COMPREHENSIVE RESEARCH ON RICE

ANNUAL REPORT
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I. PROJECT NUMBER AND TITLE

Rice Biology RB-3
Genetic and Physiological Determinants of Yield and Quality in Rice

II PROJECT LEADERS AND PRINCIPAL INVESTIGATORS

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III LEVEL OF 1976 FUNDING: $12,000

IV OBJECTIVES OF THE 1976 RESEARCH PROPOSAL

1. To identify characteristics of rice that will raise current yield ceilings.

2. Determine both heritability and the physiological nature of these characteristics.

3. To introduce these characteristics into adapted varieties and to release useful genotypes to rice breeders.

Objective 1. Identification of genetic sources of resistance to low-temperature induced floret sterility and introduction of this characteristic into useful short-stature breeding lines. (Progress Report on PhD thesis study by James Board.)

Work on this objective has been in progress for several years but the colder-than-normal 1976 season provided the best opportunity since the work was begun to establish proof of a high degree of environmental stability to temperature of selected lines. The best sources of resistance came from crosses between the California variety Caloro and two Japanese varieties, Kitaminori and Isaomochi. The latter were developed in northern Japan where the Japanese have worked on cold tolerance for more than 100 years.

Shown in table 1 are 16 lines in the F_{10} generation from various crosses along with R1659, a cross between D7 x CS-M3; Calrose 76, an induced short-stature mutation from Calrose; Earlirose; and CS-M3. The lines with the least sterility for the average of 1975 and 1976 showed 7 to 10 percent sterility compared with 32 to 33 percent for Earlirose and CS-M3. Comparison between 1975 and 1976 results indicated there may be different threshold temperatures to induce sterility in different varieties. For example, lines numbered 1 through 5 showed only about 3 percent more sterility in the cold 1976 season compared with the warmer 1975 season. However, Earlirose and CS-M3 exhibited three times greater sterility in 1976, with about 50 percent sterile florets. Work on introducing low sterility into adapted varieties is reported later.

Research on other sub-objectives has not progressed to the data summarization stage and will be reported next year.

Objective 1. Effect of nitrogen fertilization on culm elongation of near-isogenic tall and short varieties of rice. (From MS thesis by Tran Van Dat.)

Last year's report presented yield data on near-isogenic lines of tall and short versions of both glabrous and pubescent rice types. The short lines produced about 10 percent greater yield than tall ones at high nitrogen fertility levels. Data were not available at that time to show the effect of nitrogen fertility levels on culm elongation. This is shown in figure 1. The dotted lines connect the nodes of the culms at nitrogen rates of 33.5 to 201 kg per hectare at 33.5 kg increments, (30 to 180 pounds per acre with 30 pound increments).

The figure shows that both short and tall types elongate more at high fertility levels but the rate of increase is much greater (steeper slope of the dotted lines) for tall types. It is possible to induce lodging of short-stature varieties with very high fertility levels but the problem is much more severe with tall varieties. Conclusions from these experiments, as previously reported, were that the yield differences between short and tall near-isogenic types could be explained primarily by differences in the time and amount of lodging.

Objective 1. Production, movement, and storage of carbohydrates in rice. (Progress report on PhD thesis by D. B. Jones.)

Objectives of this study are to identify, if possible, those barriers to raising the yield ceiling of rice. Much progress has been made in raising yields by elimination of deficiencies (such as fertilizers) and correcting defects (such as lodging). The present experiments are aimed at the identification of physiological processes that may limit the ultimate yield of rice.

Potential physiological barriers to yield are 1) photosynthesis (production of sugars in the rice leaves), 2) translocation (movement of sugars and subsequent products of photosynthesis from the leaves to grain), and 3) storage (the accumulation of starch, protein, etc. in the grain).

In 1975, laboratory analysis of sugar levels in different parts of the plant throughout the day showed no direct evidence of resistance to the movement of sugars from leaves to panicles. The direction of flow is from the flag leaf blade to the flag leaf sheath, then to the first internode of the culm to the panicle. The sugar levels at two-hour intervals from 8 a.m. to 8 p.m. are shown in figure 2. The sugar percentage of the flag leaf increased from 1.8% at 8 a.m. to a peak of nearly 4.0% at 4 p.m. after which it declined rapidly to 2.5% by 8 p.m. This indicates rapid movement out of the leaf without evidence of concurrent accumulation as sugar elsewhere. Movement through the sheath was steady, and although the sugar concentration in the internode is high, this is normal as it serves as a temporary storage organ. No diurnal changes in sugar concentration in the leaf sheath and internode was evident, suggesting free movement through to the panicle.

Sugar concentration in the panicle remained relatively constant throughout the day, indicating that conversion from sugar to starch was occurring as rapidly as the rate of sugar movement into the kernels.

Our own research and that of others indicate that storage capacity of the panicle may be the primary physiological limitation to yield. With this in mind, a field study was done in 1975 to determine the relationships between the filling rate of the panicle (the rate at which the panicle gains in weight) and various other characteristics including yield components. Results are shown in Table 1. Filling rate was highly correlated with panicle weight and seed number per panicle. Also a highly significant negative correlation was obtained between seed number per panicle and tiller number per square meter. This indicates that as tiller numbers increase, kernels per panicle decrease. No relationhip was found between tiller number and yield.

We believe that kernels per panicle may be the most promising avenue for raising the yield capacity of rice and will be pursuing this approach in genetic and physiological studies next year.

Objective 1. Analysis of synchronous heading, panicle number, plant height, and median heading date of F_3 lines from a cross between synchronous and nonsynchronous heading parents. (Progress report on Ph.D. thesis by Tran Van Dat.)

The quality of harvested rice probably could be improved if the panicles emerged nearly simultaneously. Not only could green kernels be reduced or eliminated but the time of field draining could be determined more precisely. However, it is not known if synchronous heading is associated with other characteristics such as yield, panicle number, plant height, or time of heading.

Preliminary trials in 1975 indicated genotypic differences in heading synchrony. A cross made between synchronous and nonsynchronous heading parents was analyzed in the F_3 generation in 1976. Preliminary results are presented in Table 3. Each line is the mean of 3 replications of 5 plants each or 15 individual plants spaced one foot apart. The study was conducted by tagging and numbering each panicle as it emerged.

Inspection of the data indicate the range in panicle number among F_3 lines was as great as the two parents and the days from first to last heading date was similarly great. By inspection of the tabular data, heading synchrony does not appear to be associated with median heading date, number of panicles per plant, or plant height. Although the differences observed probably are partly hereditary and partly environmental, the prospects look promising for selecting synchronous heading, short-stature, lines from this cross.

Objective 1. Effect of maturity types on yields of several near-isogenic rice lines. (Progress report on MS thesis by Beatriz Pinheiro.)

One of the important objectives of the Rice Research Board from the beginning was to produce earlier maturing varieties to permit earlier harvesting. An unanswered question was whether or not it would be possible to produce early lines with yield capabilities equal to the later maturing ones. An opportunity to obtain data on this occurred with the development of lines of rice with various maturity types in similar genetic backgrounds, called near-isogenics.

Because maturity types could possibly respond differently to nitrogen fertility levels, this was included as a variable, with rates from 90 to 180 pounds per acre using 30-pound increments. The maturity types as classified according to days from planting to 50 percent heading were as follows:

Maturity Types	Field Trial Days	Greenhouse Trial Days
ED 7	101.8	78.6
75/31269-5	109.5	94.5
75/15070	118.3	116.9
Calrose 76	120.4	118.0
SD 7	120.9	118.8
Calrose	-	118.9

The field trial was sown May 1 and the greenhouse trial on May 4, 1976. The earlier heading of the early maturing lines in the greenhouse than in the field is probably a temperature response during early stages of development.

Yields of field plots from these near-isogenic lines in 1976 are shown in Table 4. The earliest line, ED 7, produced the highest yields (8,812 pounds per acre). Line 75/31269-5 ranked next at 8,547. This line was found to be segregating, thereby limiting somewhat the value of data from this line. 75/15070 is a smooth hull short-stature line which was only 2 days earlier at Davis than the two late maturing lines. At this location, the early lines produced the highest yields and the latest lines the least yield. Low-temperature induced sterility is believed to be the primary reason of the lower yields of the late lines.

Careful inspection of yields for each line at the different nitrogen fertility levels reveals that the early line may require less nitrogen to achieve top yields than later maturing lines.

Objective 2. Additional semidwarfing genes in rice. (Ph.D. thesis by K.W. Foster)

The semidwarfing gene in Calrose 76 was shown to be allelic (i.e., nearly identical) to the gene from the tropical semidwarfs (IR 8, etc.). Calrose mutant D66 was found to have a different semidwarfing gene. The southern long grain, CI 9858, appears to have yet another semidwarfing gene. All three semidwarfing genes are independent of each other. All paired combinations called Double-dwarf 1, Double-dwarf 2,and Double-dwarf 3, were created. Approximate heights of the various combinations are:

Line	Height, inches
Calrose = normal, tall	45
D66 = one semidwarf gene	39
CI 9858 = one " "	39
Calrose 76 = one " "	35
Calrose 76 x D66 = Double-dwarf 1	31
Calrose 76 x CI 9858 = Double-dwarf 2	31
CI 9858 x D66 = Double-dwarf 3	31

The above lines provide additional flexibility in adjusting plant height in California. Double-dwarf 1, the most interesting combination, is in a late background (3 days later than Calrose) and consequently is low yielding at Davis. Earlier versions of Double-dwarf 1 are being prepared. Also in preparation are "Triple-dwarfs," created by recombining all three semidwarfing genes into one line. It is estimated the "triple-dwarfs" will be about 27 inches tall.

Objective 2. Identification and inheritance of yet another double-dwarf combination (Progress Report on M.S. thesis study by David Mackill).

Inheritance of plant height in the Calrose short stature mutant D24 (and its smooth hull counterpart, SD 24), appears to be controlled by yet another semidwarfing gene. If this is confirmed in 1977, the D24 gene will be the third short stature gene obtained by induced mutation of Calrose (previous short stature genes were the Calrose 76 and D66 genes). Already the double-dwarf type between D24 and Calrose 76 has been created. It is about 4 inches shorter than Calrose 76, 8 days earlier, and has slightly smaller seeds. Both rough and smooth hull versions of the double dwarf were selected.

Objective 2. Inheritance of early maturity and its relationship to plant height and seedling vigor (Progress Report on M.S. thesis study by Kent McKenzie).

Inheritance of early maturity in Calrose mutant D18 (15 days earlier than Calrose) was found to be controlled by a single, partially dominant, gene. The early maturity gene is independent of the Calrose 76 short stature gene and of the smooth hull gene from CS-M3. The short stature gene and the smooth hull gene are also independent of each other. Thus it was possible to readily create all eight possible combinations of these three genes:

Height:	Maturity:	Hull Type:	Name:
short	early	smooth	ESD7
		rough	ED7
	late	smooth	SD7
		rough	"Calrose 76-like"
tall	early	smooth	SD18
		rough	D18
	late	smooth	"CS-M3-like"
		rough	"Calrose-like"

Although experience indicates that high seedling vigor is associated with early maturity and tall plant height, the previous studies have been confounded by unlike genetic backgrounds. The eight types of lines developed in the present study are in nearly identical genetic backgrounds. Thus it should be possible to determine the precise relationship of seedling vigor to the two states of each of these three genes, i.e., short/tall, early/late, and smooth/rough.

Objective 2. Inheritance of blanking in rice (Progress Report on M.S. thesis by Robert Barham).

The first segregating generation of about 30 crosses among 8 blanking tolerant lines (including lines 82, 43, and 53 from table 1), and 5 improved breeding lines (including Calrose 76 and 74Y52) was grown in 1976. This proved to be a banner year for blanking (i.e., severe blanking!). From this experiment it should be possible to determine 1) the heritable component of blanking tolerance, and 2) the relation of blanking tolerance to early maturity. The analysis of this experiment will be completed by March, 1977.

Objective 2. Inheritance of yield components (panicles/unit area, seeds/panicle, and seed weight). (Progress report on Ph.D. thesis study by Y.C. Teng).

Since grain yield is a product of its components, i.e. Yield = (panicles/unit area) x (seeds/panicles) x seed size), it follows that increases in grain yield must be accompanied by increases in one or more the components. Thus, as a companion study to the physiological work on yield components, a genetic study on yield components is underway. As reported last year, crosses were made among big-seeded lines, many-seeded lines, and several short stature lines which were expected to have many panicles/unit area. Due to the extremely cool season many crosses blanked severely in 1976, and it was difficult to draw conclusions from this experiment. One surprise was that the short stature lines did not consistently show increased numbers of panicles/unit area. This study will be continued in 1977.

Objective 3. Release of Calrose 76.

Calrose 76, formerly known as D7, was jointly released by the USDA, UC, and CCRRF on June 1, 1976. Calrose 76 is about 10 inches shorter than Calrose (14 inches shorter than CS-M3) and considerably more lodging resistant. Calrose 76 continued to perform well in 1976, especially in the variety x nitrogen trials conducted by Agricultural Extension. In those tests, Calrose 76 yielded about 10% more grain and 10% less straw than CS-M3. Calrose 76 exhibits more awning than present varieties and may require careful attention to combine adjustment. Comparative awn lengths of Calrose 76, Calrose, and CS-M3 at two locations in 1976 are given in table 5. Awn length of both Calrose 76 and Calrose was considerably longer at Biggs than at Davis.

The value of Calrose 76 lies not only in its own performance but also in its performance as a short stature, cold tolerant parent of additional breeding lines. Thus Calrose 76 was the short stature parent of 6 very good lines in the 1976 statewide late maturity variety trials (entries R1659, R1659-A, R1659-B, R1659-C, 75Y256, and 75/15070).

Objective 3. Development of six short stature germplasm lines.

The Calrose 76 gene for short stature was incorporated into four germplasm lines differing in maturity and/or hull pubescence (table 6). Thus 75/15070 is a short stature, smooth hull line which yields the same as R1659 (short stature CS-M3) and has the added merit of being 3 days earlier than R1659 (table 7). ED7 (Early D7), a selection that is nearly 20 days earlier than Calrose 76 (and about 3 days earlier than Earlirose), is short stature and has rough hulls. ED7 performed well in three 1976 trials conducted under short season conditions (table 8).

As predicted last year, we were able to develop ESD7 (Early, Smooth, D7) lines. These lines are 15-20 days earlier than CS-M3, thus placing them similar to Earlirose and ED7 in maturity (Table 6). Yields of these lines appear similar to ED7. One (ESD7-1) produced 9,300 lb/A in a 1/8 acre plot at Davis in 1976.

The short stature Calrose mutant D66, which was found to have a different short stature gene from Calrose 76, was recombined with Calrose 76 to produce a "Double-dwarf" line (table 6. The Double-dwarf line, which has 2 genes for short stature, is shorter than either of its short parents. The Double-dwarf is expected to have still more lodging resistance than either single-dwarf parent. Whether this will result in even higher grain yields remains to be seen.

VII Concise General Summary

Genetic sources of resistance to panicle blanking have been identified and are being uutilized in crosses. Studies are in progress that are expected to indicate the physiological basis for yield limitations. This information will be useful in directing further genetic studies aimed toward raising the rice yield barrier. Studies on synchronous heading of rice show wide plant-to-plant differences. The value of this and associated characteristics are being analyzed. Yields of early , medium, and late maturing near isogenic lines of rice indicated higher production from early maturing lines at the Davis location.

At least three different semidwarfing genes have been identified. The most useful gene, in Calrose 76, was found to be nearly identical to the gene in the tropical semidwarf, IR8. A gene which confers about 15 days earlier maturity was also identified. Studies are underway on inheritance of blanking, and on yield components. The short stature variety Calrose 76 was release, and six additional short stature germplasm lines were developed.

Table 1. Percent sterile florets among 16 selected lines compared with standard California cultivars and potential new cultivars

No.	Identi-fication	Generation and pedigree		% Sterility 1975	1976	Avg.
1	52	F_{10}	73/261 (Caloro x Kitaminori)	5.19	8.73	6.96
2	97	F_{10}	73/506 " "	5.18	9.35	7.27
3	82	F_{10}	73/525 " "	5.71	9.47	7.59
4	56	F_{10}	73/257 " "	5.73	9.58	7.66
5	43	F_{10}	73/213 " "	8.15	11.26	9.70
6	92	F_{10}	73/3666 (Caloro x Isaomochi)	7.11	12.83	9.97
7	61	F_{10}	73/249 (Colusa x Kitaminori)	6.80	16.29	11.55
8	65	F_{10}	73/349 " "	8.41	16.05	12.23
9	25	F_{10}	73/494 (Caloro x Kitaminori)	7.66	17.68	12.67
10	53	F_{10}	73/221 (Colusa x Kitaminori)	8.63	17.58	13.11
11	21	F_{10}	73/496 (Caloro x Kitaminori)	6.99	20.05	13.54
12	91	F_{10}	73/3776 (Caloro x Isaomochi)	12.16	19.57	15.87
13	16	F_{10}	73/3652 " "	6.34	28.50	17.42
14	22	F_{10}	73/3715 (Calrose x Isaomochi)	9.56	31.55	20.56
15	74	F_{10}	73/3760 " "	19.88	21.41	20.65
16	R1659	D7 x CS-M3		-	23.95	23.95*
17	73	F_{10}	73/3727 (Calrose x Isaomochi)	27.09	25.94	26.52
18	C76	Calrose		-	27.80	27.80*
19	ER	Earlirose		16.10	48.23	32.17
20	CS-M3			14.67	51.42	33.05
	Average			10.08	20.86**	

*Data from 1976 only
**Entry Nos. 16 and 18 omitted

Table 2. Correlations of various yield components with filling rate of rice.

	Ht, cm	D.T.H.	till#/m	pan wt, g	sd #/pan	100 sd wt, g	yd #/A
Filling rate	.54*	.23	-.52	.84**	.78**	.03	.57*
Yield lb/A (yd #/A)	.09	.08	.05	.49	.24	.37	
100 seed wt, g (100 sd wt g)	.05	-.65*	.27	.28	-.26		
Seed number/pan (sd #/pan)	.32	.54*	-.70**	.62*			
Panicle wt (pan wt, g)	.47	.07	-.64*				
Tiller number/m (till#/m)	.03	-.60*					
Days to head (D.T.H.)	.18						

*, ** Indicate significance at the 0.05 and 0.01 levels of probability respectively.

Table 3. Heading and tillering characteristics of F_3 lines from a cross between synchronous (D51) and nonsynchronous (G30) heading parents

Parent or F_3 line	Panicles	Median Heading	Heading ranges
Identification	No.	Days	Days
P1 (D51)*	38.0	115.1	8.5
P2 (G30)*	42.7	115.5	15.1
Short Stature Lines			
1	37.3	116.4	8.7
2	34.3	116.4	8.8
3	35.1	119.5	9.0
4	38.5	119.7	9.3
5	38.1	116.6	10.8
6	45.9	122.1	10.8
7	31.5	116.7	11.1
8	39.2	123.4	11.2
9	35.4	117.9	11.3
10	37.6	115.6	11.7
11	39.8	118.8	11.9
12	37.0	120.8	11.9
13	40.3	127.5	12.2
14	44.4	116.2	13.3
15	46.9	112.3	15.7
16	37.6	113.6	15.9
17	35.7	120.9	15.9
18	37.9	115.1	15.9
19	36.9	114.9	16.1
Mean	38.4	118.1	12.0
Tall Lines			
1	39.8	114.7	8.5
2	41.7	114.2	10.9
3	39.5	122.3	11.4
4	47.3	114.0	15.7
Mean	42.9	115.4	13.1

*D51 is apparently identical to Calrose 76; G30 is a sister selection to S6.

Table 4. Yield in pounds per acre of 5 near-isogenic lines differing in maturity

Nitrogen Lb/acre	ED 7	75/31269-5	75/15070	Calrose 76	SD 7	Average
90	8055	7844	7574	6724	7052	7450
120	9144	8556	8165	7837	7574	8255
150	9068	8760	8587	7833	8141	8477
180	8985	9029	8833	7878	8041	8553
Average	8812	8547	8290	7567	7702	-

Table 5. Awn length of Calrose 76, Calrose and CS-M3 at Davis and Biggs in 1976

Location	Variety and awn length, mm		
	Calrose 76	Calrose	CS-M3
Davis	5.5	2.4	1.8
Biggs	12.0	8.7	1.6

$LSD_{.05}$ for comparing any two values = 3.1 mm.

Table 6. General characteristics of six short stature rice germplasm

Germplasm	Approximate height, inches*	Maturity, days, relative to CS-M3 or Earlirose	Hull and leaf pubescence	Ancestry
<u>Lines containing the Calrose 76 gene for short stature</u>				
75/15070	35	CS-M3-1	smooth	CS-M3 x Calrose 76 F_3 selection for early maturity
ED7	35	Earlirose-3	rough	spontaneous early maturing mutant from Calrose 76
ESD7-1	35	Earlirose-4	smooth	(CS-M3 x Calrose 76) x D31† F_2 selection for early maturity
ESD7-2	35	Earlirose-1	smooth	(CS-M3 x Calrose 76) x D18† F_2 selection for early maturity
<u>Lines containing the D66 gene for short stature</u>				
D66	39	CS-M3 + 3	rough	induced short stature mutant from Calrose
Double-dwarf 1	31	CS-M3 + 3	rough	Calrose 76 x D66 F_3 double dwarf select-ion

*Reference height of standard tall varieties is about 45 inches.

†D31, D18 are induced mutants for early maturity from Calrose.

Table 7. Days to heading and grain yield of 75/15070 and check varieties in 1976 trials

Location	75/15070		Calrose 76		CS-M3		R1659	
	Days to heading	Yield, lb/A	Days to heading	Yield, lb/A	Days to heading	Yield, lb/A	Days to heading	Yield, lb/A
Kern Co.	105	5160	107	5790	104	5960	110	6210
Sutter Co.	115	7080	118	7910	118	6400	119	7990
Glenn Co.	117	6500	118	6280	116	6290	118	5850
Colusa Co.	113	8350	116	7510	112	7570	116	8160
Biggs	114	9650	121	7210	120	7940	117	9160
Average	113	7350	116	6940	114	6830	116	7470

$LSD_{.05}$ for heading = 1 day; $LSD_{.05}$ for yield = 520 lb/A

Table 8. Days to heading and grain yield of ED7 and check varieties in 1976 trials

Location	ED7		Earlirose		74Y10		74Y52	
	Days to heading	Yield, lb/A	Days to heading	Yield, lb/A	Days to heading	Yield, lb/A	Days to heading	Yield, lb/A
San Joaquin Co.	105	6380	105	5400	96	4910	101	4460
Sacramento Co.	104	6720	109	3190	96	6180	107	7060
Biggs	92	8920	96	8510	87	7820	93	8250
Average	100	7340	103	5700	93	6300	100	6590

$LSD_{.05}$ for heading = 1 day; for yield = 700 lb/A

VI Publications or Reports

1. Anonymous. 1976. Notice of naming and release of rice cultivar 'Calrose 76' (CI 9966).

2. Davis, M. D. and J. N. Rutger, 1976. Yield of F_1, F_2 and F_3 hybrids of rice (Oryza sativa L.). Euphytica 235 (in press).

3. Foster, K. F. 1976. Inheritance of short stature genes in rice. Ph.D. thesis, University of California.

4. Jones, D. B. and M. L. Peterson. 1976. Rice seedling vigor at sub-optimal temperatures. Crop Science 16:102-105.

5. Lin, S. S. and M. L. Peterson. 1975. Low temperature-induced floret sterility in rice. Crop Science 15: 657-660.

6. Rutger, J. N. and M. L. Peterson. 1976. Improved short stature rice. California Agriculture 30 (6):4-6.

7. Rutger, J. N., M. L. Peterson, C. H. Hu, and W. F. Lehman. 1976. Induction of useful short stature and early maturing mutants in two japonica rice cultivars. Crop Science 16: 631-635.

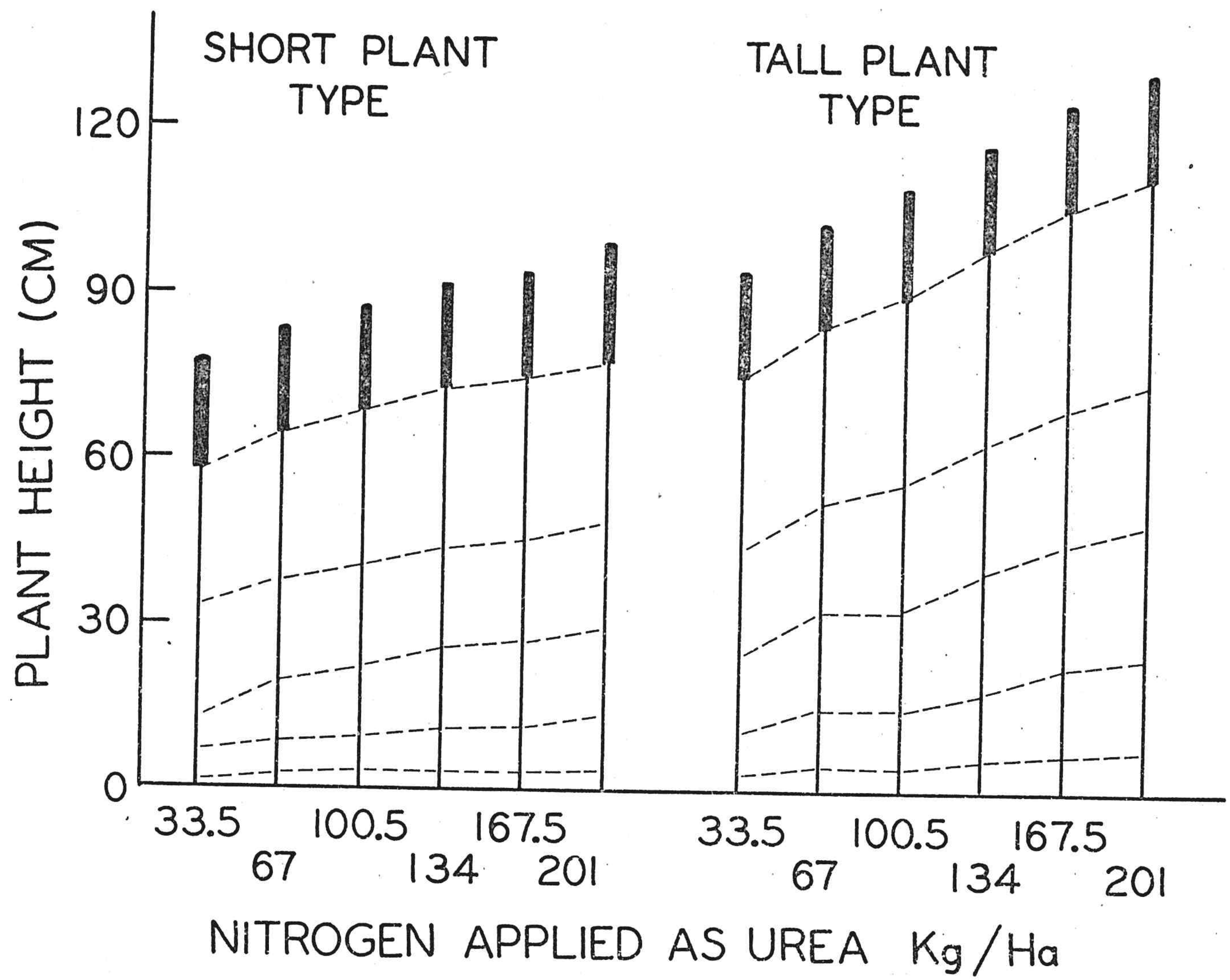

Figure 1. Effect of nitrogen fertilizer rates on plant height and internode lengths of short and tall rice plant types.

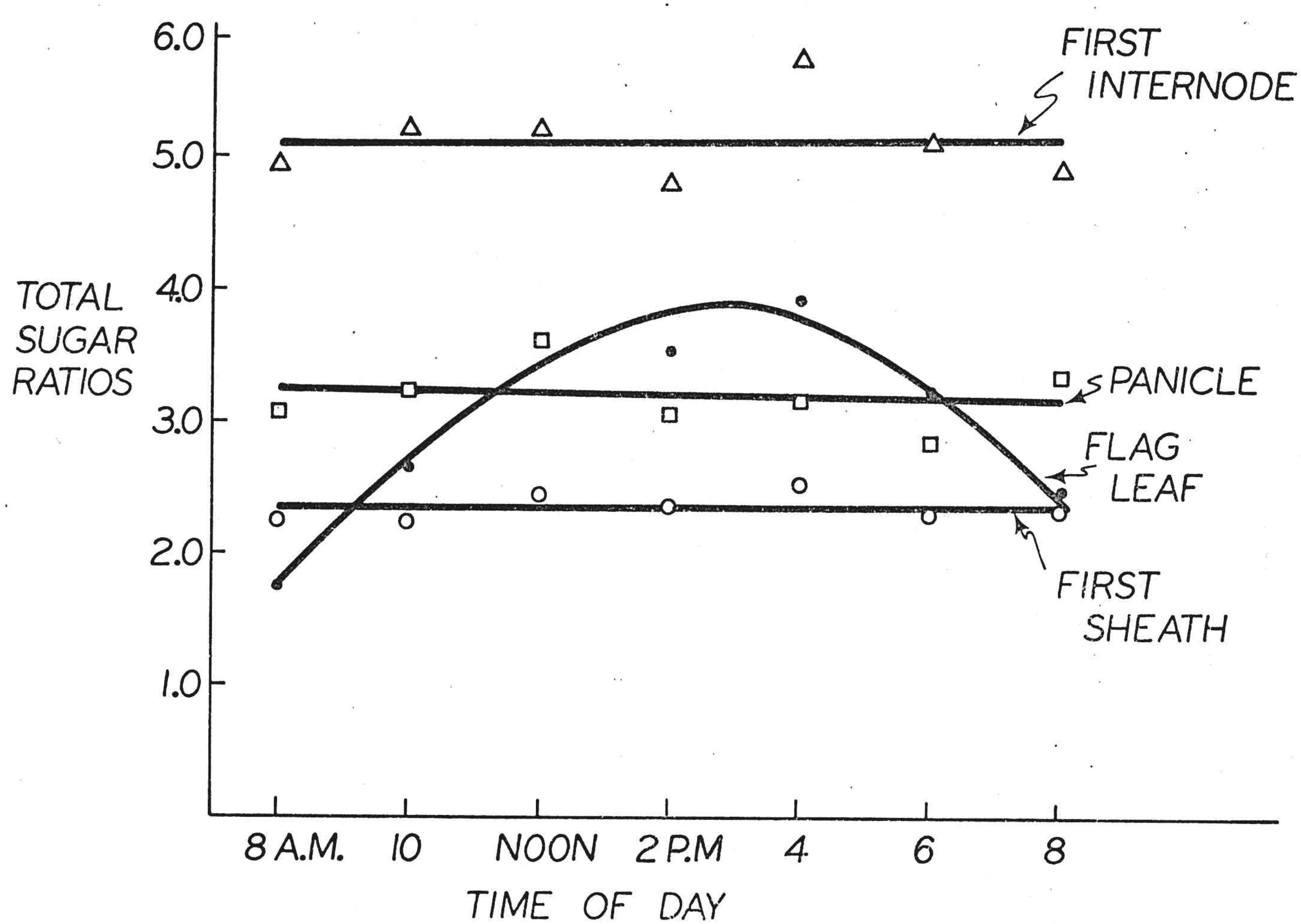

Figure 2. Total sugar ratios of rice plant parts from 8:00 AM to 8:00 PM.