PROJECT NO. RB-3

COMPREHENSIVE RESEARCH ON RICE
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PROJECT TITLE: Genetic and physiological determinants of yield and quality

PROJECT LEADER AND PRINCIPAL UC INVESTIGATORS:

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LEVEL OF 1980 FUNDING: $10,000

OBJECTIVES AND EXPERIMENTS CONDUCTED BY LOCATION TO ACCOMPLISH OBJECTIVES:

1. Continuation of basic studies on climatic effects on yield, with special emphasis on the effects of temperature extremes on sterility.

2. Basic research on factors that can raise current yield levels.

3. Genetically modify the amylose content of adapted cultivars in the direction of flaky (non-sticky) cooking quality.

SUMMARY OF 1980 RESEARCH (MAJOR ACCOMPLISHMENTS) BY OBJECTIVE:

Objective 1. Continuation of basic studies on climatic effects on yield, with special emphasis on the effects of temperature extremes on sterility.

Several studies under this objective were discontinued for 1980 when Dr. James E. Board left the project to accept a position as Assistant Professor of Agronomy at Louisiana State University. The original budget submitted to the Rice Board was for $27,292 which included $16,884 for Dr. Board's salary. At the time this project was considered by the Research Committee of the Rice Board, we informed the committee that Dr. Board was leaving and our request was reduced from $27,292 to $10,000.

Genetic studies on cold tolerance in crosses between southern long grain and California varieties (Ph.D. thesis research by H. P. Moon) were continued. Preliminary analysis of the 1979 F_1 data show surprisingly low sterility levels (about 20%) in the southern varieties, which usually show high sterility. However, in 1979 the plants were started very early in the greenhouse and then transplanted to the field. By this accelerated process almost all lines matured before cool night temperatures became a problem. Large amounts of data were collected in 1980 on the F_1, F_2, BC_1F_1 and BC_2F_1 of 36 crosses in this study, but further analysis is required for full interpretation of the results.

<u>Objective 2</u>. Basic research on factors that can raise current yield levels.

a. Basic information needed to design a more efficient and higher yielding rice plant.

This project had partial funding in 1980 from a USDA/SEA grant. The objective was to develop and test model plants or ideotypes that were superior to current best cultivars by combining morphological and physiological characteristics that increase the efficiency of conversion of solar energy to chemical energy in the rice plant. A superior rice plant model is defined as one which produces more grain per unit of time, leaf area, or land area.

Four experiments were conducted under this objective in 1980. Results are not yet fully summarized but available data are presented:

1) Effects of plant height and growth duration on yields, grain/straw ratios, and panicles/m^2.

Nine near-isogenic lines of rice that differed in plant height and growth duration were compared. Results presented in Table 1 indicate highest yields were obtained from those lines that were intermediate in maturity (105 days to heading) and intermediate in height (90 cm). The number of panicles per square meter did not appear to be positively associated with yield. Ratios of grain to straw increased with early maturity and shorter plant height.

2) Selection for large grain size as one approach to increased rice yields.

a) Eight F_5 lines from the cross M-101 x 77/11442 were field tested in 1980. Mean yields from five replications are shown in Table 2. The 77/11442 parent had been selected earlier for large grain size. In a 1979 trial at Davis, the M-101 parent had a mean grain weight of 2.74 grams/100 grains and the 11442 parent was 2.95 grams/100 grains. The eight lines grown in 1980 showed an average 100 grain weight of 3.00

grams in 1979. Grain weights for 1980 are not yet available. The yields for 1980 show all eight F_5 lines and the large grain parent 11442 exceeded the yield of M-101, with six of the eight lines yielding significantly more (5% level) and 3 lines yielding highly significantly more (0.01 level) than M-101. Panicles per square meter did not differ significantly. The ratios of grain to straw were exceptionally high in this group of selections. Results support the idea that increased grain size can increase yields.

b) Eight F_6 lines from another cross, SD7 x B18355, were field tested in 1980. The B18355 parent had exceptionally large grains averaging 3.66 grams/100 grains in 1979 trials. In the 1980 trials the SD7 parent with normal grain size produced the highest yields (Table 3). The large grained parent yielded poorly, while all but two of the F_6 lines yielded more than the mean of the two parents. Sterility was high in this group of lines and stem rot was a factor. We concluded that this particular cross would not be useful for testing the primary hypothesis concerning grain size as a yield factor. However, the best lines could be used in a further crossing program to transfer large grain size to better adapted strains.

3) Selection for panicles with many grains.

Eight selected F_6 lines of the cross SD7 x PI 344042 were field tested in 1980 (Table 4). PI 344042 is the many grained parent. Two lines (79/20115 and 79/20143) yielded significantly more than the SD7 parent. The number of panicles/m^2 was unusually high for this group of selections, and particularly line 79/20115. This line also had a high grain/straw ratio. Sterility was a problem with this group of selections, although those data have not yet been summarized for this report. We conclude that several of these lines should be further evaluated as well as being used in crosses with the large grained lines of the cross M-101 x 77/11442 to produce populations that can be selected for panicles with more and larger grain size.

Our general conclusions are that prospects for raising yield levels of rice by increasing the individual components of yield (grain size, grains/panicle, and panicles/m^2) are promising and that this line of investigation should be vigorously pursued.

b. Hybrid rice studies.

A fourth genetic element to facilitate hybrid rice production--a recessive tall gene--was described. This gene, called eui for elongated uppermost internode, produces a near-doubling in length of the uppermost internode, a 12% increase in panicle length, and little or no effect on the other internodes or plant characters. It is proposed that this gene would be a useful fourth element which would complement the other three genetic elements--cytoplasmic male sterility, maintainers, and restorers--generally used in hybrid seed production. The eui gene would be incorporated in pollen fertility restoring parents in hybrid seed production in situations where a semidwarf F_1 generation is desired. The tall paternal plant type would be desirable for windblown pollen dispersal onto semidwarf female plants and the resulting hybrid plants would be semidwarf, unlike the usual case of tall hybrids from semidwarf by tall crosses. Additionally, its increased height would permit a co-mingling of the hybrid parent seed stock to maximize crossing and would facilitate mechanical removal of the paternal parent before mass harvest of the commercial hybrid seed.

The effects of cytoplasmic male sterile:pollinator ratio and height of pollinators on the seed set of short stature male steriles (thesis study of L. E. Azzini) were investigated. Partial results of this experiment are presented in Table 5. The tall pollinators produced on average of 41% seed set on the male steriles, whereas the short pollinators produced an average of 35% seed set. Although there appears to be an advantage for the tall pollinators, the advantage was rather small. An encouraging response was the average seed set of 35% in the 3:1 ratio of male steriles (females):pollinator. Such results indicate that only one fourth of the seed production field would need to be planted to male pollinators.

Time and duration of rice flower opening were determined by recording the time of flower opening and closing on labelled panicle branches. Time of flower opening ranged from 1:05 PM to 5:25 PM with a peak between 2:00 and 3:00 PM. A significant effect of "day" (probably day temperature) was observed on the time of flowering opening. The flowers remained open from 40 to 150 minutes (average of 80 minutes) during a single day. Male steriles and pollinators did not differ in time of flower opening, nor in duration of flower opening.

Crosses between the original source of the Bir-Co cytoplasm and male-steriles having California cultivar background were made to recover the fertility restoring gene(s) for this cytoplasm. Additional backcrosses to the male steriles will be made to introduce this gene(s) into the California background. High sterility of hybrids between Bir-Co male-steriles and Taichung 65 (Boro-Rf_1) showed that the fertility restoring gene for the Boro cytoplasm of Taichung 65 does not restore the fertility of the Bir-Co cytoplasm.

The second backcross of Taichung 65 (Boro-Rf) to California cultivars were made during the summer in order to transfer the California rice germplasm to the Boro cytoplasm.

Development of genetic male steriles for use in population improvement (thesis study of M. A. Mese)was continued. Genetic male steriles are potentially useful in population improvement, since they permit making large numbers of crosses with relatively little effort. To obtain genetic male steriles we irradiated M-101 and selected over 100 semi-sterile and sterile plants in the X_2 generation in 1978. In subsequent generations we narrowed this group down to 11 steriles which appear to be under single gene control. Additional work is being carried on to determine which of these show high levels of outcrossing.

Assuming the mechanics of hybrid rice seed production can be solved, hybrid seeds will still be very expensive, creating a need for reduced seeding rates. Therefore we initiated work on seeding rates of several standard-genotypes, in order to determine if reduced seeding rates would reduce yields. Results of a large-plot, broadcast-seeded trial are presented in Table 6. In this study, reducing the seeding rates from 150 to 50/A reduced yields an average of 9%. Genotypes exhibited wide differences in yield reductions, ranging from none to 13%. In general genotypes that produced highest yields at 150 rate showed greatest yield losses at 50 rate. Hybrid variety yield increases need to be sufficient to compensate for any reductions expected from lower seeding rates as well as the added cost of hybrid seed. Future breeding for hybrid rice probably should include selection for greater tillering capacity to compensate for lower seeding rates.

<u>Objective 3.</u> Genetically modify the amylose content of adapted cultivars in the direction of flaky (non-sticky) cooking quality. (Ph.D. Thesis study of K. S. McKenzie)

The inheritance and interrelationships between amylose content and alkali spreading score was studied in two long- x medium-grain crosses, SD7/72-3764 and 76 URN 14/ED7. The SD7/72-3764 F_2 segregation for amylose content was bimodal and gave a very good fit to a single incompletely dominant gene model. Progeny tests with representative F_3 lines confirmed that one gene of major effect in addition to modifying genes of minor effect were controlling amylose content in this cross. Analysis of the 76 URN 14/ED7 F_3 frequency distributions for amylose content indicated segregation for two dominant complementary genes. Progeny tests with representative F_4 lines supported the hypothesis that amylose content in the 76 URN 14/ED7 cross was controlled by two dominant complementary genes of major effect and modifying genes of minor effect. Heritability estimates were very high and single plant selection for amylose content should be effective.

Alkali spreading scores were determined for 12 endosperms per plant using 1.4% KOH. Frequency distributions for SD7/72-3764 F_2 plants and F_3 endosperms indicated that one additive gene of major effect controlled the alkali reaction. A satisfactory inheritance model for the 76 URN 14/ED7 cross was not identified. Intermediate and extensive alkali reaction plants bred true in both crosses. Heritability estimates for alkali spreading score were also high.

Correlation coefficients for plant amylose content and mean alkali spreading score were -0.16 and -0.01 for the SD7/72-3764 and 76 URN 14/ED7 crosses, respectively. Contingency tables for amylose class and alkali reaction gave highly significant χ^2 values indicating an association between these two characters. A test of linkage between amylose content and alkali spreading was highly significant and the calculated recombination value was 0.34.

Cobalt-60 irradiation to induce amylose content mutants in the adapted California variety M-101 has not been successful to date. We are continuing some screening for mutants but will not request support for the effort.

PUBLICATIONS OR REPORTS:

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Rutger, J. N. and H. L. Carnahan. 1980. A fourth genetic element for facilitating hybrid seed production in cereals--a recessive tall in rice. In Agron. Abs. (Abstract).

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CONCISE GENERAL SUMMARY OF CURRENT YEAR'S RESULTS:

Several of the basic studies on effects of temperature extremes on sterility were discontinued following the departure of one of our most experienced investigators, Dr. J. E. Board. However, a genetic study on recombining the cold tolerance of the California variety M-101 and the long grain quality of southern varieties was continued.

Basic research on factors to raise current yield levels showed that highest yields presently are obtained by short stature, intermediate maturity varieties. Grain size studies indicate that larger grains will increase yields. In general it appears that prospects for raising yield levels of rice by increasing the individual components of yield (grain size, grains/panicle, and panicles/m^2) are promising and that this line of investigation should be vigorously pursued.

In hybrid rice studies, a fourth genetic element to facilitate hybrid rice production--a recessive tall gene--was described, and a system for using this recessive tall character was proposed. In 1980, tall pollinators produced an average of 41% seed set on short stature male steriles, while short pollinators produced an average of 35% seed set. Both values are encouraging, but much basic research on outcrossing mechanism needs to be done before hybrid rice could become a reality. Even assuming that the seed production mechanics are solved, hybrid seeds will be expensive, creating a need for lower seeding rates. However, 1980 results indicated that yields of current genotypes will be lowered by reduced seeding rates (50 lb/A). Therefore increased tillering ability may have to be incorporated into hybrid rice models.

A genetic study on amylose content showed that this character, an important determinant of long grain cooking quality, was controlled by one or two genes, depending on the cross. Another determinant of cooking quality, alkali spreading score, was controlled by one gene in one cross, but inheritance was unclear in another cross. The single genetic control of these two important quality factors means that they are relatively easy to transfer from one line to another. To date, a search for high amylose mutants in adapted California varieties has not been successful.

Table 1. Performance of nine near-isogenic lines differing in plant height and growth duration.

Genotype	Calrose germplasm	Days to heading	Plant height	Grain Yield	Panicles/m^2	Grain/Straw Ratio
	%	No	cm	kg/ha	No	
Calrose	100	115	120	8984	667	1.00
Calrose 76	100		90	9110	620	1.11
DD1	100		80	7723	741	1.11
Means				8608	676	1.07
M5	69	105	120	9005	574	0.98
M-301	77		90	10022	588	1.27
SD24 X D7	92		80	8494	661	1.31
Means				9173	608	1.19
D18	100	95	120	8342	629	1.07
ED7	100		90	8960	652	1.34
M-101 X DD1	96		80	8952	811	1.32
Means				8752	697	1.24
Means			120	8780	623	1.02
			90	9364	620	1.24
			80	8390	738	1.25
Grand mean				8845	660	1.17
LSD			1%	1243	175	0.27
			5%	927	131	0.20

Table 2. Performance of selected large-grain F_5 lines from M-101 x 77/11442 populations.

Parent or F_4 line	Grain yield, kg/ha	Panicles/m^2, number	Grain/straw Ratio
79 Ha/1107	11,369	556	1.39
79 Ha/1029	11,265	612	1.56
79 Ha/1007	10,831	538	1.32
79 Ha/1069	10,809	630	1.55
77/114422(P_2)	10,736	570	1.29
79 Ha/1128	10,669	578	1.47
79 Ha/1022	10,614	587	1.51
79 Ha/1085	10,552	622	1.60
79 Ha/1023	10,527	621	1.60
M-101(P_1)	9,951	648	1.70
LSD 1%	862	-	0.21
5%	642	-	0.16

Table 3. Performance of selected large-grain F_6 lines from SD7 X B18355.

Parent or F_5 line	Grain yield, kg/ha	Panicles/m^2 number	Grain/straw ratio
SD7(P_1)	10,487	661	1.11
79/20075	10,153	674	1.48
79/20091	10,071	623	1.46
79/20863	10,042	539	1.38
79/20059	9,915	568	1.39
79/20087	9,487	717	1.18
79/20095	9,289	593	1.38
79/20079	8,785	584	1.37
B18355(P_2)	7,401	577	1.03
79/20827	7,266	481	1.06
LSD 1%	760	98	0.25
5%	566	73	0.19

Table 4. Performance of selected many-grained panicles from F_6 lines of SD7 X PI344042.

Parent or F_5 line	Grain yield, kg/ha	Panicles/m^2, number	Grain/straw ratio
79/20115	11,351	776	1.31
79/20143	10,626	692	1.07
79/20119	10,067	638	1.10
79/20135	9,984	631	1.23
79/20131	9,774	682	1.28
79/20123	9,763	681	1.06
SD7(P_1)	9,451	701	1.14
79/20775	9,349	686	1.26
79/20147	9,242	582	1.35
PI344042(P_2)	7,988	592	0.80
LSD 1%	1,245	142	0.23
5%	929	106	0.17

Table 5. Effect of male sterile:pollinator ratio and pollinator height* on the seed set** of short stature male steriles (1 replication).

Male sterile:pollinator ratio	Tall pollinator		Short pollinator		Average	
	Seed set, %	Number of panicles	Seed set, %	Number of panicles	Seed set, %	Number of panicles
1:1	44	230	37	334	41	282
2:1	40	262	35	343	37	302
3:1	39	276	32	283	35	280
Average seed set	41	256	35	320	38	288

*Height of tall pollinator = 118 cm; short pollinator = 99 cm; male steriles = 97 cm.
**Seed set of pollinators = 85.7%.

Table 6. Effect of seeding rate on yields.

Genotype	Seeding Rate, lbs/Acre 50	100	150	Mean	50/150 %
			Grain Yield		
SD7	8737	9457	10123	9439	86.3
79/20143 (SD7 X 344042)	8747	9752	9817	9439	89.1
79/20107 (SD7 X 344042)	8879	9316	9802	9332	90.6
79/20091 (SD7 X 18355)	8539	9291	9722	9184	87.8
79/20791 (SD7 X 344042)	8318	9550	9562	9143	87.0
79/20135 (SD7 X 344042)	8816	9404	9133	9118	96.5
79/20863 (SD7 X 18355)	8769	8622	9396	8929	93.3
M-101	8045	8563	9478	8695	84.9
79/20839 (SD7 X 18355)	8233	8144	8363	8247	98.4
79/20843 (SD7 X 18355)	7452	7253	7467	7391	99.8
Mean	8453	8935	9286	8892	
%	91.0	96.2	100		