Project Number: RB-3

COMPREHENSIVE RESEARCH ON RICE

ANNUAL REPORT

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PROJECT TITLE: Genetic and Physiological Determinants of Yield and Quality

PROJECT LEADER AND PRINCIPAL UC INVESTIGATORS:

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H. P. Moon, Graduate Student
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LEVEL OF FUNDING: $20,000

OBJECTIVES AND EXPERIMENTS CONDUCTED BY LOCATION TO ACCOMPLISH OBJECTIVES

1. Enlargement of basic studies on climatic effects (both low and high temperatures) on rice growth, grain yield, head rice yield and chalkiness with the objective of identifying genotypes that are less sensitive to environmental extremes. Special emphasis will be given to performance of earlier maturing types.

2. Basic research on other factors that can raise current yield limitations.

3. Engage whole plant and cell culture selection methods for greater tolerance of rice to herbicides.

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

SUMMARY OF 1978 RESEARCH (MAJOR ACCOMPLISHMENTS) BY OBJECTIVES:

Objective 1. Enlargement of basic studies on climatic effects (both low and high temperatures) on rice growth, grain yield, head rice yield and chalkiness with the objective of identifying genotypes that are less sensitive to environmental extremes. Special emphasis will be given to performance of earlier maturing types.

A. Dr. James E. Board completed the Ph.D. degree in Plant Physiology in 1978 and has been employed as a Post Graduate Research Agronomist this past year on funds provided by the Rice Research Board. The focus of his research is on environmentally induced sterility in rice and its control by cultural practices and selection for varietal resistance to temperature stress. Although these studies are still incomplete, the following tentative conclusions can be drawn:

1) Tetrazolium bromide stain is a quick and easy method for determining if pollen grains are capable of germinating. Florets with anthers containing pollen with more than 50% sterile pollen probably will be sterile.

2) Minimum air temperatures of 12 C (54 F) for 8 hours on three consecutive nights is sufficient to cause sterility in plants placed in growth chambers.

3) A new plant characteristic not previously noted may be responsible for observed low sterility under cool field conditions. This is an unusually large and more finely branched stigma that attracts and holds more pollen. This characteristic, observed in genotype 97 (CI 11040), should be confirmed in 1980, and if determined to be valid, will provide a new characteristic for use in selecting sterility resistant genotypes.

4) Water temperatures which are always higher than minimum air temperatures have a moderating effect on the temperature of the developing panicle. Minimum water temperatures of 14 C (57 F) were below the level required to provide protection from low temperature-induced sterility (Figure 1). Sterility in a cold water basin (B-1) was between 62 and 95% for four rice cultivars. Panicle temperature in this case fell below 12 C (53.5 F).

5) Minimum water temperatures of 16 to 17.6 C (60-64 F) reduced sterility of the same genotypes from 62-94% noted above to 10-30% (Figure 1). Therefore only 2-3 C increase in water temperature had a very large effect on fertility. The warmer water increased panicle level temperatures above 12 C (53.5 F), thus reducing cold-induced sterility.

6) Sterility among four cultivars at six locations (two planting dates at Davis location) showed large differences among locations and cultivars (Figure 2).

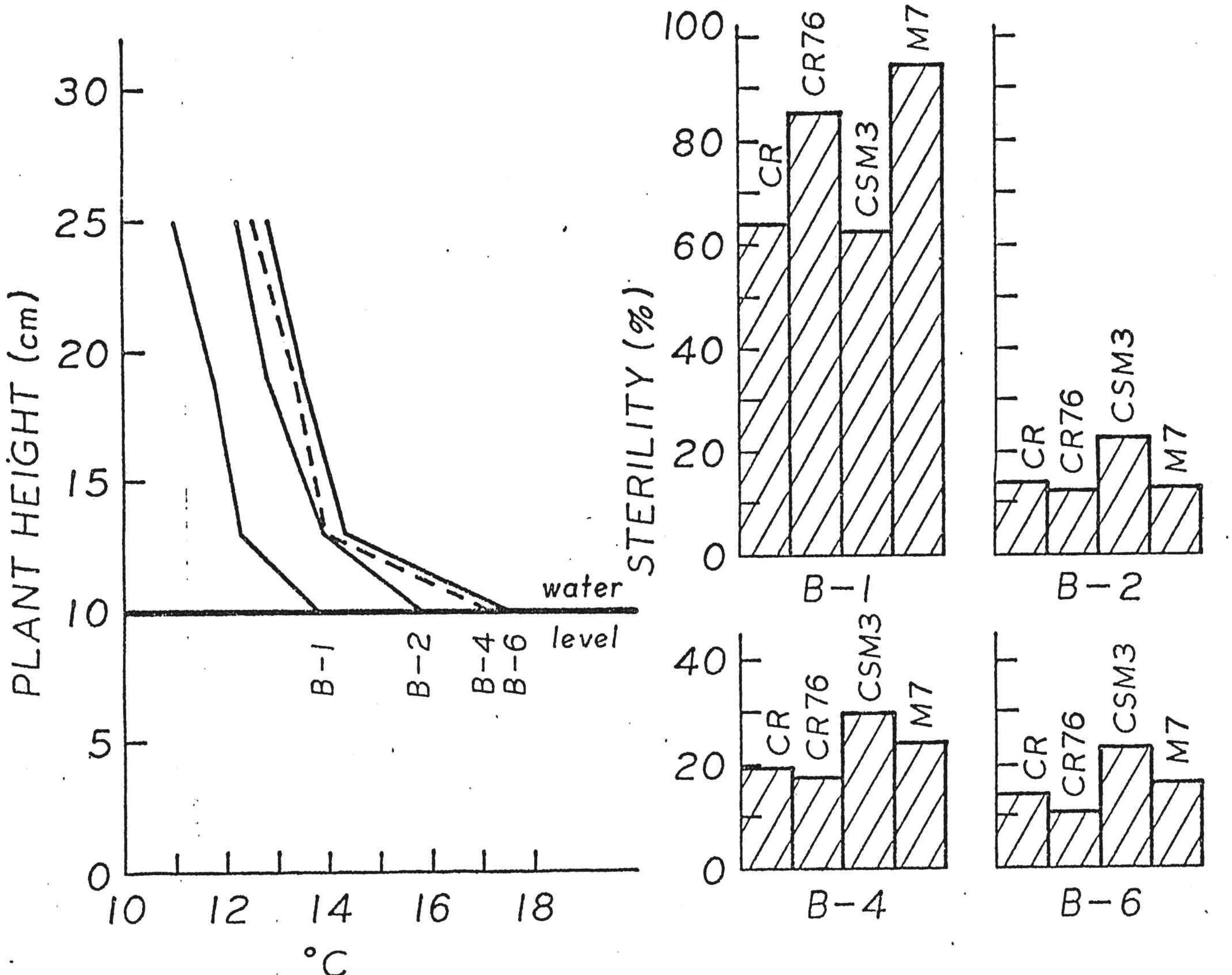
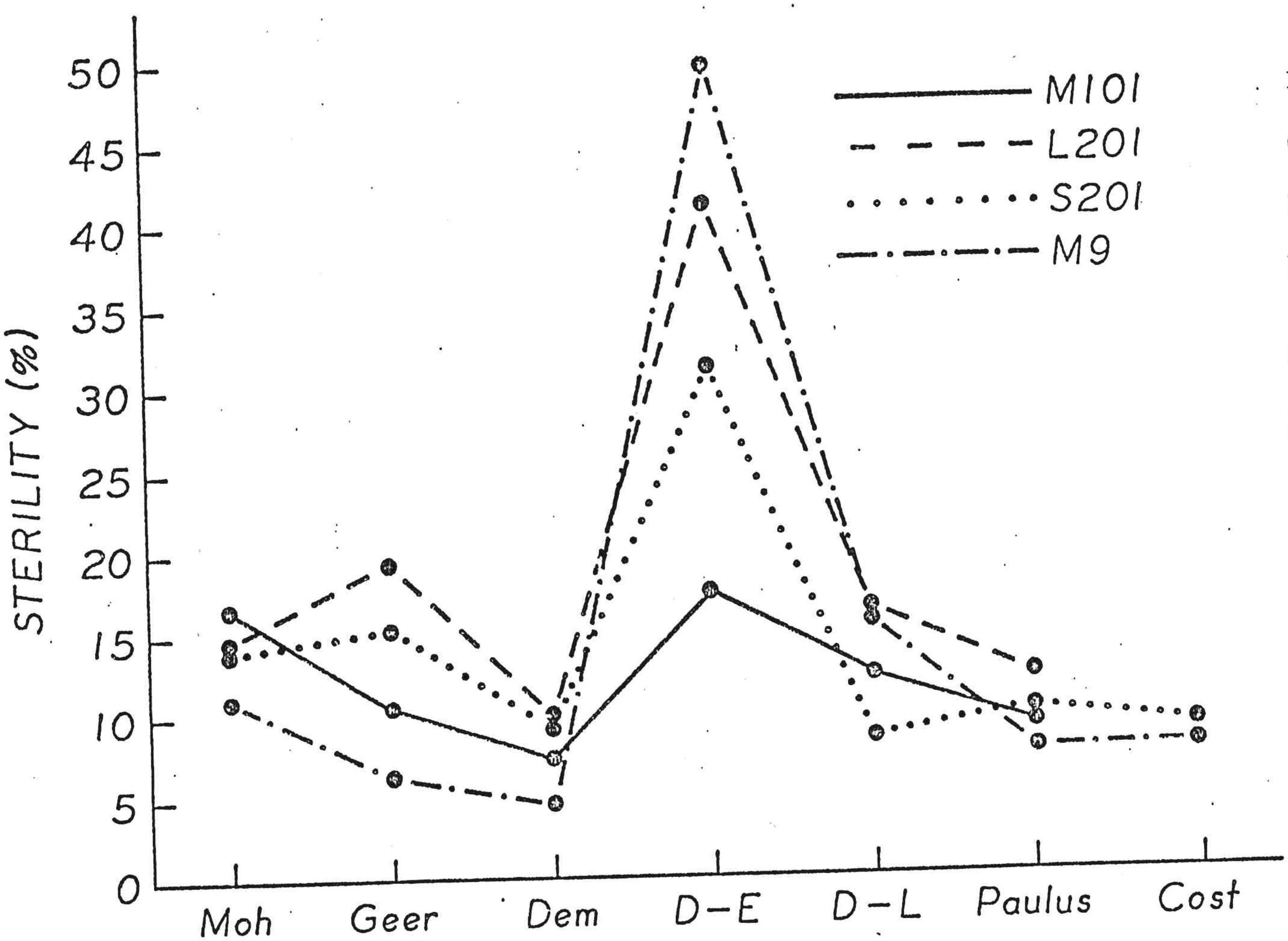


Fig. 1 . Temperature Profile During Panicle Development (8/9–8/25) and Sterility Data in Davis. 1979 Water Temperature Study.



Moh: MohammedFarm,
Yuba Co.
Geer: Geer Farm,
Yolo Co.
Dem: Demeter Corp.
Sacramento Co.
D-E, D-L: Davis early
and late trials,
Yolo Co.
Paulus: Paulus Farm,
San Joaquin Co.
Cost: Costerison Farm,
Kern Co.

Fig. 2 . Sterility Data of Four Varieties Throughout California.

7) Performance of the four cultivars at different locations show that significant sterility can occur even at locations not subject to low temperatures (Yuba Co. trial shown in Figure 2). Apparently, there are factors other than low temperatures that can induce sterility.

8) Cultivars differ in their stability to environmental influences. As shown in figure 2, cultivar M-101 exhibited little variability in sterility from location to location while M-9 showed the least sterility at five locations and the most at Davis. These results indicate that M-9 and L-201 should not be grown in areas subject to unusually cool night temperatures.

9) The sterility differences between the early and late planting dates at Davis were the result of differences in water temperatures rather than planting dates. The late planting was in a warm water basin.

10) A test conducted at the Imperial Valley Field Station on the effects of high temperatures at flowering time on sterility showed large differences among genotypes but the results have not yet been analyzed.

11) High rates of nitrogen fertilizers (150 lbs/acre) cause more sterility than low nitrogen rates but these losses are more than offset by yield increase attributable to other components of yield. We do not think that losses to sterility from nitrogen fertilization occur unless excessively high rates of nitrogen are used. (See Figures 3 and 4.)

B. Inheritance of blanking tolerance (Ph.D. thesis research by H. P. Moon).

Southern long grain varieties are desirable sources of long grain quality but are too cold-susceptible for production in California. As part of an effort to make better use of the genetic diversity of the southern varieties, additional crosses were made between southern and our cold-tolerant California varieties. The F_1 generation was grown and screened for cold tolerance in the cool Davis environment in 1979. Data on amount of blanking are being collected and analyzed this winter.

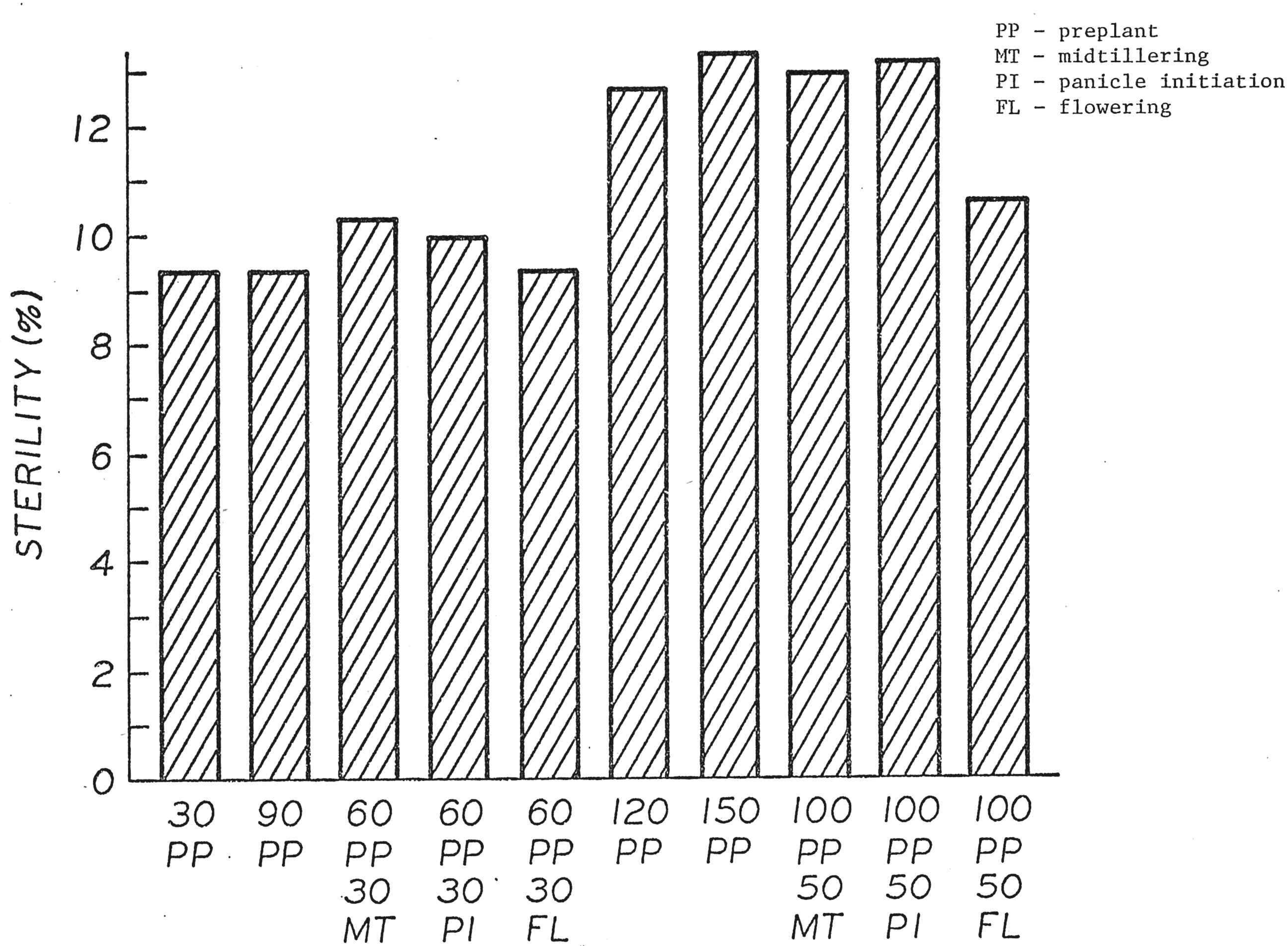


Fig. 3 . Effect of Nitrogen Application (lbs/acre) on Sterility in M101.

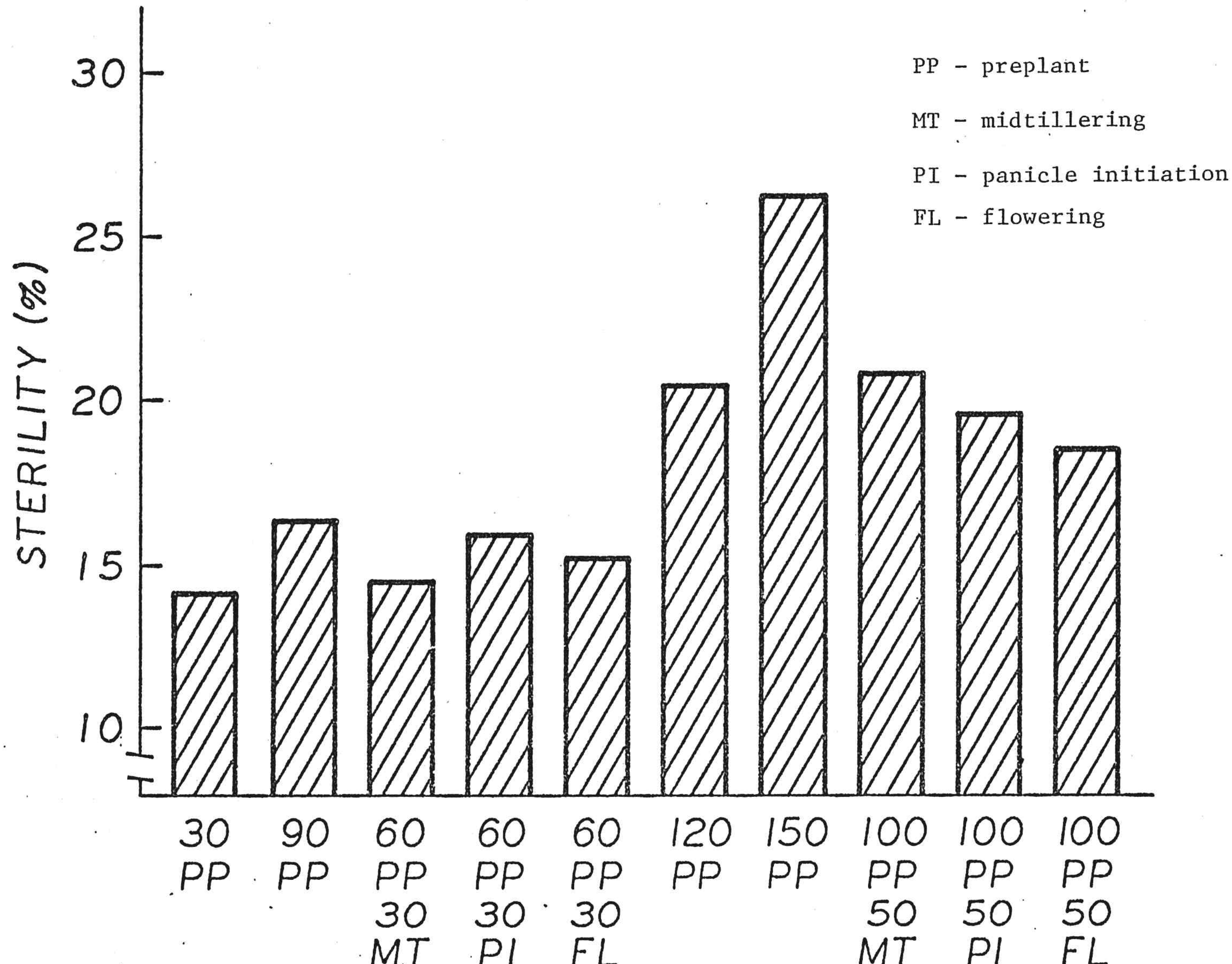


Fig. 4. Effect of Nitrogen Application (lbs/acre) on Sterility in L201.

C. Genotype and environment effects on head rice yields (M.S. thesis of S. Song).

Since head rice (whole-grains) are the most valuable rice product, it is desirable to know whether this trait can be improved genetically. Hence the effects of maturity and seed size on head rice were studied in a series of near-isogenic lines derived from crosses among Calrose mutants and CS-M3. Maturity had a large effect on head rice yields, with earlier varieties invariably having lower head rice. Thus, very early maturing lines, including M-101, averaged 57.2% head rice, while late maturing lines, including Calrose 76, averaged 61.5% head rice. In the initial series of lines, seed size had little effect on head rice yields, but there also was not much difference in seed sizes of the lines. Near the conclusion of the study, a small-seeded (20% smaller than Calrose) mutant was found to have higher head rice yields than anything else tested. This mutant (D24 and its progenies) has produced about 5 percentage points higher head rice than normal-sized varieties of similar maturity. Seed size of the mutant is controlled by a single recessive gene which also gives semi-dwarfism. In preliminary tests of a double dwarf line with the D24 gene, the small seeded line yielded 9870 lb/A, compared to 9140 lb/A for M-301, a line of similar maturity but with normal seed size. Further information is needed to determine if this small-seeded, high-head-rice line would be acceptable to the rice milling industry. its small seeds have dimensions which are intermediate between present short and medium grain classes.

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

A. David B. Jones completed the Ph.D. degree in Plant Physiology in June, 1979 and has a position as Extension Agronomist at the University of Maryland. His Ph.D. thesis was supported in part by the Rice Research Board. The objectives of his research were to determine whether photosynthetic rates, starch storage capacity of the panicle, or rate of transport of sugars from leaves to panicles was the primarily limitation to rice yields. His conclusions were as follows:

1) The supply of sugars formed in rice leaves exceeded panicle requirements during the early and late grain filling period but not during mid-grain filling.

2) Temporarily stored carbohydrates (sugars and starch) effectively supplemented current photosynthesis during mid-grain filling and, therefore, did not affect yields.

3) Under the environmental conditions of these studies, the reserve carbohydrates in the leaves together with that currently produced was sufficient to fill more grains than was available even when sunlight was reduced by more than 40%.

4) The above results indicate that rice yields under the conditions of these studies could be increased by increasing panicle size, either by increased grain number or grain weight. Proof of this conclusion will require development of genotypes with larger panicles while retaining the same leaf, stem, and other genetically controlled characteristics.

B. Tran Van Dat has completed all course requirements and passed his qualifying examination for his Ph.D. degree in Plant Physiology. His Ph.D. thesis, although not yet completed, has been supported in part by the Rice Research Board. The objectives of his research were to determine yield and the disposition of carbohydrates produced in the leaves of rice isogenic lines differing only in growth duration (i.e., early versus late maturity). A sub-objective was to determine the relative efficiency of early and late maturing genotypes in their conversion of solar radiation to chemical energy in the rice plant. His tentative conclusions are as follows:

1) An early mutant of Calrose 76 (identified as ED7) flowered 22 days earlier when sown May 12 and 15 days earlier when sown May 22. Yields of ED7 were higher than for Calrose 76 at both planting dates (these yield data were presented in the 1978 annual report). The earlier maturity of the mutant ED7 was caused by its gene-controlled loss of sensitivity to photoperiod (daylength).

2) Prior to heading, more starch accumulated in the vegetative parts of Calrose 76 than in ED7, as might be expected because of its longer vegetative growth period.

3) Starch accumulation in the panicles of Calrose 76 and ED7 during grain filling were the same for the early planting but slightly higher at maturity for ED7 for the late planting.

4) The starch content of the stems and leaf sheaths increased slightly during early grain filling but declined thereafter until maturity for both genotypes.

5) Starch remaining in the stems and leaf sheaths at maturity was very low for ED7 but much higher in Calrose 76 (see Figures 5 and 6).

6) Although the starch accumulated in the vegetative parts of both ED7 and Calrose 76 were remobilized and used for grain filling, the larger amounts in Calrose 76 was of no value to the yield, and therefore only contributed to the problem of residue disposal. (Should rice straw ultimately be used for energy production, this additional starch in the straw of Calrose 76 could prove advantageous).

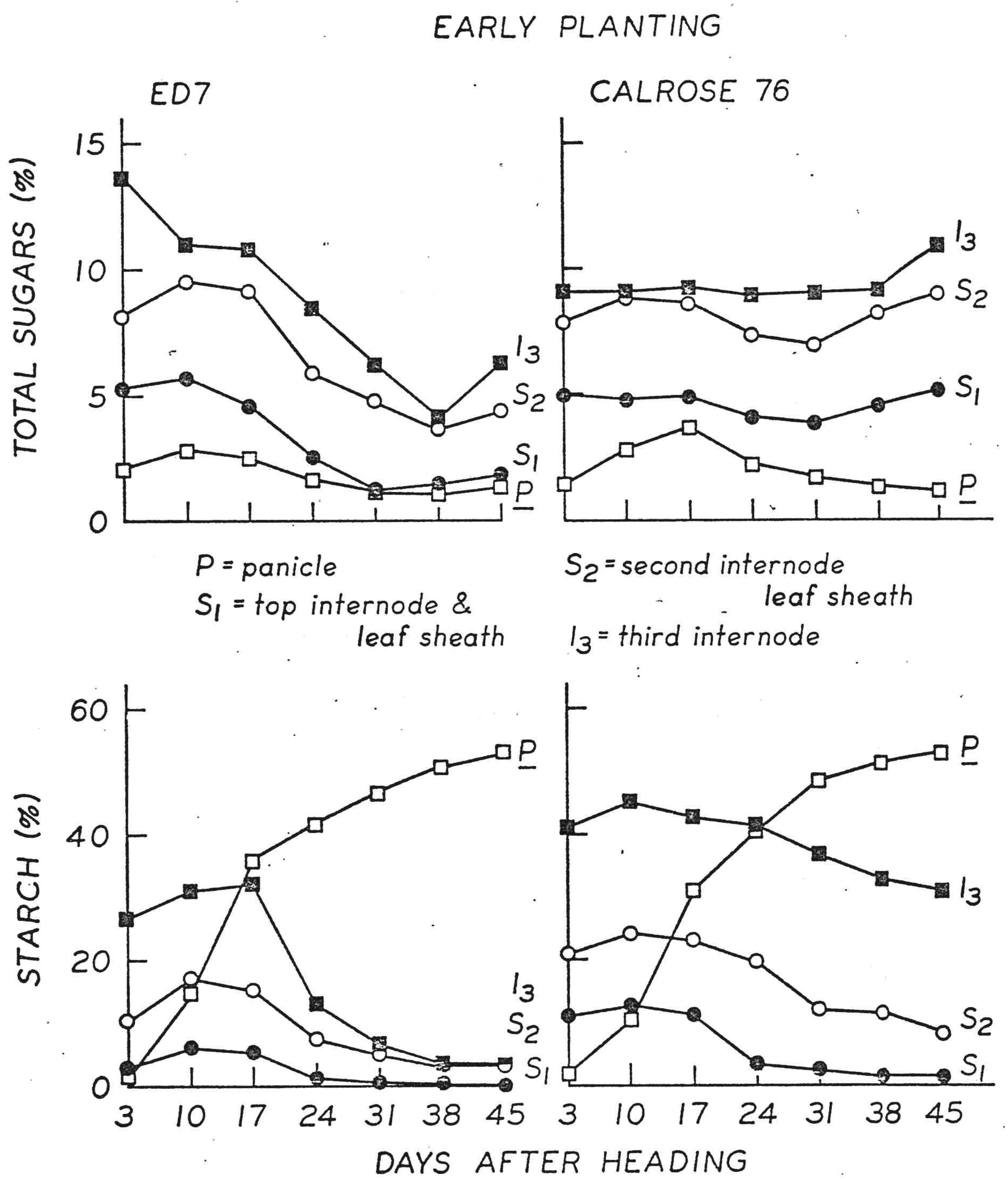


Fig. 5. Sugar and starch percentages for various plant parts during grain filling of Calrose 76 and its early flowering mutant ED-7 sown May 22.

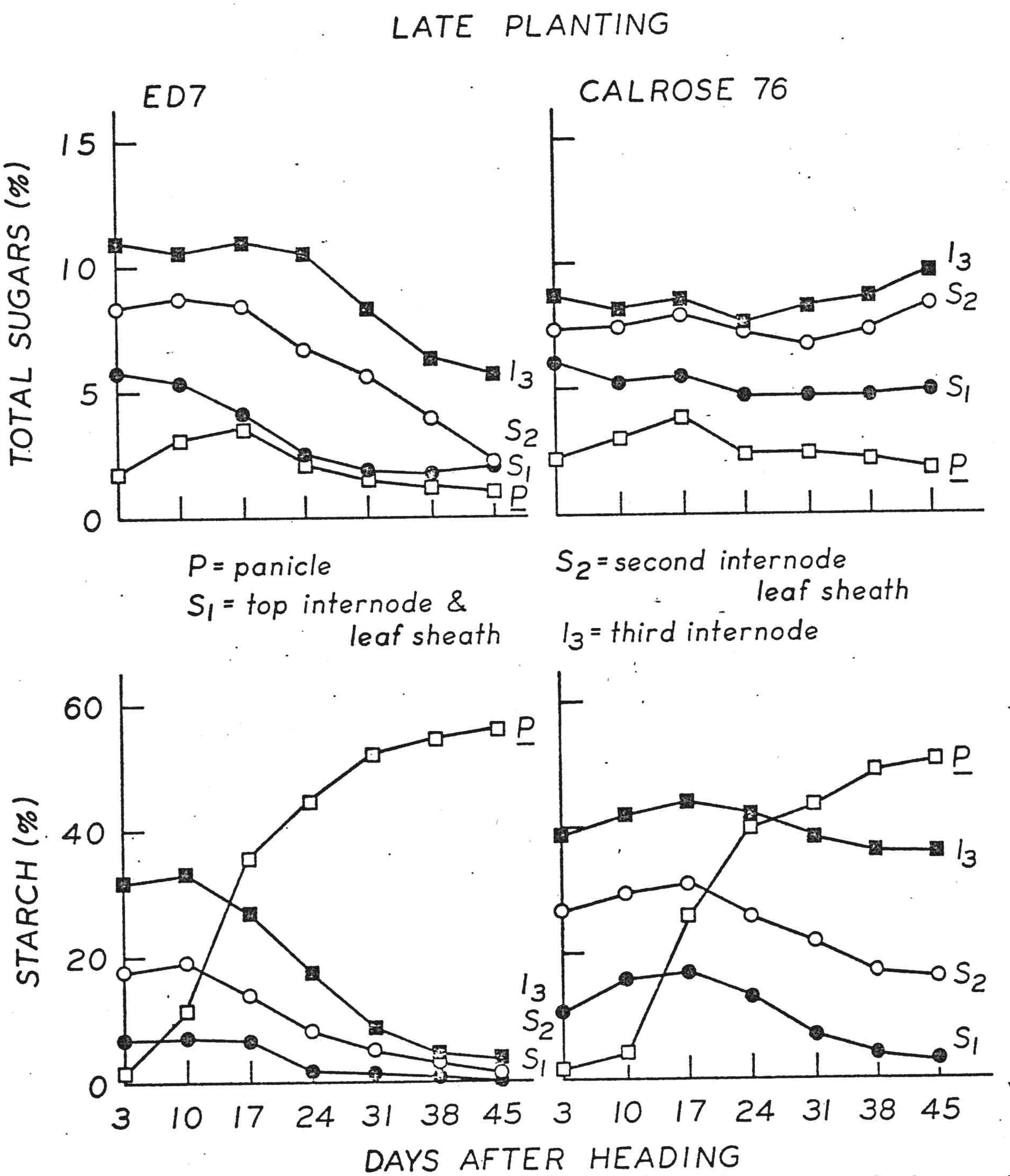


Fig. 6. Sugar and starch percentages for various plant parts during grain filling of Calrose 76 and its early flowering mutant ED-7 sown on May 12.

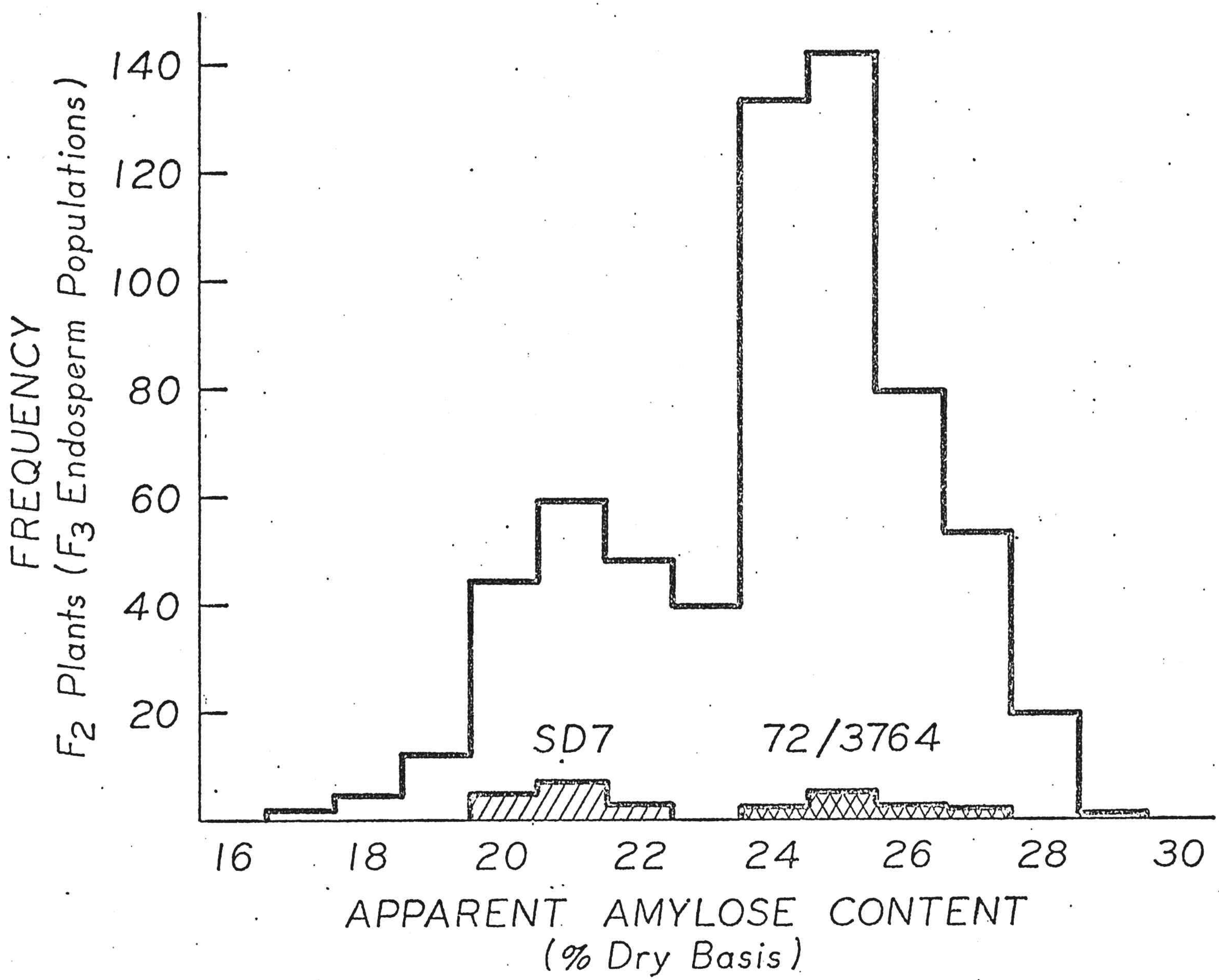


Fig. 7. Distribution of amylose content among F_2 plants of the cross between the low amylose-medium grain line SD7 and the high amylose-long grain line 72/3764.

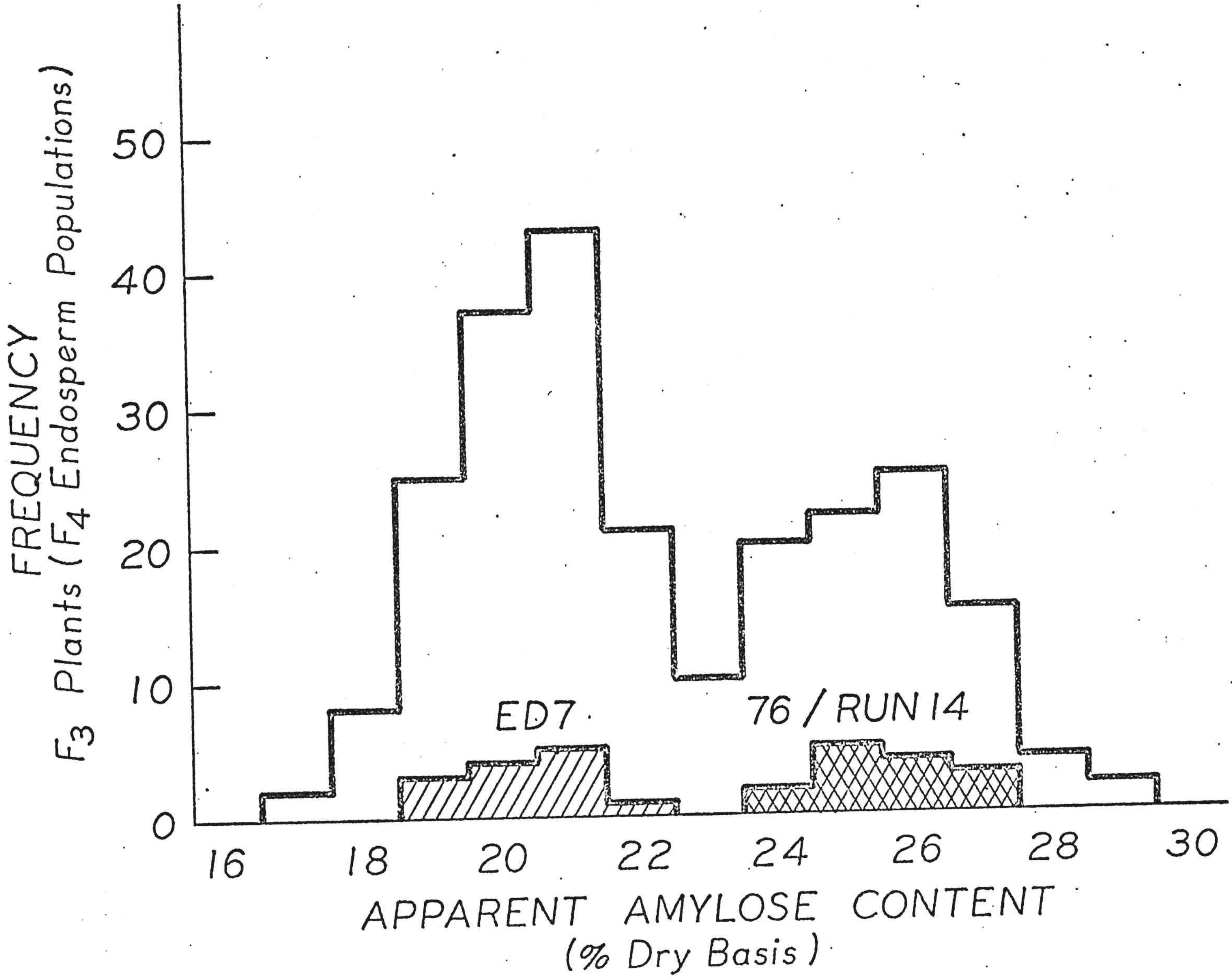


Fig. 8. Distribution of amylose content among F_3 plants of the cross between low amylose-medium grain line ED7 and the high amylose-long grain line 76/RUN14.

7) These results support the conclusions reached in Dr. D. B. Jones's Ph.D. thesis, that for the later maturing genotypes, the capacity to synthesize starch exceeds the capacity of the plant to store it in the panicle.

8) For the early maturing genotype ED7, the capacity to synthesize and to store starch appears to be in balance.

9) Under conditions of these studies, the early maturing genotype was the more efficient because it produced greater yields, required 15 to 22 fewer days from planting to flowering, left less straw residue, and that residue contained less starch to decompose or to add to air pollution if burned.

10) The above results indicate that growth duration can be reduced as much as three weeks with no adverse (and possibly positive effects) on yields and that these earlier maturing genotypes may significantly reduce the problem of rice straw disposal.

C. Hybrid rice (M.S. thesis study of L. Azzini), Rice scientists from the People's Republic of China (PRC) report that 12 million acres of F_1 hybrid rice were grown in China in 1978. Yield advantages of 15-20% are claimed. Seed production techniques are highly labor-intensive and thus it appears doubtful that hybrid rice can ever be feasible in the USA. Nevertheless, research on hybrid rice is needed, as the techniques and male steriles from such programs are potentially useful in conventional variety breeding programs. Hence the present work on hybrid rice is being conducted. A major limiting step in hybrid rice is production of enough hybrid seeds to plant farm fields. Thus our research in 1979 concentrated on the amount of hybrid seed production on male sterile lines. In previous years, hybrid seed set on steriles was usually less than 5%. This year, by converting our male sterile lines to short stature and allowing them to be wind-pollinated by tall pollinators, we averaged about 30% seed set. If these results are confirmed in future studies, this will represent a breakthrough in use of male steriles to make large numbers of crosses with little effort, in breeding programs. It is highly doubtful that this is enough crossing for commercial production of hybrid seed. Therefore, our research on this will continue for use as a possible breeding tool, rather than for farmer production of hybrid rice.

D. Inheritance of yield components (M.S. thesis study of P. J. Brookhouzen).

Progress in selection for large seed size was relatively easy in crosses between the normal seed size line SD7 and the large seed size donor B18355. It was more difficult to make progress in selection for more seeds per panicle in crosses between the normal seed number line SD7 and the many-seeded line PI 344042. Several lines with larger seeds or many seeds were selected for further tests.

Objective 3. Whole plant and cell culture selection methods for greater tolerance of rice to herbicides.

Haploid and diploid rice plant cells have been cultured as callus and cell suspensions. The cultured cells and callus have been regenerated back to whole plants. To date no progress has been made in selection for rice herbicide tolerance in cell culture. This work, which is very basic in nature, was not supported by RRB funds; consequently it will be removed from the list of 1980 objectives for research under RRB funding.

Objective 4. Genetically modify the amylose content of adapted cultivars in the direction of flaky (non-sticky) cooking quality.

A. Genetic analysis of quality characters in rice (Ph.D. thesis of K. S. McKenzie).

Studies are being undertaken to determine the inheritance of the factors that influence the cooking quality of rice. Amylose content of milled rice is recognized as a primary factor determining cooking quality. Long-grain cultivars, which typically cook dry and flaky, have intermediate amylose contents (25%). Medium- and short-grain cultivars have low amylose contents (20%), and cook moist and chewy.

Crosses have been made between long- and medium-grain lines and the amylose contents of progeny generations determined. Data from two crosses, SD7/72/3764 and 76RUN14/ED7, are shown in Figures 7 and 8. The frequency distributions in these two figures are bimodal with peaks close to the parental values. These results suggest that amylose content in these are under simple genetic control (1 gene of major effect). X^2 tests of single gene segregation ratios in these crosses support the above hypothesis. Transgressive segregation (values outside the range of the parents) is indicated which may be a reflection of other genes of minor effect influencing the amylose content in these crosses. Dominance appears to differ in these two crosses. In the SD7/72/3764 population high amylose content appears to be dominant over low amylose whereas in the ED7/76/RUN14 population the reverse situation was observed. Progeny lines from these populations are being analyzed to verify this data and additional crosses are also under study.

Two other quality factors, alkali digestion and kernel dimensions, are under investigation. Alkali digestion is used to measure the gelatinization temperature of rice. Results indicate that this cooking quality factor is also controlled by 1 gene of major effect. Studies on the inheritance of kernel length, width, and thickness are just getting underway.

Objective 5. Stem rot studies (not stated in 1979 specific objectives). Transfer of stem rot tolerance from wild species of rice (Ph.D. thesis research of R. A. Figoni).

This work, because of its high-risk nature, has been conducted without RRB funds. It is giving some exciting results. Seventeen wild *Oryza* species (cultivated rice belongs to the species (*Oryza sativa*) were screened for stem rot tolerance. Thirteen species were more tolerant than Colusa, which in itself has been the most tolerant cultivated rice variety in California. The wild species are all unacceptable for cultivation in their present forms, since most are cold-sensitive, late maturing, and shatter their seed onto the ground before harvest. Hence the best approach to utilize their greater stem rot tolerance is to hybridize the wild species with cultivated rice. Successful hybrids were obtained between the new California variety M-101 and five wild rice species. Hybrids with two species were completely sterile. The F_2 generation of the three remaining species were screened for stem rot tolerance in the field in 1979. In most crosses, all seed-producing plants were harvested for further studies. Stem rot scores of the more tolerant *Oryza* species were:

Species and entry			Stem rot score*, averaged over 4 tests
Oryza	rufipogon	#912	2.8
"	nivara	#512	3.0
"	rufipogon	#923	3.1
"	nivara	#524	3.2
"	spontanea	#943	3.4
"	rufipogon	#945	3.4
"	fatua		3.4
"	rufipogon	#946	3.6
"	sativa (cultivated rice) variety Colusa		3.7
"	" " " M-101		4.0

* 1 = immune to stem rot, 5 = killed by stem rot. The first 4 entries are significantly more tolerant than Colusa.

Because of the importance of having greater stem rot tolerance if straw burning is further restricted, we propose to accelerate this work in 1980. To facilitate the accelerated work, a separate project proposal entitled "Transfer of stem rot tolerance from wild species of rice" will be submitted to the RRB for 1980 funding.

CONCISE SUMMARY OF CURRENT YEAR'S RESULTS:

Differences in water temperatures within a narrow range from 14-17.6 C (57-64 F) have large effects on panicle sterility. High temperatures at flowering time can cause high sterility. Field studies show wide differences in response of different cultivars to location. Although moderately high rates of nitrogen fertilizers increased sterility, these losses were more than offset by yield increases attributable to other components of yield. Heritability studies on susceptibility to sterility are continuing.

Although environment and stage of maturity at harvest have large effects on head rice yields, a small seeded mutant (20% smaller seeds than Calrose) was found to have higher rice yields than anything else tested.

Physiological studies of carbohydrate formation in rice indicate higher capacity to produce than to store starch in the panicles of late maturing types (Calrose 76 or M7 maturity) while early maturing types appear to be well balanced.

Production of hybrid rice using male sterile lines gave a 30% seed set in 1979, making this method a promising breeding tool. It is highly doubtful that this is enough crossing for commercial production of hybrid seed.

Crosses analyzed for determining the inheritance of high amylose content in rice revealed this characteristic was probably under single gene control modified by minor genes.

Studies not funded by the Rice Research Board indicated that certain wild rice species gave stem rot tolerance to progeny in crosses with California cultivar M-101. We propose to accelerate this work with a proposal to the Rice Board on "Transfer of Stem Rot Tolerance from Wild Species of Rice."

PUBLICATIONS OR REPORTS:

Jones, Davis B. 1979. The rate and duration of grain filling and carbohydrate availability during the maturation period of rice (*Oryza sativa*). Ph.D. thesis.

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Song, S. 1979. Genotype and environmental effects on rice milling yield. M.S. thesis, UCD.