PROJECT NO. RB-6

COMPREHENSIVE RESEARCH ON RICE

Annual Report
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PROJECT TITLE:

Cultivar and Environmental Influences on Head Rice in California

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OBJECTIVES AND EXPERIMENTS CONDUCTED BY LOCATION TO ACCOMPLISH OBJECTIVES:

1. Quantify the environmental influences of commercial cultivars on head rice under farm conditions through the analyses of California farm and weather data.

   Data from seven years (1979-1985) and 2234 lots were obtained from Butte County RGA. These data were analyzed to evaluate the yields of head rice of commercial cultivars under farm conditions. The effects of temperature and moisture content at harvesting time were updated for old cultivars and quantified for newly released cultivars. The impacts of cultivar replacement on maturity, grain size and head rice were critically investigated.

2. Investigate the effects of cultivar, time of drainage and nitrogen rate applications on the growth and development of panicles, kernel uniformity characteristics and head rice yield.

   Two experiments were conducted in 1986; one at Davis and one at Biggs. Three cultivars (S-201, M-201, and L-202) in combination with three nitrogen levels (low, medium and high) were arranged in nine basins in each location. The basins were drained at different times so that crops could be harvested at various degrees of maturity. Detailed data were collected on panicle growth parameters and kernel characteristics so that the effects of cultivar and management methods on head rice could be studied.

3. Develop and implement computer management programs by which cultural practices can improve the head rice yield.

   This is the ultimate goal of the project. At this stage, we are in the process of generating the necessary information, or data base, to develop management programs. In addition to the above mentioned experiments, we have also collected rice phenological data from 24 fields in Butte County. These fields varied in planted cultivars and planting dates. Observations for leaf stages, tiller development, panicle initiation and time of heading were made in each field. Micrologger weather recorders were placed in three fields so that air, water and soil temperature effects on crop growth and development could be compared.

SUMMARY OF 1986 RESEARCH (MAJOR ACCOMPLISHMENTS) BY OBJECTIVE:

OBJECTIVE 1

Head rice, total rice, moisture content at harvest, and yield data were obtained from Butte County Rice Grower's Association (BUCRA). Temperature data of Butte county were obtained via the computer system in the IPM office at Davis Campus. These data are summarized and presented in Tables 1 to 8. The means and standard errors of the head rice for each maturity group are presented in Table 1, and for each cultivar are presented in Table 2. Likewise, summaries of the total rice are shown in Tables 3 and 4, the moisture contents in Tables 5 and 6, and the yields in Tables 7 and 8.

The average head rice in 1985 was 51.5 percent in Butte County, the second lowest since 1979. The 0.1 percent higher head rice of 1985 over that of 1984 is primarily due to the shift from mostly S-201 in 1984 to mostly M-201 in 1985. Differences of head rice among maturity groups are highly significant ($p > 0.01$, Table 1). M-401 has the lowest head rice (42%, Table 2) and also the lowest total rice (62.7%, Table 4) when compared with all the other cultivars. Due to the small number of lots of M-401, no detailed analysis can be performed on this cultivar. Further careful evaluation of M-401 is needed for future recommendations.

Comparing 1985 to 1979, yields have increased by about 580 lbs per acre (Table 7), but at the same time head rice has decreased by 4.4% (Table 1). According to 1985 prices, every cwt increase in yield means 7 cents more return to the grower, and every percent decrease in head rice (for medium and short grains) costs growers 5 cents less in return. Thus, based on yield alone, there was a potential for a 41 cent per acre increase in return. However, because of decreased head rice, only 22 cents per acre of this was realized. That is, 56% of the potential gains were lost due to milling quality problems.

Table 5 shows the average moisture contents at harvest for each maturity group. There is no statistically significant difference ($p > 0.05$) in the averages of maturity groups. The average moisture concentrations of the cultivars ranged from 20 to 23 percent (Table 6). Fitted curves of head rice in relation to moisture content can be seen in Figure 1. Early cultivars were combined to produce the moisture curves shown in Figure 2. In figure 1 three curves were fitted for each cultivar: the mean curve and the curves based on extreme values. The mean curve was derived by fitting a cubic polynomial function to the average head rice. The average head rice at a harvesting moisture level was calculated from head rice values within 0.5% moisture contents from that level. If a moisture level contained less than 3 lots it was not included in the curve fitting process. Curves of extreme values give us some idea of the actual variation observed in the field, but can't be used to compare cultivars because they depend on the number of lots harvested. The R^2 values of the fitted mean curves ranged from 92 to 99 percent, indicating excellent fits. The estimated minimum moisture required to achieve a maximum head rice return for each cultivar is presented in Table 9. For all cultivars except L-202, the minimum of the optimum harvesting moisture ranged between 21 and 23 percent. L-202 has a rather narrow range of optimal harvesting moisture levels. The head rice increased sharply for moisture level approached 18%, and then decreased sharply as moisture greater than 20%. The estimated best moisture content for L-202 is 18%, which is 3% to 5% lower than the other medium and short grain types. The predicted head rice is highest for Cal pearl (60%) followed by M-201 (56%), if moisture content is at optimal level. The head rice of L-202, M-101 and S-201 are generally lower than the others. No estimation was attempted for M-401 due to the small number of lots.

Head rice in relation to high temperature at harvest has been plotted for each maturity type and is shown in Figure 2. M-101 has consistently lower head rice than other cultivars at any harvesting high temperature. Cal pearl seems to be sensitive to temperature changes. The best harvesting high temperature for Cal pearl are between 80-90°F.

Degree days from planting to harvesting were calculated for each cultivar and year (on the lot basis). The number of days to harvest was divided into 2.5-day intervals. For each year, the mean of degree days to harvest was then calculated for each interval, and a regression line was fitted to these means (Figures 3 and 4). Two general remarks can be made; 1) in a given year, degree days required during the growing season is linearly related to days to harvest, 2) there is large variation in degree days between years. Analysis of variance indicated that 80% of the total degree day variation is due to differences between years and 11.5% due to days to harvest. There is little difference between cultivars. The slopes of changes of degree days per calendar day range between 6.27 for M-9 and 8.37 for Cal Pearl. All the fitted lines (shown in Figures 3 and 4) have R^2-values greater than 0.90, except M-101 in 1981 (45%), Cal Pearl in 1984 (54%) and M9 in 1979 (67%) and 1981 (77%).

OBJECTIVE 2

Seeds of three cultivars (S-201, M-201 and L-202) were sown in Davis on May 5, and in Biggs on May 13. With the combination of 3 nitrogen rates and 9 basins, a total of 81 plots were used in each location. The nitrogen rates applied in the fields were 25, 100 and 175 lbs/acre in Davis, and 50, 125 and 200 lbs/acre in Biggs. Four drainage times were scheduled at each field according to the maturity of the crop at each level. Panicle samples were taken from each plot twice a week after 100% flowering, which first occurred on August 12 at Davis and August 7 at Biggs. Each panicle was divided into three parts (upper, middle, and lower), and 100 grains were randomly selected from each part. Filled and unfilled grains were weighed separately. Growth curves will be fitted to the data to estimate the duration and rate of grain filling and the maximal weight of the kernel. The final harvesting dates were October 26 and October 28 at Biggs and Davis, respectively. Samples that were taken at harvesting will be processed to provide data on kernel characteristics and yield components. The kernel characteristics to be measured include the shape, size, % hull, % bran, density, % total rice and head rice. Results of these data will be presented in future reports.

We have completed analyses of kernel samples from 1984 and 1985 experiments. These results have not been reported previously and are briefly discussed in this section.

Two locations, Biggs and Colusa, were involved in the 1984 study; and three locations, Biggs, Colusa and Davis, were used in 1985. Six cultivars, M-101, S-201, M-201, L-202, M-302 and M7 were compared in the fields. Some 1985 data from Colusa are shown in figure 5. There were two basic types of data collected, panicle growth data and grain characteristic data. Data were obtained from each of the 3 parts of the panicle so that uniformity of the traits could be quantified and their consequences on milling quality could be evaluated. Curves were fitted to the panicle growth data, and the following growth characteristics were derived from the curve: duration of grain filling (days); maximal kernel weight (g); maximal rate and mean rate of grain filling (g/day). Grain characteristics include length, width, depth and weight of the kernel, % total rice and % head rice. The dimensions of the kernel size are used to calculate shape (length/width), volume ($4\pi lwd/3\ mm^3$) and density (g/mm^3). In 1985, % hull and % bran were also measured.

Since our studies were conducted in growers' fields, we have no choice but to harvest all cultivars at a fixed date. As a result, the maturity of the cultivars at harvest was uneven. This is evident from the data of percent greenness which are 4.76, 9.56, 16.78, 22.48, 11.54

and 51.53 percent, respectively, for cultivars M-101, S-201, M-201, L-202, M-302 and M7. This may confound our results of percent head rice and make comparisons between cultivars difficult. Nevertheless, M7 (66.8%) and M-201 (66.7%) have significant higher head rice yields than that of L-202 (61.5%), S-201 (62.7%) and M-101 (63.4%). M-302 has 64.1% head rice which is not significantly different from either group. The middle part of the panicle tends to have higher head rice (64.7%) than the upper part (63.9%) and the lower part (64.1%), though the differences are not statistically significant.

Total rice. L-202's total rice (70%) is lower than that of the other cultivars, and is significantly lower than that of M-101 (72%) and S-201 (73%), which has the highest total rice of the six cultivars tested. It appears that total rice increases from the lower to the upper part of the panicle. The average percentages are 71.3%, 71.9% and 72.2%, respectively, for the lower, middle and upper parts of the panicle. Total rice is significantly ($p < 0.01$) correlated with head rice (= 0.712).

Percent hull. Generally speaking, grains on the upper part of the panicle have higher percent hull content (18.3%) than the middle (18.09%) and lower (18.08%) parts. L-202 has the highest percent hull (19.6%) followed by M-201 (19.0%), M7 (18.1%), M-302 (18.0%) and S-201 (16.5%). Percent hull is significantly and negatively correlated with head rice ($r = -0.456$) and total rice ($r = -0.884$). It is also negatively correlated with volume ($r = -0.734$) and maximal rate of grain filling ($r = -0.443$), but positively correlated with grain shape ($r = 0.683$). Thus the longer the grain, the larger portion of the rough grain is hull and the smaller the volume of the grain. The rate of the grain filling will also be slower for grains with larger proportion of hull. More importantly, grains with greater hull percentage result in less total and head rice.

Percent bran. Contrary to the hull, percent bran is lesser in grains of the upper part of the panicle (8.3%) than in the lower parts (8.5% and 8.8% for the middle and lower part, respectively). However, when % bran is added to the % hull, the resulting sum is smallest on the middle part of the panicle (26.63%) when compared to the upper part (26.65%) and lower part (26.88%). Percent bran is also negatively correlated with total rice ($r = -0.61$).

Shape. The ratios of grain length to width range from 3.3 for L-202, 2.05 to 2.20 for medium size grains and 1.67 for S-201. Overall, the middle part grains are more round-shaped than upper and lower part grains. Shape is also negatively correlated with total rice ($r = -0.348$).

Volume. The average volumes of the grain are 15.15, 14.83 and 14.88 mm^3, respectively, for upper, middle and lower parts of the panicle. Longer grains tend to have smaller volumes: L-202 has the smallest grains (13.89 mm^3), and S-201 the largest (16.93 mm^3). M-101's grain volume is 15.19 mm^3 and the others are between 14 and 15 mm^3. Volume is negatively correlated with shape ($r = -0.478$) and positively correlated with total rice (r = 0.755) and the rate of grain filling (r = 0.515).

Grain filling. Among the three parts of the panicle, grains on the middle part filled sooner (about 2 days) and faster (the mean rate of grain filling is 0.0066 mg/day), and weighed more (the estimated maximal weight is 2.52 mg) than the upper and lower parts. Among the cultivars, M-101 and L-202 require shortest durations for grain filling. The maximal grain filling rates for M-101, L-202, S-201, M-201, M-302 and M7 are 0.127, 0.102, 0.097, 0.097, 0.093 and 0.085 mg per day, respectively. The average kernel weight was greatest for M-101 (2.60 mg) and followed by S-201 (2.58 mg). The lightest is L-202 (2.28 mg).

Density. The average grain densities (mg/mm^3) are 0.1717, 0.1652, 0.1648, 0.1621, 0.1575 and 0.1517 for M-101, M7, L-202, M-302, M-201, and S-201. Density is negatively correlated with head rice (r = 0.264) and total rice (r = -0.295). This is because cultivars (such as M-101 and L-202) that have high average density also have large variation, which reduces head rice. These cultivars have relatively shorter grain filling durations, higher rates of grain filling, and heavier kernels. This results in high average grain densities for these cultivars, but also causes large variation among grains on the panicle.

Uniformity and Interrelationships among traits. The purpose of dividing the panicles into 3 parts was to estimate the uniformity of the above measured and calculated traits. Therefore, for each of the above-mentioned traits, we have calculated the absolute maximal difference between the 3 parts, and used these differences to represent nonuniformity. Correlation analysis was performed on the data to evaluate the relationships among these traits.

All nonuniformities of traits are negatively correlated with head rice, except the total rice (r = 0.376). The associations of variations in maximal weights and density to head rice are statistically significant with coefficients of -0.448 and -0.407, respectively. The other significant correlations are positive, which means that variation in one trait is usually associated with variation in the other trait. The variation of maximal weight of grain is strongly influenced by variation of maximal rate (r = 0.384) and mean rate (r = 0.563) and in turn causes variation in density (r = 0.945). The variations of grain filling characteristics seem to be influenced by the variation of the grain shapes. The correlation coefficients between variations of shape and variations of maximal grain filling rate, mean filling rate and maximal weight are respectively 0.358, 0.409, and 0.322. All variations in grain filling parameters causes variation in density. The correlation coefficient is 0.558 between mean filling rate and density variations, 0.78 between maximal filling rate and density variations, and is 0.945 between maximal weight and density variations. Therefore, it is suggested that grain shape variation determines the grain filling variation which in turn affects maximal weight and density variation and therefore reduces head rice percentages.

Uniformity and cultivars. The six cultivars were ranked based on their average uniformity in each physiological and morphological trait

(Table 10). The last row of table 10 shows the rank order of cultivars according to the average head rice percentages. The first two columns contain predominantly L-202, M-101 and S-201, and the last two columns M-302 and M7. As we have discussed in the previous section, variations (nonuniformity) in any one of the above-discussed physiological and morphological traits either directly or indirectly contribute to a reduction of head rice. When these traits are combined, the overall ranking of the cultivars from less to more uniform is closely correlated with the ranking order based on head rice from low to high yields. These results offer a physiological and morphological explanation as to why M7, M-201 and M-302 have higher head rice yields than L-202, S-201 and M-101. Furthermore, the traits we have evaluated are not necessarily associated with maturity. Therefore, it may be possible to develop cultivars with early maturity and high milling quality. Our analysis indicates that head rice can be improved by selecting cultivars with high degree of uniformity in the above-discussed traits.

OBJECTIVE 3

The timing of critical management actions is most effectively based on the developmental stage of the rice crop, as opposed to the numbers of days after planting. During the vegetative growth period, leaf stage is the appropriate developmental index. The timing of herbicides, pest control, fertilizer applications and water management can therefore be based on the leaf stage of the rice crop. Other developmental events such as early, mid and late tillering, panicle initiation and flowering can also be based on leaf stage.

Degree-day summations have proven useful in the Southern U.S. rice growing region as an environmental index to predict the developmental stage of rice. The utility of degree day accumulation as an environmental index and predictor of the leaf stage of rice will be evaluated.

In cooperation with the Butte County Rice County Growers Association, 22 rice fields were selected to monitor rice growth and development (see figure 6). These monitoring sites were selected to include the three varieties M201, S201 and L202, with a range of planting dates from 4/27 through 5/18. Rice plant development was characterized by measuring leaf stage development for the main stem and primary tillers, tillering, above ground plant weight, flowering, and grain fill.

At three of the locations, dataloggers were installed to record the daily minimum and maximum air, water and soil temperatures for use in degree-day calculations. A single sensor, shielded from direct sunlight, monitored the air temperature 5 feet above the soil level. Water temperature was monitored at four locations, approximately 80 feet from the levee on which the datalogger was installed. The water sensors were placed within a 3 inch PVC pipe and recorded the temperature one inch above the soil surface. Two soil temperature sensors were placed 4 inches below the soil surface, adjacent to two of the water sensors. These datalogger locations (DLL) were used for detailed monitoring of rice growth and development. Adjacent to each of the four water temperature sensors, a single plant was tagged to follow the leaf stage development of the main stem and primary tillers, tiller formation and flowering. Plant samples were taken from a 0.753 ft^2 area adjacent to the tagged plants at 14 day intervals to evaluate stand density, tillering and aboveground plant weight. Grain fill was followed at these DLL by taking 4, 10 panicle samples at 3 to 4 day intervals.

Within the remaining 19 general field locations (GFL) single plants were tagged at approximately 50 yards from both the inlet and outlet boxes. The mainstem leaf stage was scored for each of these plants. Adjacent to these tagged plants, whole plant samples were taken from a 0.753 ft^2 area at 14 day intervals to evaluate stand density, tillering and aboveground plant weight. Grain fill was followed by taking 10 panicle samples at 3 to 4 day intervals at both locations within the GFL.

At six locations, grain was hand harvested from 2 square yards at 3 to 4 day intervals to establish the relationship between grain moisture and milling yield.

The leaf stage is assigned using the following scoring system: The number of the latest fully expanded leaf is added to the decimal percentage of the youngest, partially expanded leaf. The decimal percentage of the partially expanding leaf is scored using the following pretransformed scale:

Decimal Percentage Score	Actual Percentage Range
0.05	0-9%
0.25	10-34%
0.50	35-64%
0.75	65-89%
0.95	90-99%

This decimal scoring system accounts for the distribution of stages within a sampling area and eliminates the problems encountered with skewed behavior of percentage data.

In addition to the plant growth and development data, a detailed survey questionnaire was sent to each cooperator to document their management practices. Information requested included previous crop history, fertility and water management, crop growth evaluation, pest control, harvest methods, and milling appraisal.

The daily air, water and soil temperatures recorded at each DLL are shown in Figure 7. Throughout the growing season, the fluctuation between the high and low air temperatures were much greater than that of the soil and water. Yet, prior to canopy closer, approximately 40 days after planting (DAP), the water frequently reached higher temperatures than the air. After complete canopy closure the fluctuation between the high and low water and soil temperatures decreased dramatically.

Environmental indices were calculated based on the air, water and soil temperatures. These environmental indices included degree-day accumulation (DDA), and mean temperature summation for the air, water and soil. These six indices were plotted against main stem leaf stage of the DLL plants. Minimal differences were observed among the indices, in terms of their ability to describe the rate of leaf development. Air temperature DDA was selected as the representative environmental index to compare with DAP, since air temperature data is much more readily available from various local weather stations and is easily measured on the farm.

Leaf stage development data from representative plants at each DLL were plotted against DAP in figure 8 and air DDA in figure 9. Similar leaf development patterns were observed among the fields for both DAP and air DDA. The patterns of leaf stage development for the main stem and primary tillers were nearly identical, with the primary tillers producing progressively fewer total number of leaves. The utility of DAP and air DDA were evaluated for their predictability of main stem leaf stage development at each of the DLL by fitting the cubic model (see Figure 10). The fitted equations combining all three varieties based on DAP and DDA are:

$$DAP = 6.26X = 0.362X^2 + 0.024X^3, \quad R^2 = 0.952$$

$$DDA = 34.4X + 0.023X^2 + 0.186X^3, \quad R^2 = 0.943$$

These equations generate the required DAP and DDA for each leaf stage. The predicted requirements were compared to the actual observations in the GFL. The DDA for the GFL were calculated from average air temperatures of the 3 DLL. This comparison for eleven representative fields is shown in figures 11 and 12. Excellent agreements were achieved using either DAP or air DDA. The R^2 values using the DLL regression equations to predict the leaf stage development at the GFL ranged from 0.78 to 0.99 for DAP, and from 0.57 to 0.92 for DDA (excluding two fields 26 and 28 which need to be verified). Early season estimations of leaf stage based on DAP were excellent. However, the predicted requirements became biased and underestimated the actual field values after 10 leaves had developed. The DDA prediction of leaf stage at the GFL showed a small, systematic underestimation of the actual observations throughout the growing season. These underestimations may in part be due to the weather data used to make the calculated requirement from the DLL not being representative of the actual temperatures in the GFL. A slight overestimation of the air temperature at the GFL would inflate the cumulative requirement of degree-days in the GFL. A small but insignificant overestimation at each stage could result in a significant deviation of the accumulated degree-days later in the season. Of course, differences in management practices between fields could contribute to the variation observed. The variability associated with management practices may be identified from the information obtained from the survey of the cooperators management practices.

We have established some moisture curves to predict head rice of California cultivars based on growers' data of a large number lots from different locations and years. These curves need to be verified experimentally. Six fields, two planted M-201, two planted S-201 and two planted L-202, were chosen to experimentally estimate the relationship between harvesting moisture and head rice. About 1.5 kg grain samples were taken twice a week from each field. The first set of samples (Sept. 22, 1986) were taken at a moisture content of about 35%, and the last set of samples (Oct. 16, 1986) were taken at roughly 10% moisture. All samples were dried in room temperature until the moisture content dropped below 14% prior to the milling. Millings were done in the USDA Grain Inspection office in Sacramento. Results and the fitted curves for head rice and total rice are shown in Figure 13. There exists no particular meaningful relationship between total rice and moisture levels but all moisture curves of head rice are significant. The estimated optimal moisture levels of harvesting for M-201, S-201 and L-202 are respectively 23%, 24% and 19%, and the estimated maximal head rices of these cultivars are respectively 56%, 58% and 52%.

CONCISE GENERAL SUMMARY OF CURRENT YEAR'S RESULTS:

1. BUCRA data from seven years (1979-1985) and 2234 lots were analyzed. There is a significant difference in head rice among cultivars of maturity groups. The overall averages of very early, early, intermediate and late cultivars are 52%, 53.8%, 55.2% and 57.4% respectively.

2. Since 1979, yields have been increased about 580 lbs per acre but head rice decreased by 4.4%.

3. Cubic polynomial curves were used to fit the head rice as a function of moisture for each cultivar. All cultivars except L-202 have the minimum of the optimum harvesting moisture between 21 and 23 percent. L-202 has a rather narrow range of optimal moisture levels. The head rice increased sharply as harvesting moisture approached 18%, and then decreased sharply for moisture greater than 20%.

4. Four physiological traits of panicle growth and six morphological characteristics of grain have been measured and analyzed for six cultivars. It was found that head rice is significantly affected by percent total rice, volume and density of the grain. Total rice and volume is primarily influenced by the shape and the percent hull of the grain. Density is more or less determined by the physiological traits such as duration and rate of grain filling as well as the volume of the grain.

5. Uniformity is a complex concept which can be defined in many ways. We have found that the maximal absolute difference between grains on different parts of a panicle is a meaningful and effective definition. Based on the differences, we have determined that variations in maximal weights and grain densities are more detrimental to the head rice yields than other variations studied. Furthermore, variations in maximal weight, and grain densities are induced predominantly by variations of rate of grain filling and the shape of the grain.

6. Each of the examined physiological traits and grain characteristics contributes in some way to the head rice yields. The differences of head rice percentage among cultivars can almost perfectly be explained by the relative degree of non-uniformity of these traits

combined. Thus the difference in head rice between L-202, M-101 and S-201 to M-201, M-302 and M7 can now be explained on the basis of plant characteristics and physiological processes rather than on a non-specific term of maturity.

7. The significance of this study is that: 1) since the physiological traits and grain characteristics are not necessarily dependent on maturity, it should be possible through breeding programs to improve head rice yields of cultivars in early and very early maturity groups. 2) Criteria and priority of selection to improve head rice can now be derived from the relationships among traits and their effects on the head rice that were established in this study.

8. Basic phenological data were collected from 22 fields in Butte Co. These data include leaf stage developmental ratio and their relations to degree days and days after planting. This information will be used to help develop and to validate a rice model which can be used as a management tool for California rice growers.

Table 1. Mean and standard error (s.e.) of percent head rice by year and maturity group in Butte County.

Year		Maturity Group				
		V. Early	Early	Int.	Late	All
1979	# lots	1	192	3	55	252
	mean	-	55.0	-	59.0	55.9
	s.e.	-	0.307	-	0.408	0.272
1980	# lots	3	205	2	39	249
	mean	-	56.3	-	59.6	56.7
	s.e.	-	0.253	-	0.423	0.242
1981	# lots	18	272	12	31	333
	mean	47.4	51.5	56.7	57.8	52.1
	s.e.	1.218	0.334	1.260	0.541	0.314
1982	# lots	44	281	10	3	338
	mean	49.3	53.1	54.4	-	52.6
	s.e.	0.732	0.286	0.912	-	0.268
1983	# lots	101	183	-	1	285
	mean	55.1	57.4	-	-	56.6
	s.e.	0.587	0.305	-	-	0.294
1984	# lots	16	330	-	-	346
	mean	45.1	51.7	-	-	51.4
	s.e.	1.819	0.379	-	-	0.378
1985	# lots	-	421	-	10	431
	mean	-	51.8	-	42.0	51.5
	s.e.	-	0.336	-	2.006	0.339
1979 to 1985	# lots	184	1884	27	139	2234
	mean	52.0	53.8	55.2	57.4	53.5
	s.e.	0.495	0.138	0.848	0.477	0.129

Table 2. Mean and standard error (s.e.) of percent head rice by year and variety in Butte County.

Year		CULTIVAR										
		Very Early		Early					Intermediate		Late	
		M-101	Cal Pearl	M-9	M-201	S-6	S-201	L-202	M-301	M-302	M-7	M-401
1979	# lots	-	-	119	-	73	-	-	-	-	54	-
	mean	-	-	56.2	-	53.2	-	-	-	-	59.0	-
	s.e.	-	-	0.359	-	0.488	-	-	-	-	0.413	-
1980	# lots	3	-	147	-	58	-	-	1	-	39	-
	means	-	-	56.9	-	54.6	-	-	-	-	59.6	-
	s.e.	-	-	0.281	-	0.477	-	-	-	-	0.423	-
1981	# lots	18	-	172	-	-	100	-	12	-	31	-
	mean	47.4	-	52.6	-	-	49.7	-	56.7	-	57.8	-
	s.e.	1.218	-	1.063	-	-	0.625	-	1.260	-	0.541	-
1982	# lots	34	10	176	-	-	105	-	-	10	-	3
	mean	49.0	50.4	53.5	-	-	52.7	-	-	54.4	-	-
	s.e.	0.829	1.587	0.329	-	-	0.531	-	-	0.912	-	-
1983	# lots	14	87	17	89	-	77	-	-	-	1	-
	mean	50.9	55.7	56.5	60.3	-	54.4	-	-	-	-	-
	s.e.	1.196	0.627	0.572	0.255	-	0.423	-	-	-	-	-
1984	# lots	2	14	2	18	-	310	-	-	-	-	-
	mean	-	46.6	-	54.6	-	51.5	-	-	-	-	-
	s.e.	-	1.643	-	1.037	-	0.396	-	-	-	-	-
1985	# lots	-	-	-	219	-	57	145	-	-	-	10
	mean	-	-	-	54.7	-	42.3	51.1	-	-	-	42.0
	s.e.	-	-	-	0.280	-	0.880	0.570	-	-	-	2.006
1979 to 1985	# lots	71	101	633	326	131	649	145	13	10	125	13
	mean	48.6	54.5	54.6	56.2	53.8	51.0	51.1	55.7	54.4	58.8	44
	s.e.	0.650	0.663	0.181	0.250	0.348	0.273	0.570	1.517	0.912	0.275	1.977

Table 3. Mean and standard error (s.e.) of percent total rice by year and maturity group in Butte County.

Year		Maturity Group V. Early	Early	Int.	Late	All
	# lots	1	192	3	55	252
1979	mean	-	69.4	-	70.1	69.6
	s.e.	-	0.081	-	0.101	0.070
	# lots	3	205	2	39	249
1980	mean	-	69.7	-	70.3	69.6
	s.e.	-	0.062	0	0.842	0.451
	# lots	18	272	12	31	333
1981	mean	69.4	69.4	69.3	70.9	69.5
	s.e.	0.305	0.067	0.738	0.124	0.064
	# lots	44	281	10	3	338
1982	mean	70.0	69.9	70.3	-	69.9
	s.e.	0.126	0.069	0.225	-	0.060
	# lots	101	183	-	1	285
1982	mean	69.8	69.3	-	-	69.4
	s.e.	0.106	0.082	-	-	0.069
	# lots	16	330	-	-	346
1984	mean	69.0	68,0	-	-	68.0
	s.e.	0.301	0.064	-	-	0.063
	# lots	-	421	-	10	431
1985	mean	-	67.3	-	60.5	67.2
	s.e.	-	0.102	-	1.186	0.114
1979	# lots	184	1884	27	139	2240
to 1985	mean	69.7	68.8	69.5	69.6	68.9
	s.e.	0.079	0.039	0.204	0.244	0.038

Table 4. Mean and standard error (s.e.) of percent total rice by year and variety in Butte County.

Year		CULTIVAR										
		Very Early		Early					Intermediate		Late	
		M-101	Cal Pearl	M-9	M-201	S-6	S-201	L-202	M-301	M-302	M-7	M-401
1979	# lots	-	-	119	-	73	-	-	-	-	54	-
	mean	-	-	68.9	-	70.2	-	-	-	-	70.1	-
	s.e.	-	-	0.086	-	0.106	-	-	-	-	0.973	-
1980	# lots	3	-	147	-	58	-	-	1	-	39	-
	mean	-	-	69.5	-	70.2	-	-	-	-	70.3	-
	s.e.	-	-	0.071	-	0.101	-	-	-	-	0.084	-
1981	# lots	18	-	172	-	-	100	-	12	-	31	-
	mean	69.4	-	69.1	-	-	69.9	-	69.3	-	71.0	-
	s.e.	0.305	-	0.081	-	-	0.101	-	0.213	-	0.124	-
1982	# lots	34	10	176	-	-	105	-	-	10	-	3
	mean	69.9	70.2	69.5	-	-	70.4	-	-	70.3	-	-
	s.e.	0.124	0.365	0.092	-	-	0.750	-	-	0.225	-	-
1983	# lots	14	87	17	89	-	77	-	-	-	1	-
	mean	69.1	69.8	69.1	68.6	-	70.1	-	-	-	-	-
	s.e.	0.237	0.114	0.196	0.079	-	0.117	-	-	-	-	-
1984	# lots	2	14	2	18	-	310	-	-	-	-	-
	mean	-	69.2	-	68.1	-	68.0	-	-	-	-	-
	s.e.	-	0.298	-	0.256	-	0.066	-	-	-	-	-
1985	# lots	-	-	-	219	-	57	145	-	-	-	10
	mean	-	-	-	67.9	-	68.7	65.8	-	-	-	65.8
	s.e.	-	-	-	0.105	-	0.261	0.166	-	-	-	0.166
1979 to 1985	# lots	71	101	633	326	131	649	145	13	10	125	13
	mean	69.5	69.8	69.3	68.1	70.2	69.0	65.8	69.3	70.3	70.3	62.7
	s.e.	0.122	0.108	0.043	0.077	0.074	0.061	0.166	0.197	0.225	0.086	1.483

Table 5. Mean and standard error (s.e.) of percent moisture at harvest by year and maturity group in Butte County.

Year		Maturity Group V. Early	Early	Int.	Late	All
1981	# lots	18	272	12	31	333
	mean	22.7	20.9	21.2	21.8	21.1
	s.e.	0.677	0.153	0.563	0.310	0.137
1982	# lots	44	281	10	3	338
	mean	22.3	22.2	22.2	-	21.7
	s.e.	0.515	0.136	0.915	-	0.316
1983	# lots	101	183	-	1	285
	mean	21.8	23.8	-	-	23.1
	s.e.	0.361	0.178	-	-	0.181
1984	# lots	16	330	-	-	346
	mean	18.0	20.2	-	-	20.1
	s.e.	0.534	0.137	-	-	0.136
1985	# lots	-	421	-	10	431
	mean	-	21.4	-	21.5	21.4
	s.e.	-	0.178	-	0.949	0.175
1979 to 1985	# lots	179	1487	22	45	1733
	mean	21.7	21.5	21.6	21.7	21.5
	s.e.	0.268	0.078	0.515	0.316	0.038

Table 6. Mean and standard error (s.e.) of percent moisture by year and variety in Butte County.

		CULTIVAR									
		Very Early		Early				Intermediate		Late	
Year		M-101	Cal Pearl	M-9	M-201	S-201	L-202	M-301	M-302	M-7	M-401
1981	# lots	18	-	172	-	100	-	12	-	31	-
	mean	22.7	-	21.0	-	20.8	-	21.2	-	21.8	-
	s.e.	0.677	-	0.205	-	0.225	-	0.563	-	0.310	-
1982	# lots	34	10	176	-	105	-	-	10	-	3
	mean	20.3	18.7	22.2	-	22.2	-	-	22.2	-	-
	s.e.	0.651	0.405	0.173	-	0.219	-	-	0.915	-	-
1983	# lots	14	87	17	89	77	-	-	-	1	-
	mean	23.1	21.6	23.0	24.9	22.7	-	-	-	-	-
	s.e.	0.630	0.404	0.272	0.266	0.216	-	-	-	-	-
1984	# lots	2	14	2	18	310	-	-	-	-	-
	mean	-	17.8	-	20.9	20.2	-	-	-	-	-
	s.e.	-	0.565	-	0.502	0.143	-	-	-	-	-
1985	# lots	-	-	-	219	57	145	-	-	-	10
	mean	-	-	-	22.4	19.7	20.5	-	-	-	21.5
	s.e.	-	-	-	0.265	0.382	0.794	-	-	-	0.949
1979 to 1985	# lots	68	101	367	326	649	145	12	10	32	13
	mean	23.0	21.1	21.7	23.0	20.9	20.5	21.2	22.2	21.9	21.2
	s.e.	0.359	0.380	0.132	0.205	0.102	0.794	0.563	0.915	0.327	0.745

Table 7. Mean and standard error (s.e.) of yield (100 lb/A) by year and maturity group in Butte County.

Year		Maturity Group: V. Early	Early	Int.	Late	All
	# lots	1	192	3	55	252
1979	mean	-	68.3	-	72.3	69.0
	s.e.	-	0.768	-	1.355	0.675
	# lots	3	205	2	39	249
1980	mean	-	66.6	-	67.5	66.7
	s.e.	-	0.583	-	1.886	0.517
	# lots	18	272	12	31	333
1981	mean	63.0	70.7	63.8	67.6	69.7
	s.e.	0.305	0.470	2.754	1.482	0.441
	# lots	44	281	10	3	338
1982	mean	61.8	67.4	67.7	-	66.6
	s.e.	1.782	0.590	2.140	-	0.570
	# lots	101	183	-	1	285
1983	mean	71.2	74.1	-	-	73.0
	s.e.	0.819	0.726	-	-	0.555
	# lots	16	330	-	-	346
1984	mean	79.1	73.8	-	-	74.0
	s.e.	2.128	0.602	-	-	0.585
	# lots	-	421	-	10	431
1985	mean	-	74.9	-	69.7	74.8
	s.e.	-	0.461	-	2.336	0.455
1979	# lots	184	1884	27	139	2234
to 1985	mean	68.5	71.3	66.2	69.9	70.9
	s.e.	0.781	0.235	1.516	0.767	0.215

Table 8. Mean and standard error (s.e.) of yield by year and variety in Butte County.

Year		Very Early: M-101	Very Early: Cal Pearl	Early: M-9	Early: M-201	Early: S-6	Early: S-201	Early: L-202	Intermediate: M-301	Intermediate: M-302	Late: M-7	Late: M-401
1979	# lots	-	-	119	-	73	-	-	-	-	54	-
	mean	-	-	72.5	-	61.4	-	-	-	-	72.4	-
	s.e.	-	-	0.791	-	1.179	-	-	-	-	1.377	-
1980	# lots	3	-	147	-	58	-	-	-	-	39	-
	mean	-	-	68.8	-	60.9	-	-	-	-	67.5	-
	s.e.	-	-	0.638	-	0.934	-	-	-	-	1.886	-
1981	# lots	18	-	172	-	-	100	-	12	-	31	-
	mean	63.0	-	69.0	-	-	73.6	-	63.8	-	67.6	-
	s.e.	1.311	-	0.570	-	-	0.740	-	2.754	-	1.482	-
1982	# lots	34	10	176	-	-	105	-	-	10	-	3
	mean	58.6	72.4	66.2	-	-	68.6	-	-	67.7	-	-
	s.e.	1.935	1.946	0.831	-	-	0.806	-	-	2.139	-	-
1983	# lots	14	87	17	89	-	77	-	-	-	1	-
	mean	63.3	72.5	70.7	74.0	-	74.9	-	-	-	-	-
	s.e.	1.880	0.826	4.221	0.858	-	1.070	-	-	-	-	-
1984	# lots	2	14	2	18	-	310	-	-	-	-	-
	mean	-	79.8	-	65.1	-	74.3	-	-	-	-	-
	s.e.	-	2.306	-	2.179	-	0.617	-	-	-	-	-
1985	# lots	-	-	-	219	-	57	145	-	-	-	10
	mean	-	-	-	77.4	-	77.8	70.1	-	-	-	69.7
	s.e.	-	-	-	0.574	-	1.059	0.794	-	-	-	2.336
1979 to 1985	# lots	71	101	633	326	131	649	145	12	10	125	13
	mean	61.4	73.5	68.9	75.8	61.2	73.7	70.1	63.8	67.7	69.6	72.4
	s.e.	1.122	0.816	0.374	0.494	0.774	0.387	0.794	2.754	2.139	0.815	2.377

Table 9. Estimated minimum moisture required to achieve maximum head rice.

Variety	Minimum of the max. moisture	Nearly Max. percent head rice	Range of percent head rice at this percent moisture	
			Low	High
M-101	23	52	42	57
Cal Pearl	23	60	51	64
Early	22	54	36	63
M-9	22	54	44	62
M-201	23	56	47	63
S-201	21	52	36	62
L-202	18	51	40	59

Table 10. Ranking order of cultivars based on the maximal absolute difference between measurements of the three parts of the panicle.

Characteristics	Ranking Order From Less Uniform to More Uniform 1	2	3	4	5	6
% Total rice	L-202	S-201	M-302	M-201	M7	M-101
% Hull	M-101	L-202	M-201	M-302	M7	S-201
% Bran	L-202	S-201	M-302	M-101	M7	M-201
Max. weight	L-202	M-201	M-101	S-201	M-302	M7
Volume	S-201	M-101	L-202	M-302	M-201	M7
Density	M-101	M-201	L-202	S-201	M-302	M7
Duration of filling	S-201	M-101	M-201	M-302	M7	L-202
maxm. rate of filling	L-202	M-101	M-201	S-201	M-302	M7
Mean rate of filling	L-202	M-101	M-201	M-302	M7	S-201
Overall ranking	L-202	M-101	S-201	M-201	M-302	M7
Ave. % HR (low to high)	L-202	S-201	M-101	M-302	M-201	M7

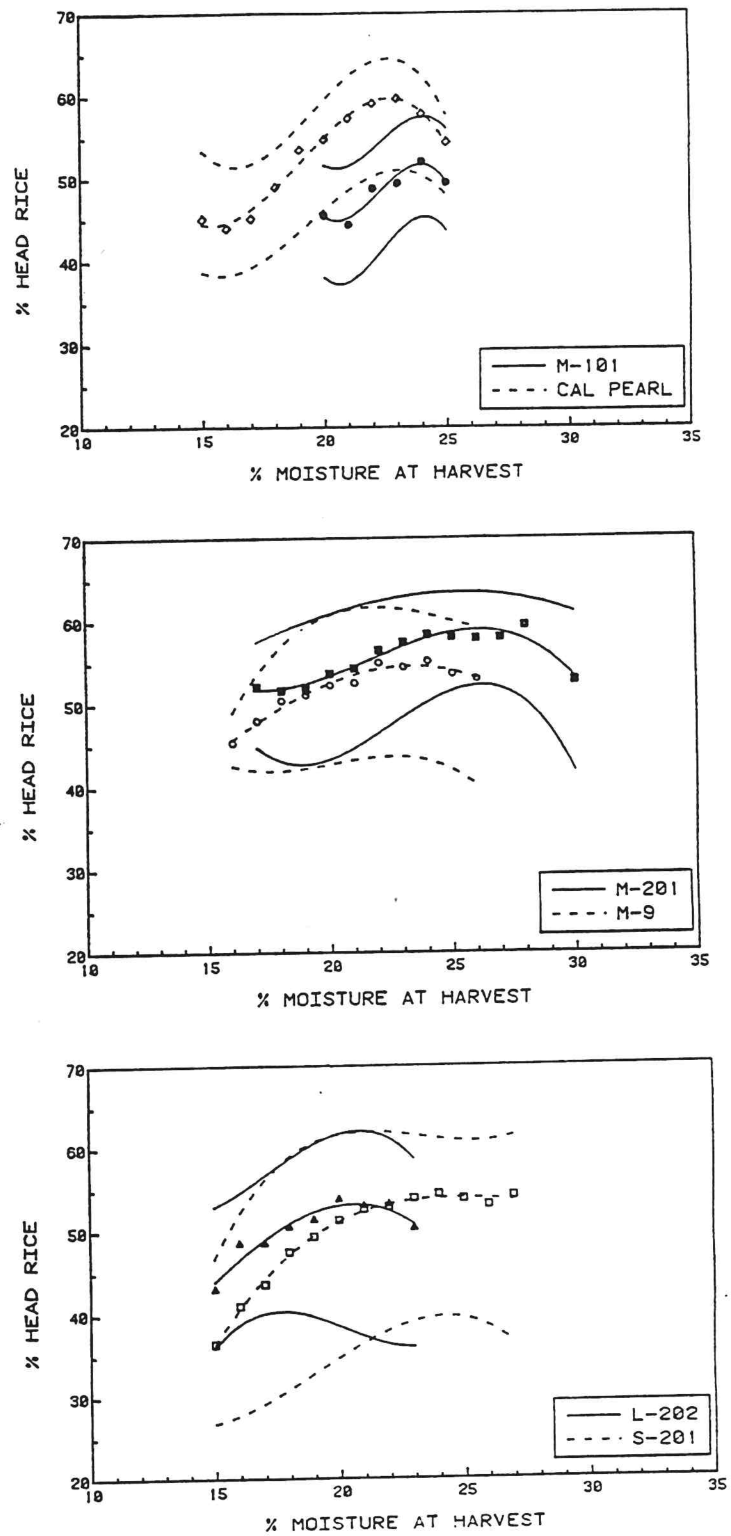
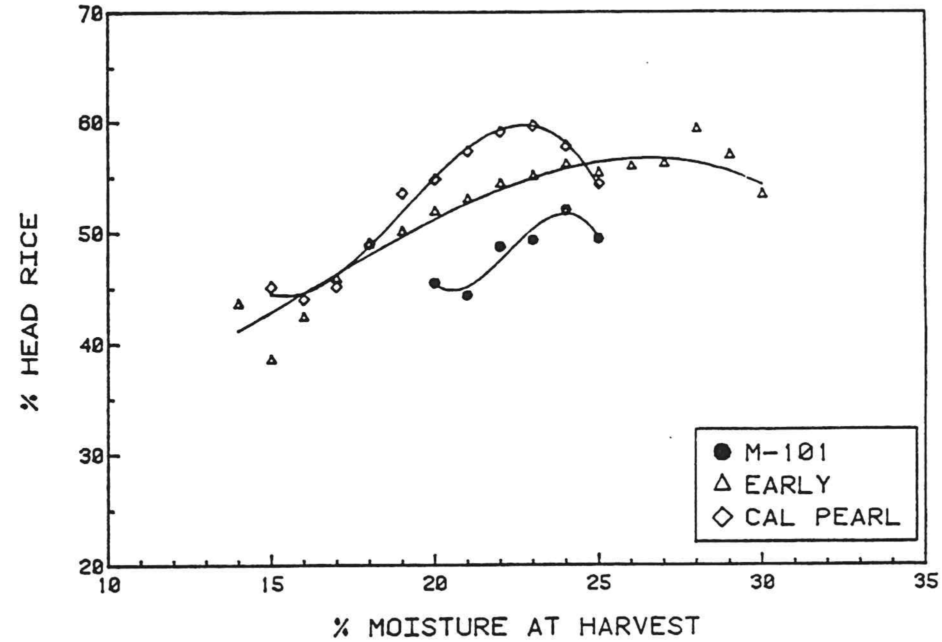


Fig. 1. Percent head rice in relation to the moisture at harvest. Center line is the mean curve, and the outside lines are boundaries of extreme values. Points along the mean curves are actual observed means (BUCRA data 1979-1985).



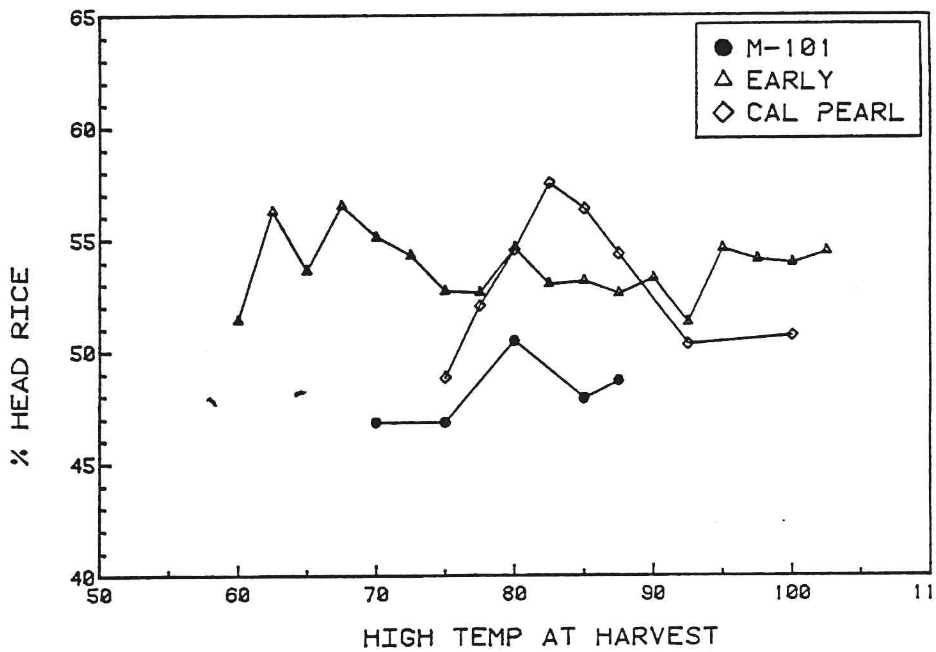


Fig. 2. Average lines of head rice for M-101 (very early cultivar), early cultivars combined, and Cal Pearl in relationship to moisture content and high temperature (°F) at harvest (BUCRA data 1979-1985).

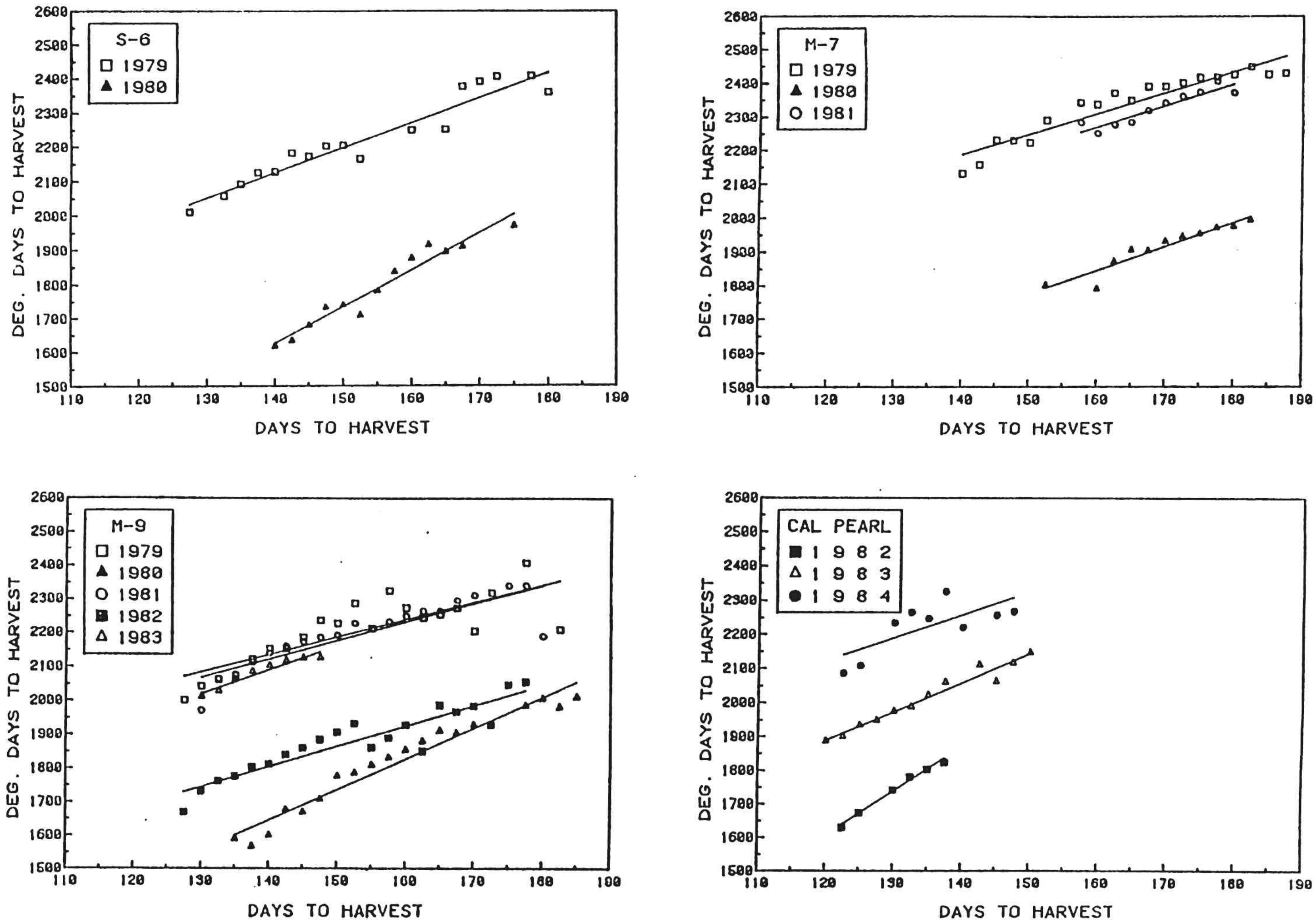


Fig. 3. Relationship of degree days and actual days required from planting to harvesting (BUCRA, 1979-1985 data) for S-6, M-7, M-9 and Cal Pearl.

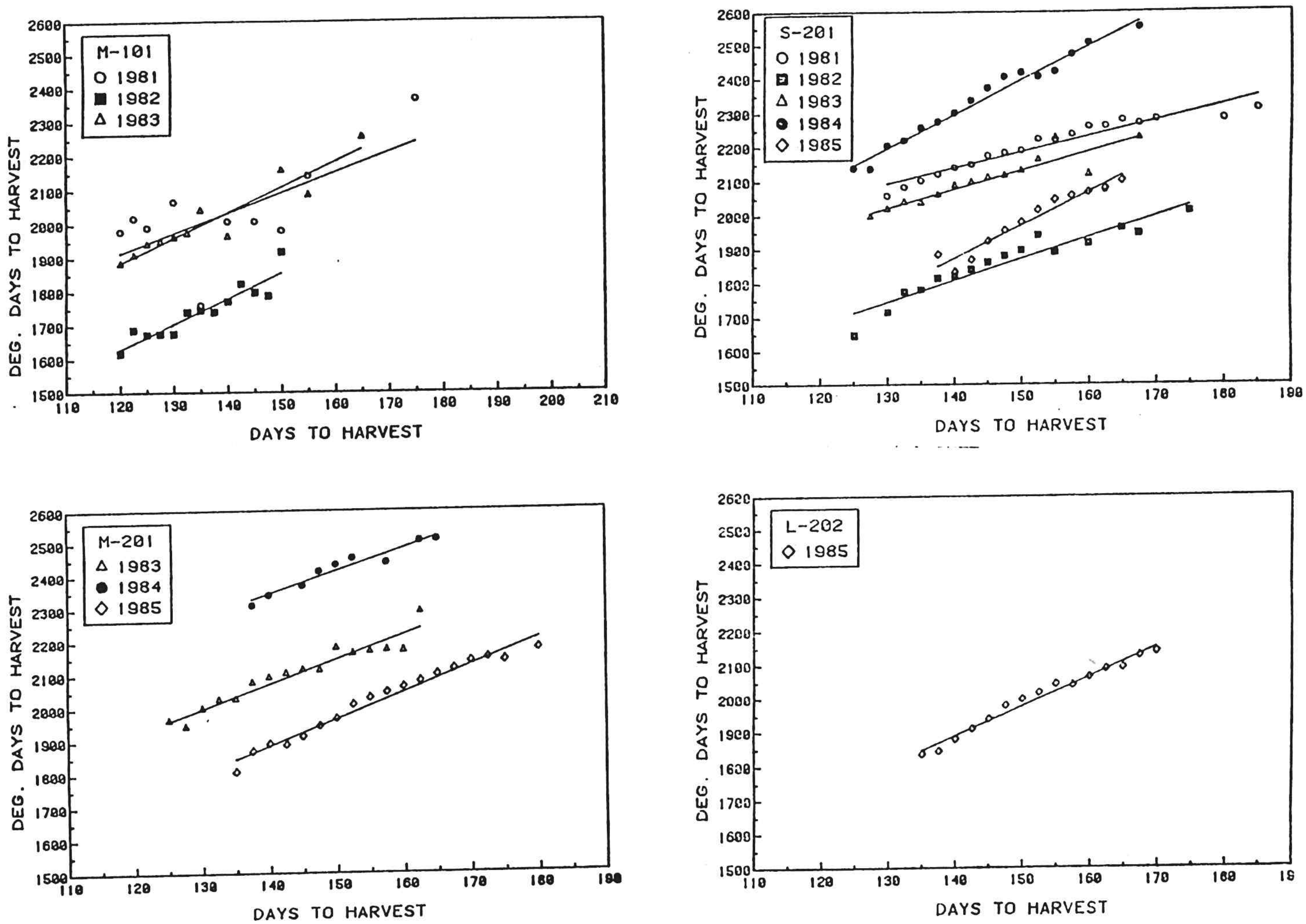


Fig. 4. Relationship of degree days and actual days required from planting to harvesting (BUCRA, 1979-1985 data) for M-101, M-201, S-201, and L-202.

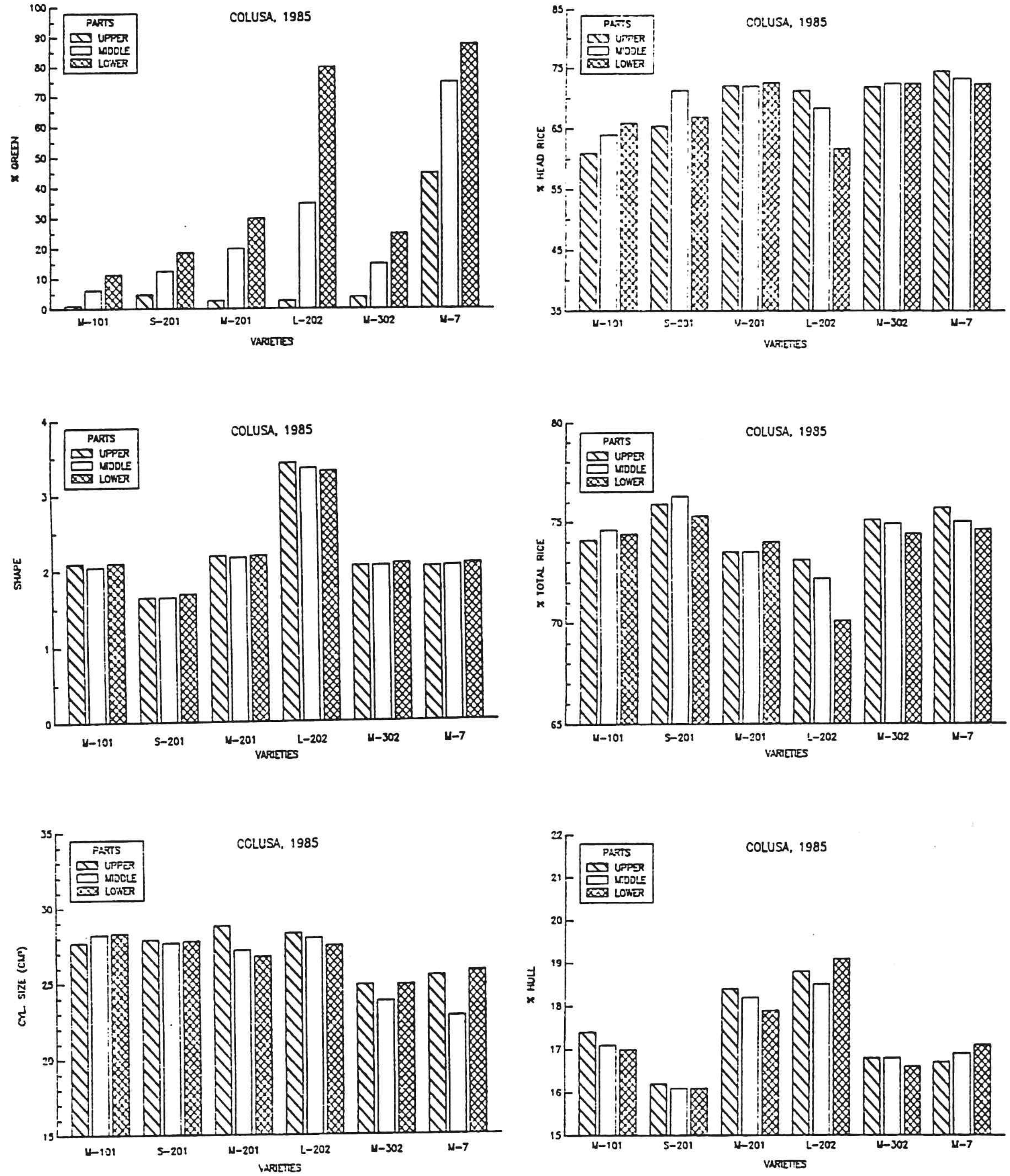


Fig. 5. Means of grain characteristics of each part of the panicle and cultivar.

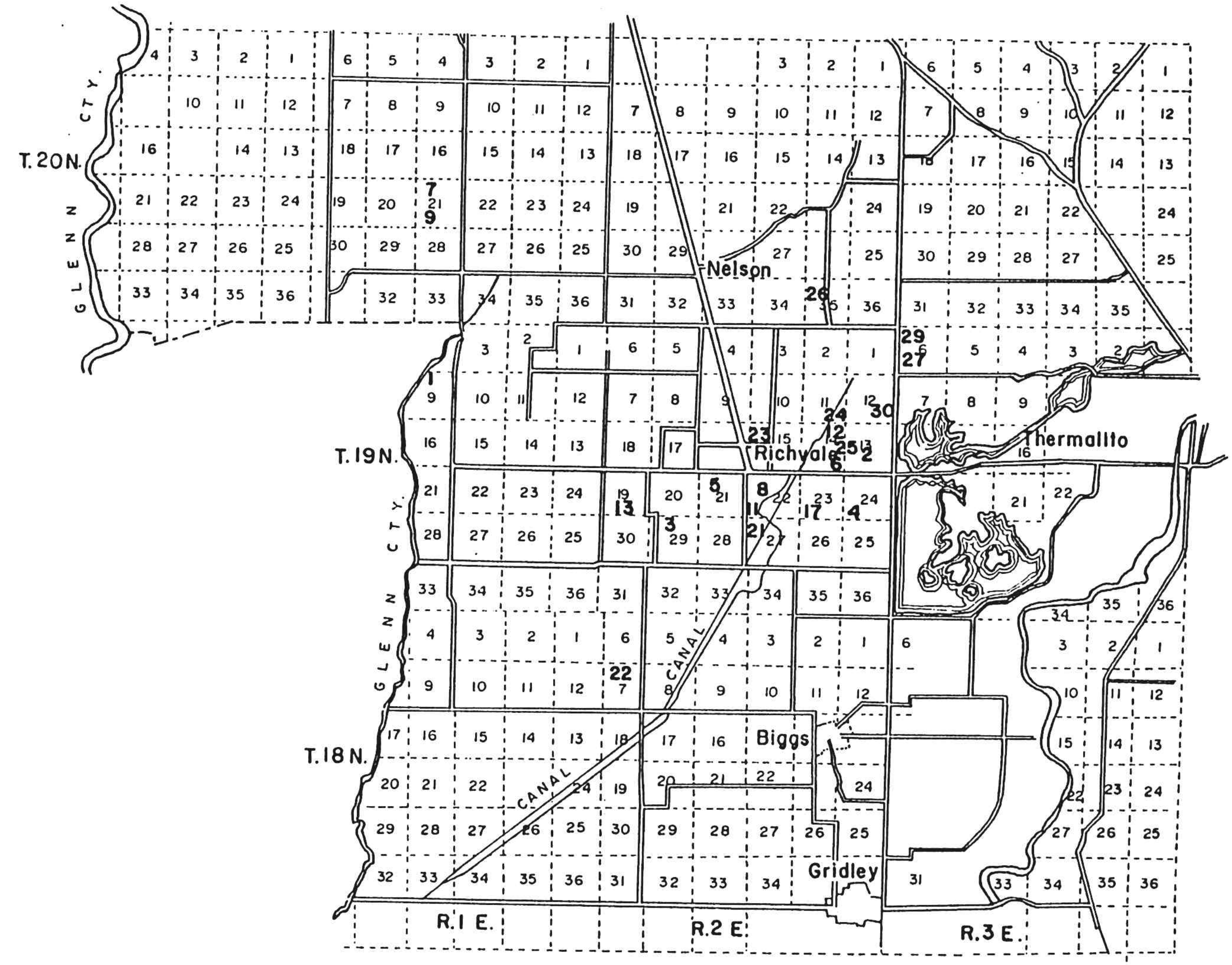
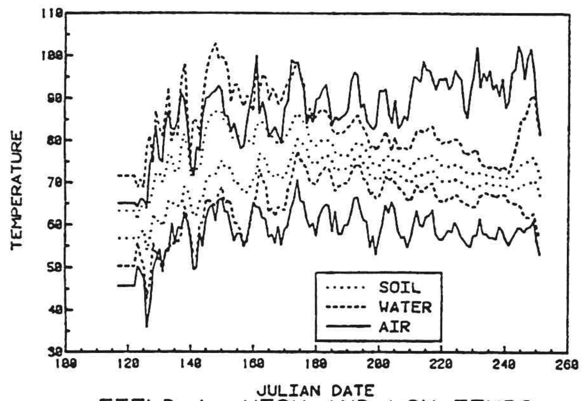
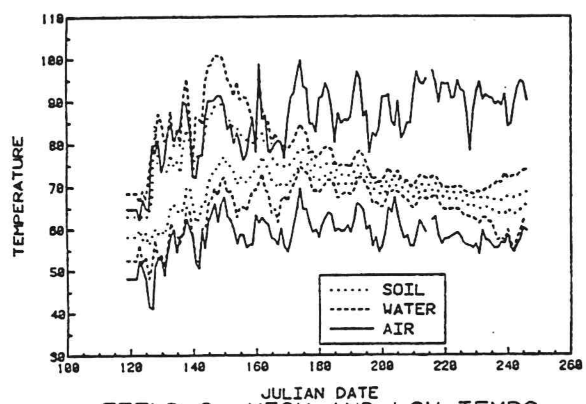


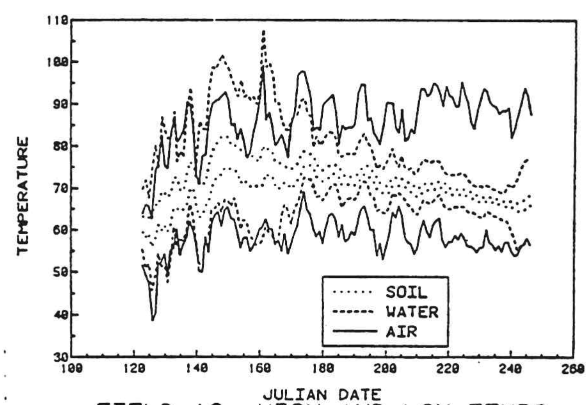
Fig. 6. Field map of Butte County where 22 fields were surveyed for rice phenological data (1986).



FIELD 1, HIGH AND LOW TEMPS

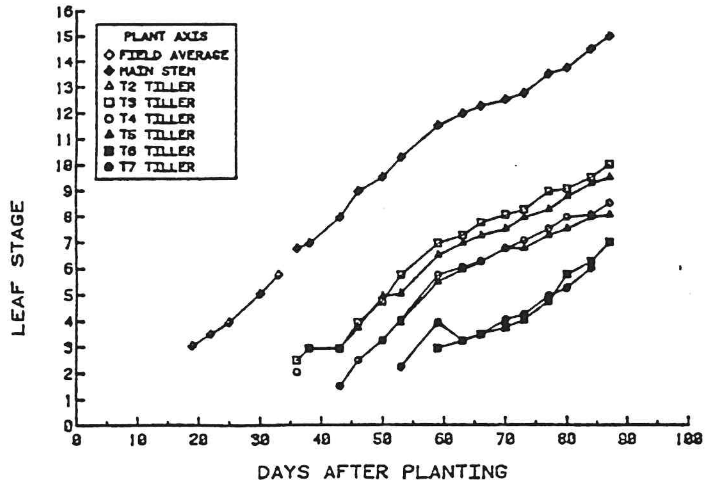


FIELD 2, HIGH AND LOW TEMPS

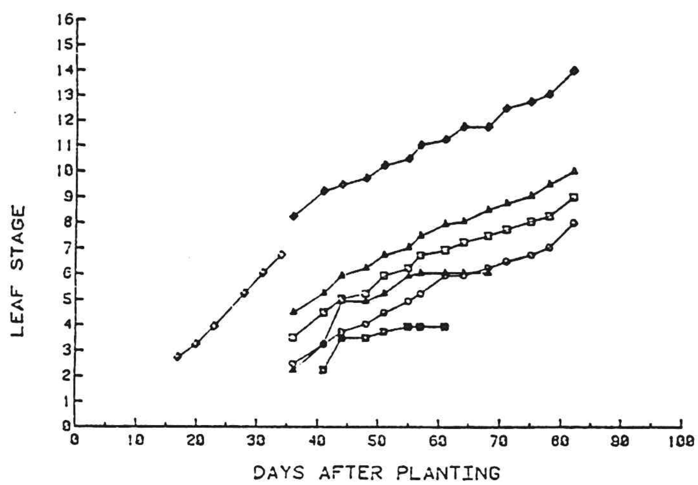


FIELD 13, HIGH AND LOW TEMPS

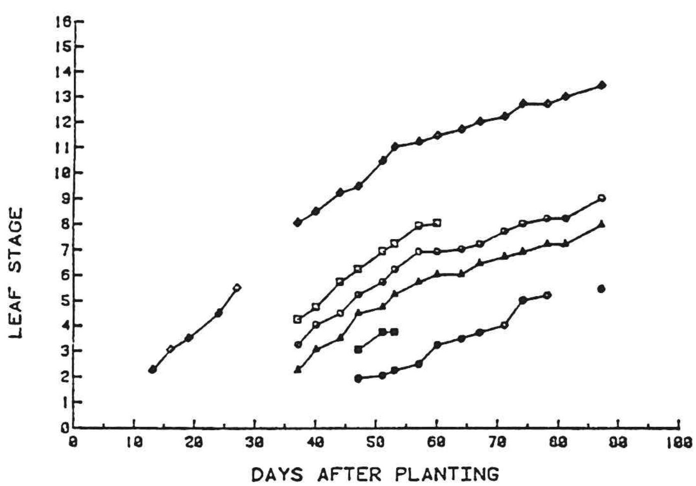
Fig. 7. Air, water and soil temperatures of three datalogger locations (DLL) in Butte Co. during the rice growing season in 1986.



FIELD 1



FIELD 2



FIELD 13

Fig. 8. Leaf stage development by days after planting (M-201 was planted in fields 1 and 3, and S-201 was planted in field 13).

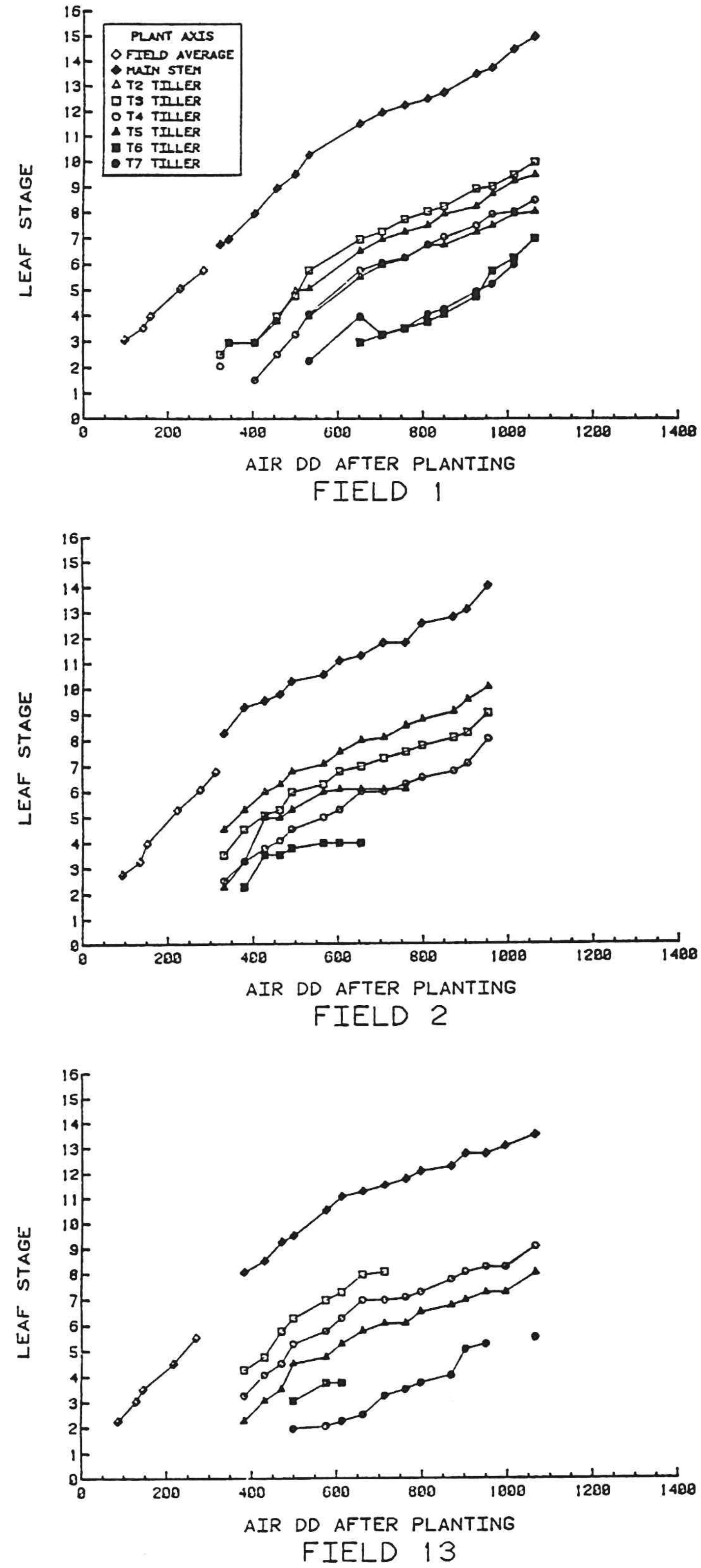


Fig. 9. Leaf stage development by degree-day accumulation (M-201 was planted in fields 1 and 2, and S-201 was planted in field 13).

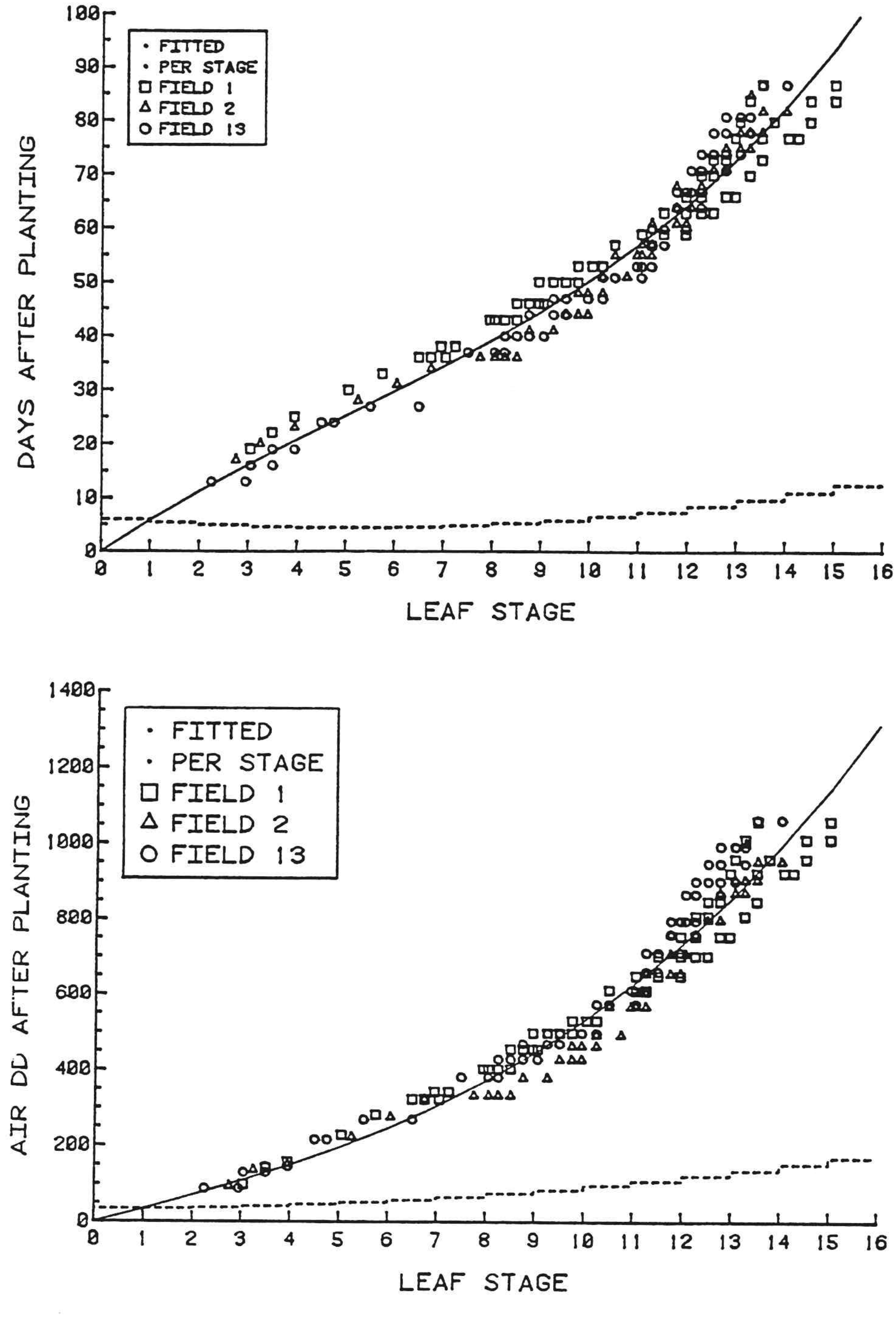


Fig. 10. Requirements of growth indexes based on data of datalogger locations. The smooth curve is the cumulative requirements of the index for the leaf stages. The dashed line represents the required index value for each leaf stage increment.

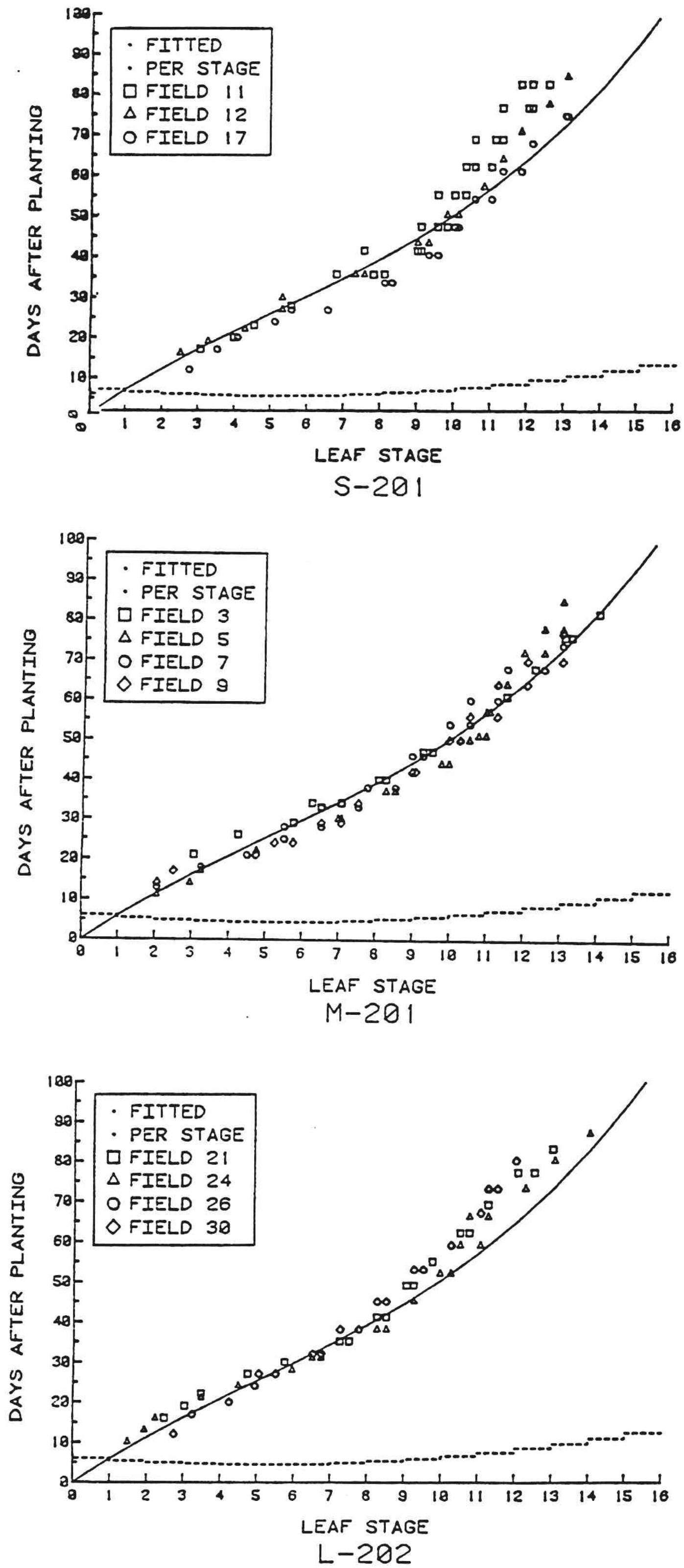


Fig. 11. Actual observed days in general fields (GFL) for leaf stage developments and the calculated requirements (curves) ~~than~~ datalogger fields (DLL).

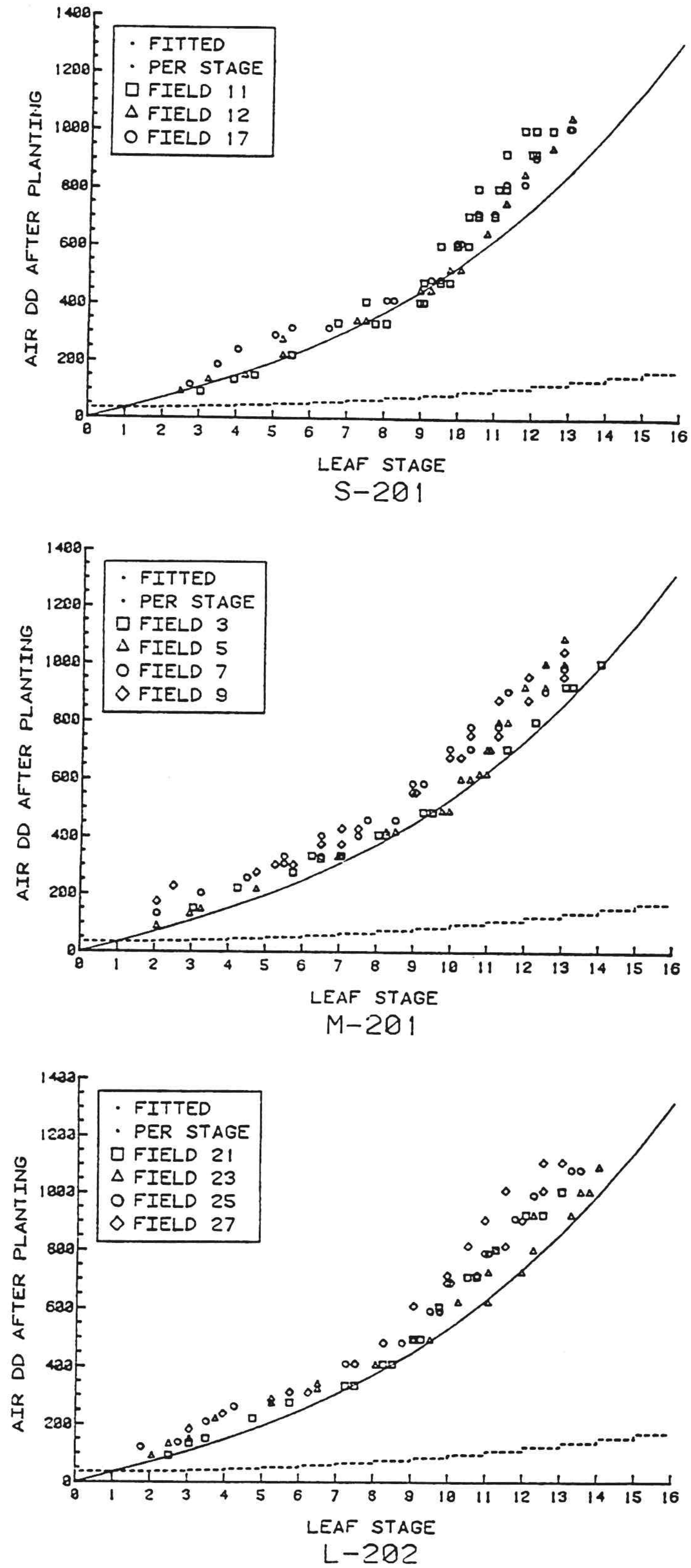
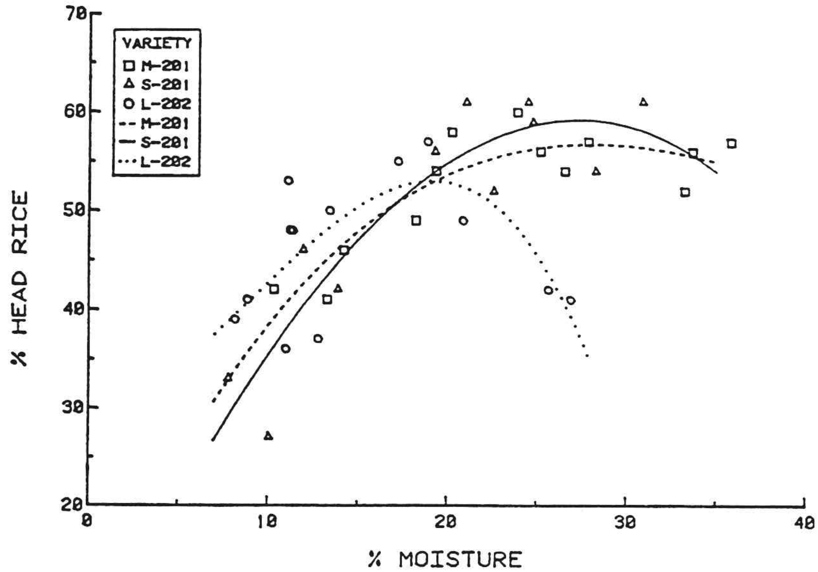


Fig. 12. Actual observed degree days in general fields (GFL) for leaf stage developments and the calculated requirements (curves) from datalogger fields (DLL).



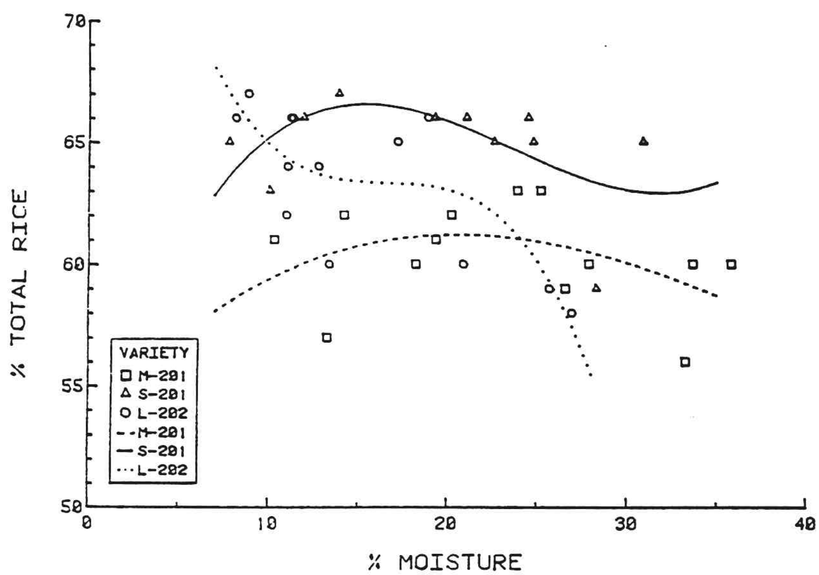


Fig. 13. Percent head rice and total rice in relation to the moisture content at harvest.