations in the culture solution or different iron contents in the shoot. On the other hand, the contents of the newly matured or the older leaves were closely correlated with those in the shoot.

2. Effect of iron level on plant growth

Both plant weights and growth indices before and after different periods of iron level treatments during two stages of growth are shown in Table 1. In general, plant weight increased in accordance with the number of growth days, and there was no appreciable difference in the rates of growth expressed as growth indices between the plants with different levels of iron.

The growth indices were also plotted against the respective iron concentrations in the shoot (Fig. 4). The data again showed no appreciable difference of plant growth between the plants of different iron concentration in the range of 200 750 ppm and during the period of 8 days maintaining such iron concentrations. There were also no bronzing symptoms developed on the leaves. These results were quite contradictory to those of Tanaka et al. 1966, and Tadano 1976 who reported significant growth retardation as well as the development of bronzing with even a smaller concentration of iron in the plant. It should be noted, however, that in those experiments in which signficant growth retardations were reported, the lengths of iron treatment were much longer (e.g., 4 weeks as compared to the 8-10 days in this experiment).

Although there was no apparent growth retardation observed for the plant even with 750 ppm iron for 8 days, the rate of potassium uptake was found to be apparently lower in the plants with iron contents greater than 400 ppm after 6 days of the corresponding iron level treatments (Fig. 5). Thus it can be postulated that an iron concentration even as high as 750 ppm may not be directly harmful to the metabolic activities of leaves or shoots at least for the period of 8 days. But judging from the fact that the rate of potassium uptake in such plants had already begun to deteriorate, the growth rate would be lowered soon, if the iron level treatment continued and the high iron content in plant persisted.

SUMMARY

To review chemical criteria for diagnosing iron toxicity in rice, a water culture experiment with graded levels of iron given for different periods of time during the active tillering stage and the maximum tillering stage was conducted. The iron concentrations occurring in plants in relation to growth were studied.

1. The iron concentration of shoot increased sharply during the active tillering stage in accordance with the increase of iron level in culture solution; with 202 ppm in culture solution, the concentration was as high as 750 ppm within 2 days. This level persisted for 6 days further with continuous treatment, however, there was no appreciable growth decrease observed in the plants.

2. The rate of potassium uptake, however, was found apparently lower in the plants with iron concentrations greater than 400 ppm 6 days after the corresponding iron treatments.

3. Thus it is postulated that an iron concentration even as high as 750 ppm may not be directly harmful to the metabolic activities of leaves or shoots at least for the period of 8 days, but judging from the fact that the rate of potassium uptake in such plants had already begun to deteriorate, this growth rate would be lowered if the iron level treatment continued and the high iron concentration in plants persisted.

Table 9. Effect of iron levels given for different periods during two stages of growth on plant weight and growth index (var M-9, (May 20 ~ July 1).

Fe PPM in culture solution / Growth stages treatments given	4	12	52	102	202
	Plant Weight (g/hill) and Growth Index				
Active Tillering Stage					
before treatments	2.32	2.20	2.01	2.35	1.76
2 days after "	2.84	2.72	2.66	2.89	2.19
growth index	122	126	136	124	125
before treatments	2.33	2.27	1.92	2.01	1.89
5 days after "	3.94	3.64	3.15	3.52	2.96
growth index	166	163	166	156	157
before treatments	2.27	2.28	2.21	2.36	1.68
8 days after "	5.27	5.10	4.82	5.15	3.80
growth index	231	225	225	221	228
Maximum Tiller Number Stage					
before treatments	12.5	12.4	12.5	12.4	11.9
4 days after "	14.8	14.7	15.4	13.9	14.5
growth index	119	119	123	112	122
before treatments	12.6	12.4	12.8	12.5	12.6
10 days after "	22.4	23.6	23.4	21.1	23.7
growth index	177	190	182	170	189

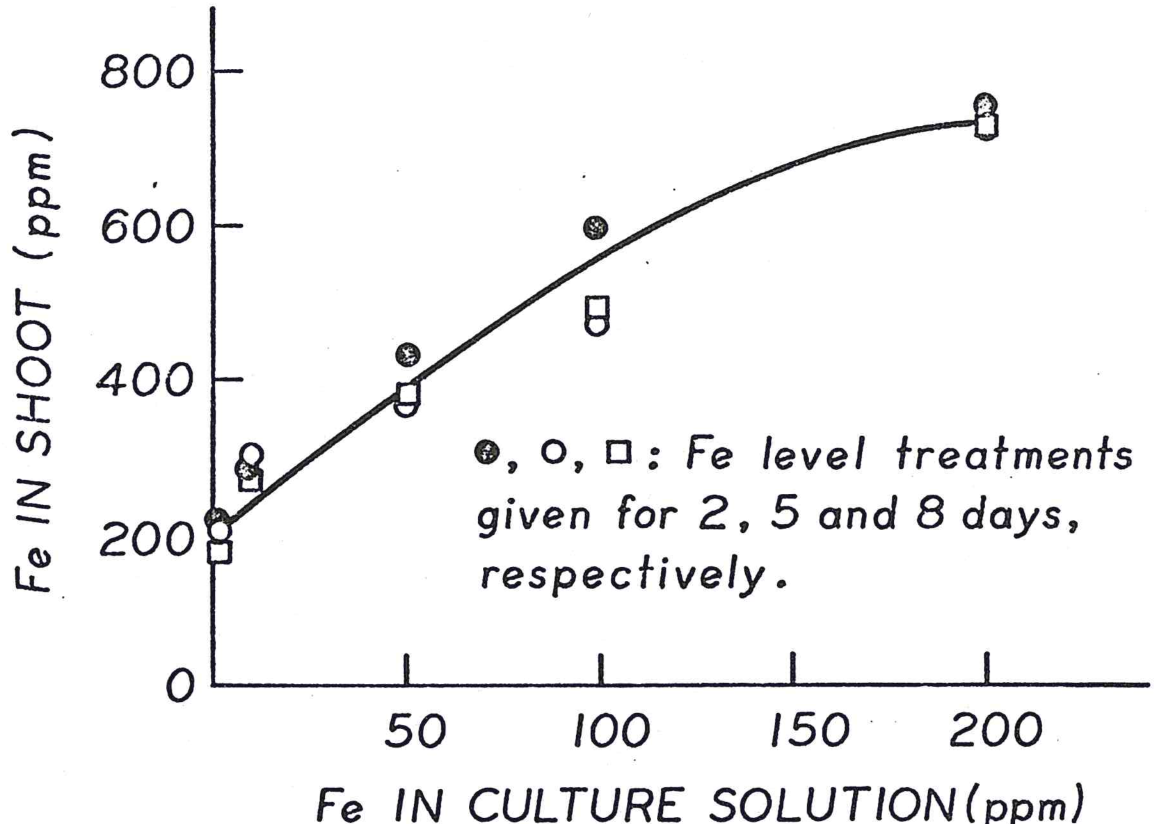


Fig. 1. Effect of iron levels given for different periods of time during active tillering stage on iron content in shoot.

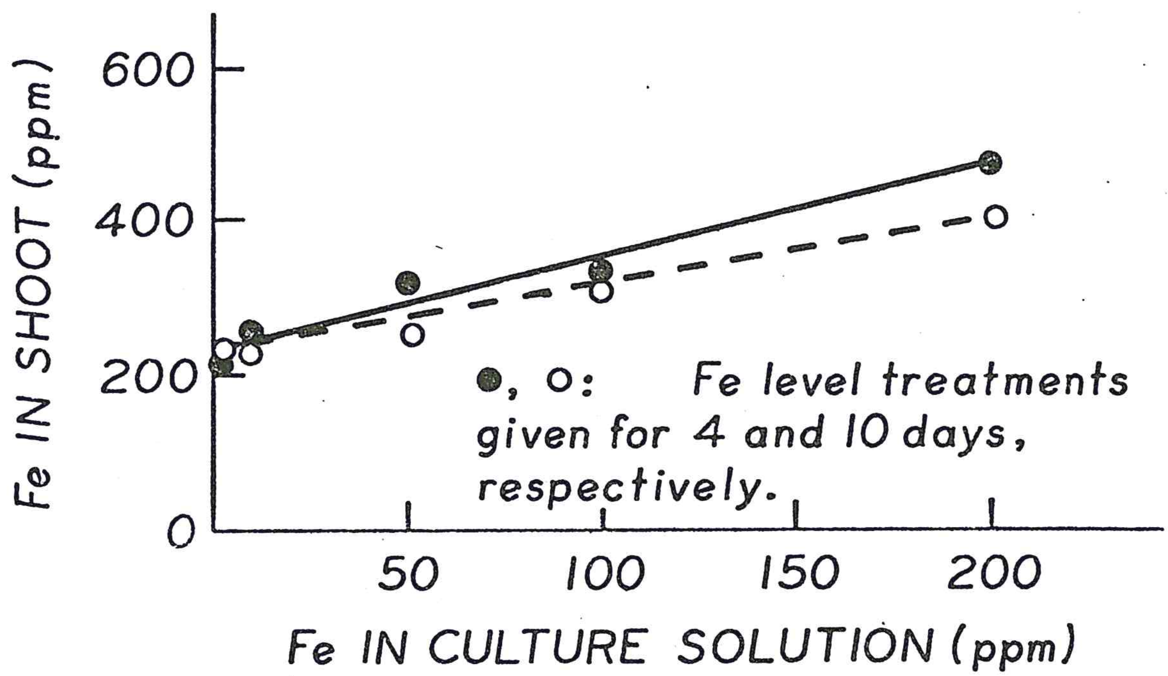


Fig. 2. Effect of iron levels given for 4 and 10 days during maximum tiller number stage on iron content in shoot.

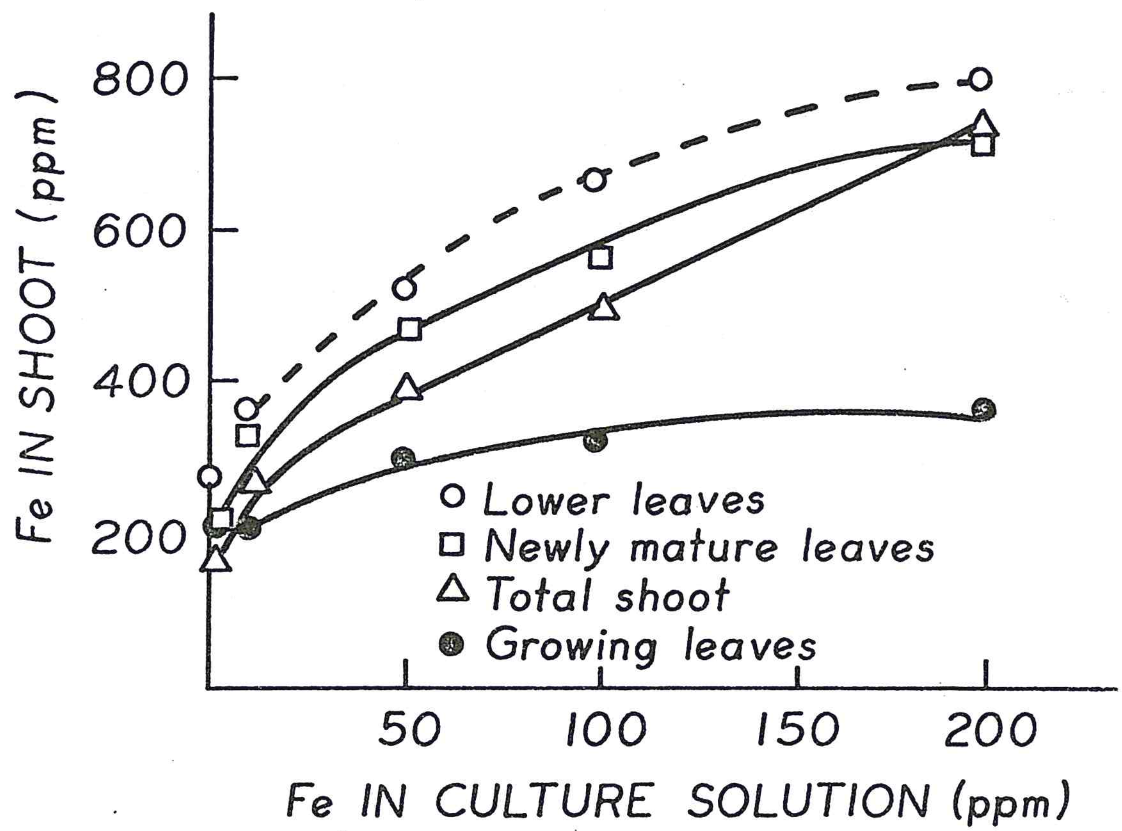


Fig. 3. Iron contents of shoot and leaves of various positions related to iron levels in culture solution.

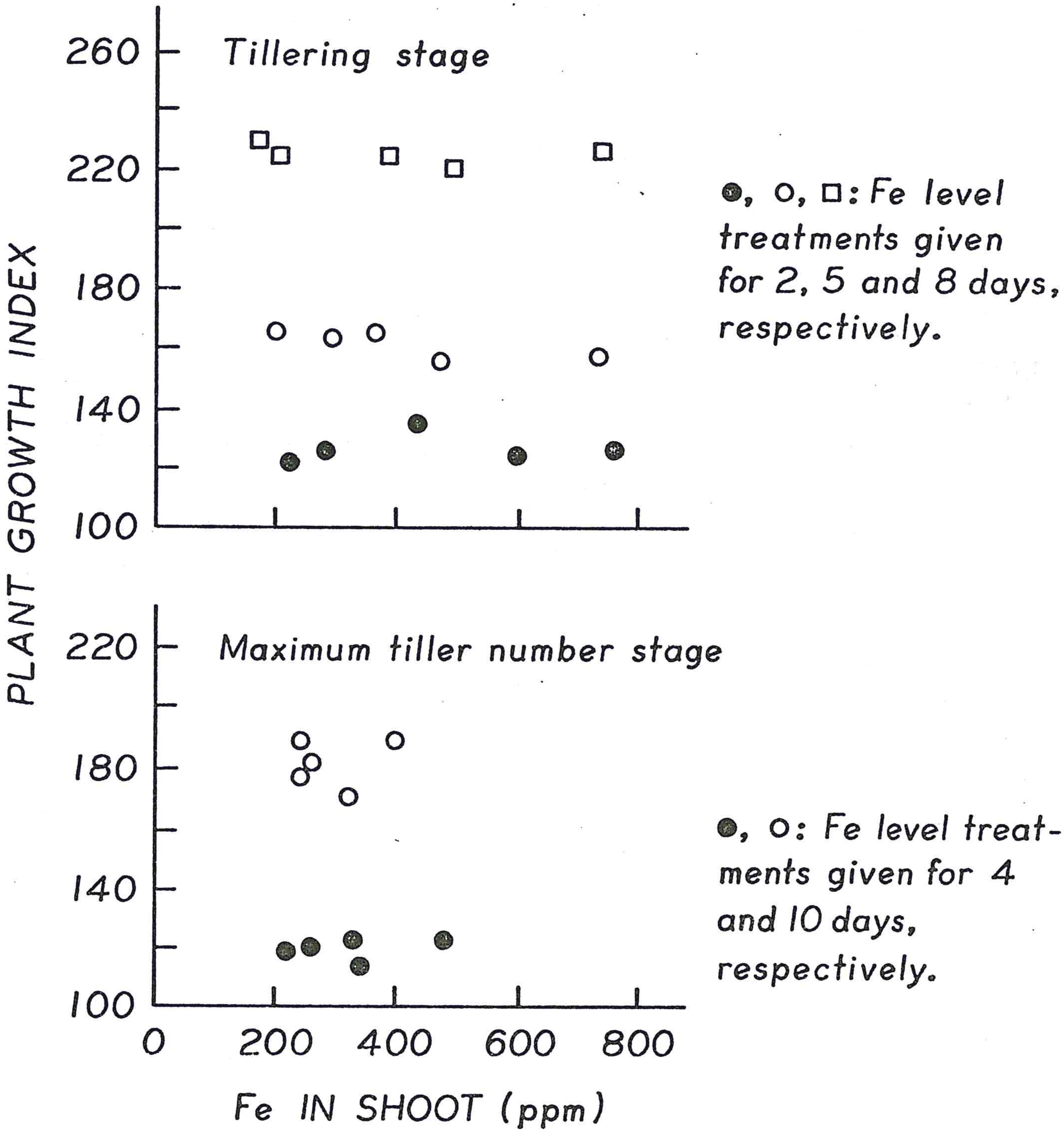


Fig. 4. Plant growth for the periods from the start of iron level treatment to different number of days after the treatment versus iron contents in shoots.

Note: All the values indicated in figures 1 - 4 are the means of three replicates, each replicate consists of either one or two hills.

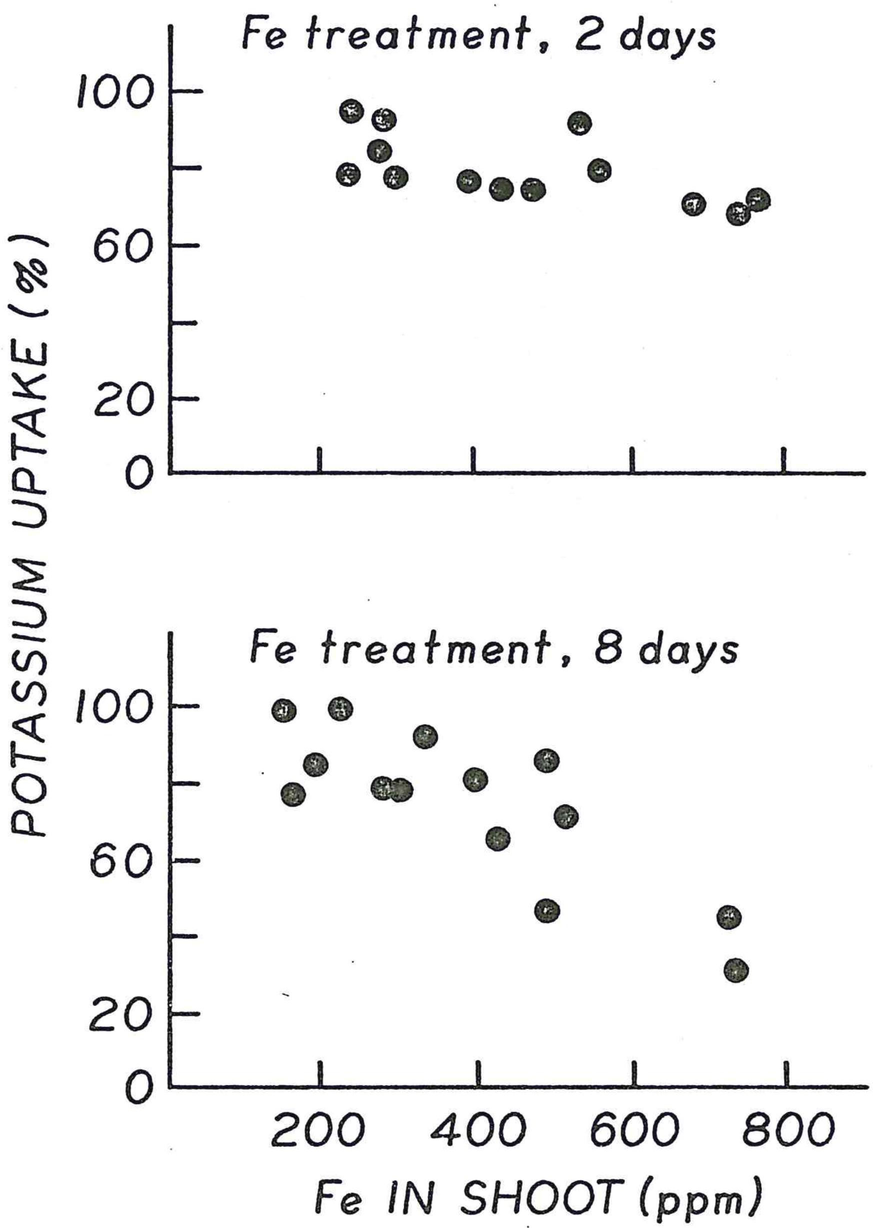


Fig. 5. Relationship between iron content of shoot and percentage potassium in culture solution being absorbed by two days of culturing.

Evaluation of Sulfur-Coated Urea as a Nitrogen Fertilizer

The efficiency of nitrogen use by rice on flooded soils is usually in the range of 30 to 40 percent recovery, a level significantly lower than that observed for many upland crops. The low nitrogen use efficiency of rice grown in flooded soils is usually attributed to potentially greater losses from the flooded soil environment due to nitrification-denitrification, ammonia volatilization, run-off and leaching. The use of improved methods of nitrogen placement and timing, nitrification inhibitors and controlled release fertilizers have been visualized as means by which losses could be diminished and crop fertilizer use efficiency increased.

Field Experiments

During the 1982 rice season in California, field experiments were conducted on typical rice soils to evaluate the effect of two sulfur-coated urea products, namely sulfur-coated urea (25-30% dissolution rate) and forestry grade sulfur-coated urea and also nitripyrin treated urea and commercial grade fertilizer urea. At the time of maturity, an area of 160 ft was harvested from each treatment by a small plot harvester, grain moisture was determined anm all yields were converted to a standard 14 percent moisture basis.

Grain yields obtained on Sacramento clay, Stockton clay adobe, and Willows clay from the certilizer materials at various nitrogen rates, drilled into the soil to a depth of 2-4" prior to flooding are reported in Table 1. Yield data in pounds per acre are listed and the ranking of each treatment is shown in parenthesis.

The grand mean of all three experiments is also given showing the average yields of the experiments and their ranking. Alphabetic designations are given to indicate statistical significance by the Duncan Multiple Range Test. From these combined data there was no significant differences noted in yield of urea and sulfur-coated urea at the 160N rate of application. Likewise in each of the 40 N, 80 N and 120 N rate comparisons, there were no significant yield differences among forestry grade urea, sulfur-coated urea, fertilizer grade urea, and nitrapyrin treated urea. This data suggests that when fertilizer nitrogen is properly placed in the soil, so that it is predominantly in the reduction zone after flooding, that the use of controlled release nitrogen or nitrapyrin treated nitrogen does not affect crop yields that differ statistically from the commercial urea source used in these experiments.

In a nitrogen source and rate experiment conducted on Alamo cl. (University Rice Facility), fertilizers were banded into the soil to a depth of about 10 cm at the time of planting, water was applied to germinate the seed and then drained for 14 days prior to the application of the experiment flood. At harvest time the plots were harvested for grain yield. Moisture samples were collected for each plot and yields were adjusted to a standard 14% moisture basis. The yields obtained from rates and nitrogen sources including sulfur-coated urea, forestry grade urea, nitrapyrin treated urea (1%) and prilled urea are shown in Table 2.

Sulfur coated urea (160 N) produced significantly higher rice yields than prilled urea (160 N) but there were no statistically significant differences in yield from forestry grade urea, sulfur coated urea, nitrapyrin treated urea and prilled urea at the 120 N rate. Similarly, no significant differences were observed with nitrogen sources compared at the 80N and 40 N rates although the sulfur-coated urea and forestry grade urea materials were numerically higher. All fertilizer treatments were significantly better than the unfertilized control treatment.

Table 10 Effect of rate and sources of fertilizer nitrogen on the yield of rice (cultivar 101) at three California locations.

Fertilizer treatment		Grand mean	Sacramento Cl. Colusa Co.	Stockton Cl. Butte Co.	Willows Cl. Glenn Co.
lbs/acre		lbs/acre	lbs/acre	lbs/acre	lbs/acre
160N Urea	9	8412.(1)a	9448.(1)	8311.(4)	7478.(2)
160N SCU	5	8208.(2)ab	8463.(5)	8489.(3)	7671.(1)
120N FGU	11	7991.(3)bc	8207.(7)	8612.(1)	7153.(3)
120N SCU	4	7923.(4)bc	8489.(4)	8550.(2)	6730.(5)
120N Urea	8	7850.(5)bcd	8893.(2)	8070.(8)	6587.(6)
120-N-U-NIT	14	7744.(6)cde	8561.(3)	8134.(5)	6538.(7)
80N Urea	7	7493.(7)def	8281.(6)	8114.(6)	6085.(9)
80N-U-NITR	13	7407.(8)ef	8111.(8)	8109.(7)	6001.(10)
80N FGU	10	7269.(9)f	7539.(9)	8011.(9)	6257.(8)
80N SCU	3	7267.(10)f	7237.(10)	7824.(10)	6740.(4)
40N SCU	2	6454.(11)g	6437.(13)	7249.(12)	5676.(11)
40N Urea	6	6314.(12)g	6605.(12)	7375.(11)	4964.(12)
40N-U-NITR	12	6301.(13)g	6874.(11)	7230.(13)	4800.(13)
Control	1	4895.(14)h	4090.(14)	6287.(14)	4309.(14)
Grand Mean		7252.	7660.	7883.	6213.
CV		6.5	8.6	4.7	5.6
LSD (.05)		379,731	941,571	532,722	498,005
LSD (.01)		502,134	1260,754	714,864	668,692

Table 11 Effect of delayed flooding on rice yields as affected by rates and sources of fertilizer nitrogen.

Fertilizer Treatment	Grain Yield Alamo Cl.
160 N SCU	7231 a
120 N FGU	7057 ab
120 N SCU	6698 ab
160 N Urea	6641 ab
120 N Nitrapyrin	6619 ab
120 N Urea	6483 b
80 N FGU	5645 bc
80 N SCU	5456 c
80 N Nitrapyrin	5079 cd
80 N Urea	5028 cd
80 N SCU	4574 cd
40 N FGU	4167 cde
40 N Nitrapyrin	3789 de
40 N Urea	3425 ef
Control	2922 f

* 14% moisture basis.

RESPONSE OF DRILLED RICE TO NITROGEN FROM SULFUR-COATED UREA AND SCU-DISSOLUTION RATES

Sulfur-coated urea, SCU, has been developed by the National Fertilizer Development Center as a slow-release nitrogen source for crops which may grow where nitrogen losses from the soil are inordinately high and where conventional fertilizers rate low in plant-use efficiency. Nitrogen loss from flooded rice is often high resulting in poor nitrogen use-efficiency ranging from 30 to 40 percent. The nitrogen losses in lowland rice may occur from leaching, ammonia volatilization, nitrification-denitrification and immobilization by organic matter and clay-fixation. Research has shown that the use of a slow-release nitrogen source can minimize these nitrogen losses thereby contributing more available nitrogen to the rice crop. Where flood water can be applied soon after the placement of ammonium-form fertilizers, the nitrogen losses can be minimized, but where fertilizer nitrogen is applied to moist, warm, well aerated soils before flooding, the losses can be inordinately high.

This experiment was designed to (1) compare sulfur coated urea SCU-25 with commercial fertilizer grade pelleted urea in their effects on rice production, and (2) to compare the dissolution rates of SCU-11 and SCU-25, two demonstration materials produced by the National Fertilizer Development Center. Sulfur coated urea (SCU-25) and urea were applied to replicated plots in a randomized-complete block design with four replications of each treatment. The nitrogen rates were 66,99,132, and 165 kg N/hectare from each source. On a Myers clay loam soil, pH 6.3 at the University of California Rice Research Facility. The broadcast materials were incorporated by discing to a depth of 5-10 cm as is conventionally practiced in California. Shortly after fertilization, rice seed, cultivar M101 was drill-planted into the soil and the field was promptly irrigated to start germination. The irrigated rice was drained after 24 hours and then subsequently irrigated three times over 42 days as water was required before permanent flood was applied. The crop received normal cultural practices and the flood was drained two weeks prior to harvest. At harvest time yield data was collected from plots 8'x30', moisture samples were obtained and subsequently all yield data was corrected to a 14% moisture basis.

Simultaneously with the establishment of the field experiment, nylon bags (7x30 cm) were filled with 650 grams of crushed, screened-air dry soil containing 99 kg N/hectare equivalent from SCU-11 and SCU-25. The bags were closed with nylon cord. Four replications of bags, to be removed for assay at six different sampling dates, were placed horizontally in the soil at a depth of 10 cm. These were reconed just prior to the permanent flooding, and at 14 day intervals thereafter, specifically June 25, July 8 and 23 and August 6 and 21, 1981.

One nylon bag was removed for each SCU materal and each replication. The contents of the bags were placed on a 12 mesh screen and the soil was washed away with water. Undissolved SCU residues were retained in the screen, then transferred to absorbent towels for drying. When dry, the SCU residues and adhering soil were crushed to enable removal of the intact SCU granules. The dry weight of the recovered granules was obtained and the dissolution values were calculated as follows:

$$\frac{\text{Ave Wgt of recovered granules} \times \text{\% N in original SCU sample} \times .90}{2.33} \times 100 = \text{\% Recovery}$$

100 = % recovery = % dissolution rate

Results and Discussion:

Yield data from the SCU-25 and urea N fertilizer rate comparisons are shown below:

Fertilization Rate Kg N/Ha	Urea	SCU-25	Nitrogen Rate means
		Kg/ha	
66 N	3100 a	5462 d	4281 b
99 N	3311 a	6244 c	4778 ab
132 N	3410 a	7310 ab	5360 a
165 N	3598 a	7784 a	5691 a
Treatment means	3355 b	6700 a	

Means with the same letter are not statistically different at the 5% level.

Treatment means LSD (.05) = 695 .01 = 946
N rate means LSD (.05) = 983 .01 = 1339

Yield data from the urea-nitrogen treatments indicate that rice grain yields increase slightly with increased rates of N but the difference are not statistically significant. SCU-25 treatments gave a statistically significant yield increase with each increment of added N, with the highest grain yields attained with 165 kg N/ha.

In this flush-drain-flood cultural system, apparently most of the fertilizer N applied as urea was hydrolyzed and nitrified during the 42 days of pre-flood treatment. The nitrogen that was nitrified was presumably lost through drainage or denitrification and did not contribute significantly to increase rice yields. Since rates of 66 kg N/ha through 165 kg N/ha did not give statistically significant differences in yield, it is presumed that most of the fertilizer N was lost. SCU-25, in contrast, gave a step-wise increase in yield with consecutive rates of 66 through 165 kg N/ha. It appears that the slow-release N in SCU-25 was not lost from the soil at the same rate as urea and each increment of nitrogen made a significant contribution to rice grain yields.

The dissolution values obtained for the two SCU materials are reported below for 6 different sampling dates.

Sampling Date	Percent Recovery of Sulfur-Coated Urea Formulations SCU-25	SCU-11
Before Permanent Flood	32.5%	55.5%
June 25	28.0	53.5
July 8	20.6	52.5
July 23	16.5	33.6
August 6	7.5	27.1
August 21	6.0	21.3

Evidence suggests that SCU-25 gave a good pattern of nitrogen release for rice under the experimental conditions imposed, as revealed in the yields of rice. Approximately 2/3 of the total N was dissolved prior to permanent flood and the release thereafter was in a reasonably linear fashion, only 6% of the fertilizer N remained on August 21, about 1 month prior to harvest. This N release pattern appears to be suitable for meeting the N needs of rice. In contrast, SCU-11 dissolution prior to permanent flood, was about 45%. There was a slow initial rate of N dissolution during the 6 week period after the permanent flood. By August 21, about 21% of the fertilizer was still not dissolved, representing a significant portion of N that had no benefit to the rice crop. It appears that the dissolution rate of SCU-11 is too slow for optimum crop performance in this flush-drain-flood system of rice culture.

Plant Growth Regulators in Rice Production

Chemical plant growth regulators, applied as foliar spray materials, have been investigated for several years in UC-rice research. Amongs the products which have given rather consistent rice grain yield increases have been two materials provided by the Abbott Laboratories, namely GA_3 and 6BA. Research plots conducted at UC-Davis during 1982 with results shown in Table 12, show significant yield increases from applications of GA and 6BA applications made during the period of reproductive development. In past years combination treatments of these chemicals have usually performed better than each applied separately, but this was not fully demonstrated in the 1982 trials. It does appear however from several years of observation that a combination treatment of GA + 6BA is desirable when environmental stress factors and general growing conditions require some form to "compensatory regulation".

The growth regulation effects observed with these compounds involve both increase in grain yield and a change in plant form. The two plant growth regulators have an effect of increasing the longivity of leaves, making them capable of photosynthesis over a longer period of time, but also in elongating the panicle above the plant canopy during the period of flowering and grain maturity.

Slow-release Nitrogen Fertilizers for Rice

Slow-release nitrogen fertilizers have several potential advantages over conventional fertilizer sources in (1) being less predesposed to nitrogen loss through nitrification-denitrification, ammonia volatilization and leaching, and (2) slow release of available nitrogen to rice to provide sustained plant development through maturity.

Two experiments were conducted during 1982, in cooperation with Carl Wick and Jack Williams, Farm Advisors, to evaluate a slow release nitrogen fertilizer material commercially called "Melamine-Super 66", which is chemically 2,4,6-treamins - 1,3,5 triazine containing 66% total nitrogen. The fertilizer is a blend of 67% melamine and 33% urea with a fertilizer nitrogen value of 60%. In the 1982 field trials in Butte and Sacramento Co., Melamine was compared with commercial urea at rates of 30,60,90,120, and 180 pounds N per acre. The materials were broadcast onto a rough seedbed and then incorporated to a depth of 2-6 inches by discing. Rice was sown at 150 pounds seed per acre directly into the flood water and subsequently received the usual management practices. At the mid-tillering stage, eight plants were removed by random selection from the fertilized plots for dry matter and growth evaluation. The dry matter data for the two test locations is shown in Table 13.

At the Sacramento Co. location (Natomas) seedling plants grown with nitrogen fertilization were better than the unfertilized control, but there were no statistically significant yield differences due to fertilizer rate or source Melamine and urea responses appear to be about equal. Plant growth differences in the Butte Co. (Kelleher) experiment showed highly signficant mid-tillering differences with urea producing considerably more plant growth than the Melamine source. In this soil it appeared that Melamine did not supply sufficient nitrogen to maintain a high level of crop performance.

Yield data from the experiments in Sacramento and Butte Co. from harvested rice are shown in Table 14. The Sacramento experiment showed a significant yield increase from both Melamine and urea nitrogen sources, but yield differences between sources were not statistically significant. At the Butte Co. location the response of rice to urea was statistically better than from Melamine at all rates of application. The poor seedling growth observed at the mid-tillering stage continued with Melamine fertilization until grain maturity and the poorer performance was reflected in lower grain yields at each level of nitrogen fertilization.

A similar comparison of Melamine and urea fertilizers was made at the Rice Research Facility, UC-Davis, but a flush and drain program of irrigation was used on drill-planted rice. This experiment was to determine how a slow-release fertilizer would perform under the most extreme conditions where nitrogen losses would be promoted. At harvest time yield data was obtained from the Melamine and urea sources supplying 0,30,60,90, 120, and 180 pounds N per acre. Yield data of harvested grain are shown in Table 15.

Under the conditions imposed in this experiment, field nitrogen losses were very high as observed in the small response of the rice crop to nitrogen fertilization. High nitrogen losses observed were also reflected in plant analysis data which showed nitrogen deficiency conditions throughout all plant growth stages. In the final yield data, there were no statistically significant yield responses from rates of fertilizer application or nitrogen source.

Table 12. Effect of Plant growth regulators on the rice yield (14% moisture) at the Rice Facility, Davis (1982).

TREATMENT	TIMING	GRAIN YIELD (lbs/acre)
Control		6701
GA_3 20 ppm	Panicle Initiation	7163
GA_3 20 ppm	Early Boot	7460
GA_3 20 ppm	50% Heading	7090
6BA 20 ppm	Panicle Initiation	7352
6BA 20 ppm	Early Boot	7012
6BA 20 ppm	50% Heading	6473
GA_3 + 6BA 20 ppm each	Panicle Initiation	6891
GA_3 + 6BA 20 ppm each	Early Boot	6745
GA_3 + 6BA 20 ppm each	50% Heading	7217
MEAN		7010
F-Test		Sig. at 5%
CV %		2.7
LSD 5%		550
LSD 1%		738

Table 13. Effect of Melamine and Urea at different levels of N on the Dry matter yield of 8 plants/plot. (mid-tillering stage)

T. No.	Treatments	Dry Matter Yield (g)	
		Sacramento Co.	Butte Co.
1	Control	3.3	26.1
2	60 lb N/Acre as Urea	11.0	35.9
3	120 lb N/Acre as Urea	10.3	67.0
4	180 lb N/Acre as Urea	16.6	64.2
5	30 lb N/Acre as Melamine	4.4	28.8
6	60 lb N/Acre as Melamine	8.4	30.8
7	90 lb N/Acre as Malamine	13.9	30.2
8	120 lb N/Acre as Melamine	15.3	32.5
9	180 lb N/Acre as Melamine	16.9	33.9
MEAN		11.1	39.2
F-Test		n.s.	Sig. at 1%
CV %		29.5	17.4
LSD 5%		10.7	19.9

Table 14. Effect of Melamine and Urea at different levels on the grain yield of rice (14% moisture) at Natomas and Tim Kelleher (1982)

T. No.	Treatments	Grain Yield (lbs/Acre) Sacramento Co.	Butte Co.
1	Control	3106	4452
2	60 lbs N/Acre as Urea	6081	5881
3	120 lbs N/Acre as Urea	8620	8961
4	180 lbs N/Acre as Urea	8993	8786
5	30 lbs N/Acre as Melamine	4961	4860
6	60 lbs N/Acre as Melamine	6658	4799
7	90 lbs N/Acre as Melamine	7069	5534
8	120 lbs N/Acre as Melamine	8339	5752
9	180 lbs N/Acre as Melamine	8513	6250
MEAN		6927	6142
F-Test		Sig. at 1% Level	Sig. at 1% Level
CV %		9.3	5.1
LSD 5%		1875	914

Table 15. Effect of different levels of Urea and Melamine on the grain yield (14% moisture) of rice at Rice Facility, Davis. (1982)

T. No.	Treatments (lbs/Acre	Grain Yield (lbs/Acre)
1	Control	1734.5
2	60 N as Urea	1880.2
3	120 N as Urea	2737.6
4	180 N as Urea	1930.9
5	30 N as Melamine	1541.5
6	60N as Melamine	1737.6
7	90N as Melamine	1741.0
8	120 N as Melamine	1803.0
9	180 N as Melamine	1878.5
MEAN		1790.4
F-Test for treatment		NS
CV %		17.0
LSD 5%		--

Variety M101

CONCISE GENERAL SUMMARY OF CURRENT RESEARCH

A. The kernel dimensions of rice are important varietal considerations since they influence such factors as threshing quality, co-mingling possibilities, water sorption and thermal characteristics, deformation under mechanical stress and milling qualities. The approximate dimensions of grain types are characterized by grain length, width and grain length/width ratios. Medium grain rices should have 5.5-5.9 mm length and 2.4-3.0 mm length/width dimensions while short grains have less than 5.5 mm length and length/width ratios between 2.0-2.39.

Measurements of California medium grain rices were made on 8 varieties collected from 38 locations in California to determine their conformity to established kernel dimensions. These data reveal:

1. The length of unhulled grain of varieties S6 and S201 did not differ statistically in grain length either with variety or area of production in California. Grain width did vary with variety.

2. The length of unhulled grain of varieties Calrose, Calrose 76, Earlirose, M7, M9, M101 and M301 did vary significantly with both variety and area of production. Variety M9 and M101 had longer average grain length than others. The order of grain length was M9 > M101 > Calrose 76 > Earlirose = M7 = Calrose > M301. Grain length also varied with area of production. Grain width also varied with medium statured variety and with location.

3. Among the hulled short grain varieties S6 and S201 there were no statistically significant differences in grain length due to variety or area of production, but grain width did vary with variety.

4. Statistically significant differences exist among the medium grain varieties examined for differences in average length. Hulled grain length of variety M9 was > M101 = Earlirose = M7 > M301 = Calrose and length did vary with area of production. The width of hulled medium grain varieties varied with variety and area of production.

5. The significance of differences in kernel dimensions on such factors of co-mingling of rice and its effect on total milling yield and head yields have not yet been determined.

B. Studies made on the rates and time duration required for grain-filling of California rice varieties were conducted at 3 locations in the Sacramento Valley. Results indicate that genetic differences exist which determine the rate and time required for grain filling and varieties also differ with location effects and cultural practices, particularly levels of nitrogen fertilization. Data are being processed to determine relationships with kernel weight, crop yield and rice quality.

C. Growth chamber experiments provide information on the strong influence exerted by air temperature during the ripening of rice grain. High daytime temperatures of 30 C (86 F) increased the grain filling rate and decreased the grain filling duration of rice variety M101. Daytime temperature of 20 C (68 F) significantly retarded grain development and prolonged the grain filling period. At 30 C daytime temperature grain filling was maximized at about 17 days, at 25 C, 23 days were required and at 20 C about 30 days filling time was required.

D. The effect of rice variety, moisture content at harvest, production location and several management practices on total milling yield, head yield and chalkiness are currently being evaluated. Data are not yet summarized to draw conclusions. Preliminary observations suggest that varietal quality is significantly altered by the percent moisture at harvest, time of harvest and management practices. These observations suggest that greater concern for production and harvesting requirement of specific varieties if optimum quality is to be realized.

E. Foliar fertilization of rice does not appear to significantly improve rice yields in California production where adequate pre-flood soil applications are made. Although rice does pass through a quiescent stage after maximum tiller formation, foliar sprays at panicle initiation, early booting or a 50% heading do not significantly increase rice yields.

F. Iron toxicity can be a problem in flooded acedic rice soils where large amounts of organic matter is incorporated and low redox potentials are attained. Plant composition as high as 750 ppm Fe have been observed in nutrient culture experiment 2 days after exposure to soluble iron. Increased iron composition is accompanied by a large exclusion of potassium so the possibility of a Fe x K interaction is likely.

G. Straw release nitrogen fertilizers evaluated under California conditions have not shown to have a significant yield producing advantage over the commercially available ammonium-nitrogen sources when they are incorporated 4-6" deep in soil prior to flooding.