PROJECT NO. RB-3

COMPREHENSIVE RESEARCH ON RICE
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PROJECT TITLE: Genetic and Physiological Determinants of Yield and Quality

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OBJECTIVES AND EXPERIMENTS CONDUCTED BY LOCATION TO ACCOMPLISH OBJECTIVES:

1. To develop new germplasm useful in variety development and in crop physiological studies.

2. To investigate standard and innovative breeding methods which can raise yield levels and/or accelerate variety development.

SUMMARY OF 1983 RESEARCH (MAJOR ACCOMPLISHMENTS) BY OBJECTIVES:

1. To develop new germplasm useful in variety development and in crop physiological studies.

   a. Many-seeded and large-seeded lines, for use in physiological studies on increasing the yield level of rice.

Twenty-one lines selected for big and/or many seeds per panicle were evaluated in spaced plantings in 1983 along with three check varieties (Table 1). Relative to the check variety M-101, selection for increased seed size was effective in 11 of 14 lines which were derived from crosses with this objective in mind. Selection for increased number of seeds per panicle was effective only for 5 of 14 lines. None of the selections showed any increase in yield per plant, as in most cases the selection gains for seed size or number were offset by a decrease in number of panicles per plant.

Since selection for increased yield in these materials was ineffective, the lines shown in Table 1 will not be continued. However, we will continue to screen world collection lines for additional sources of genetic diversity for yield components, in anticipation that better donors eventually will be identified.

b. Cytoplasmic male sterility for hybrid rice.

i) New systems, from crosses between wild species of rice and cultivated rice. We are continuing our search for new systems, on a reduced scale, since the Chinese cytoplasmic male sterile source now appears adequate for our purposes. However, a weedy species line, O. fatua (PI 239671), which we are using in sheath blight inheritance studies, shows different fertility patterns in reciprocal crosses. Differences in sterility patterns in reciprocal crosses is an indication of cytoplasmic male sterility, so we are following up on crosses involving this donor.

ii) Induction of cytoplasmic male sterility in California rice varieties by the antibiotics streptomycin and mitomycin. Recent reports indicate these chemicals induce cytoplasmic male sterility in another crop, pearl millet. If they also work in rice, this would enable us to develop cytoplasmic male sterile stocks in California rice varieties much faster than through conventional backcross breeding procedures. In 1983 we treated seeds of M-201 with streptomycin and mitomycin. At maturity we searched for plants which were expected to be almost completely sterile. A total of 35 such plants were found and were ratooned to the greenhouse (Table 2). These plants will be progeny-tested in 1984 to determine if cytoplasmic male sterility has been induced. We also saved 1000 random panicles from two antibiotic treatments (Table 2), in order to determine, in 1984, if these antibiotics may also induce other mutants. Included in this latter category will be screening for plants of M-201 that are more resistant to wind-shattering.

c. Further evaluation of the pale-green-hull mutant for possible use in variety identification and separation.

Four different marker-gene mutants have been accumulated in the M-101 or a closely-related background. In order to determine if these mutants had any beneficial or detrimental effects on yield, a small-plot yield test was conducted at Davis. Three mutants--pale-green-hull, waxy endosperm, and yellow panicle--did not differ significantly in yield from the M-101 check (Table 3). The fourth mutant, goldhull, was significantly lower yielding than the check. The yellow panicle mutant was two days earlier than M-101.

Since there were no detrimental effects associated with the pale-green-hull and yellow panicle mutants, these would have possible use as marker genes for identifying varieties. The waxy endosperm type is also useful as a genetic marker for outcrossing studies. These three genes--waxy endosperm, pale-green-hull, and yellow panicle--represent accumulated tools that have been collected for genetic and breeding studies, and will hence be preserved in the USDA rice germplasm bank.

Although we feel almost certain that the pale-green-hull type is a single recessive gene mutant, it has not segregated in the expected ratios. Thus the F_2 segregation ratio in a cross of the pale-green-hull by a normal green hull, as determined by F_3 progeny tests, was 176 homozygous pale-green: 289 segregating: 110 normal green. This represents an excess of pale green types for the expected 1 pale-green:2 segregating: 1 normal ratio.

d. Inheritance and interspecific transfer of sheath blight resistance from weedy rice species (not listed in 1983 objectives)

Since our previous work has shown the usefulness of weedy species as donors for stem rot resistance, we decided to use the same approach for sheath blight. In cooperation with Dr. R. K. Webster, we had previously evaluated several weedy species of rice for sheath blight reaction, and found two lines which appeared to be more resistant than cultivated rice: *Oryza rufipogon* A100923, and *Oryza fatua* PI 239671. By coincidence we had been using both of these lines for another study, the one on searching for additional sources of cytoplasmic male sterility (see objective 1.b.i above).

In the summer of 1983 we re-tested the sheath blight reaction of these two weedy species and the California check line 78:18347. We also included the hybrids between the weedy species and the check, 9 international lines reported to have sheath blight resistance in Louisiana or the Philippines, and one Arkansas variety (Nortai) which was reported to have some resistance in Louisiana. In this test the only entries which were significantly more resistant than the check line 78:18347 were *Oryza fatua* PI239671 and the F_1 hybrid between it and the check line, *O. fatua*/78:18347 (Table 4). However, simultaneously with this test we also evaluated F_2 progenies of the cross *O. rufipogon* A100923/78:18347 and observed some apparently resistant segregates (Figure 1). Confirmation of this resistance will require progeny tests.

Recently Dr. S. T. Tseng supplied us with additional materials from crosses with the resistant weedy parent *O. fatua* PI 239671. This cooperative research will be continued in 1984.

e. Performance of semidwarf lines from crosses between California and Egyptian varieties (not listed in 1983 objectives)

As part of the cooperative UC-Egypt rice program, a number of crosses were made between semidwarf California rice varieties and tall Egyptian varieties with large panicles. For California purposes, the objective was to introduce additional genetic diversity for panicle size from the Egyptian varieties, in the hopes this would increase yield potential for California rice. In 1983, for the first time, we were able to run a two-replicate yield-test on 24 recombinants from these crosses. To our disappointment, none of the 24 recombinant lines significantly outyielded the best California check variety in the test, M-101 (Table 5). General observations of these recombinant lines indicate that the large panicle size from the Egyptian parents was not transferred to the semidwarf lines.

f. Introduction of new rice germplasm from China (not funded by RRB)

The Office of International Cooperation of Development, USDA, sponsored a rice scientific exchange visit with China in September and October of 1983. The U.S. team, consisting of Rutger (team leader), C. N. Bollich from USDA in Texas, and D. M. Brandon, Louisiana State University, brought back 30 Chinese varieties which have not been previously introduced to the U.S. These will be evaluated under U.S. conditions in 1984.

2. To investigate standard and innovative breeding methods which can raise yields and/or accelerate variety development.

a. Population improvement, through the use of genetic male sterility.

The development of male sterility offers the opportunity to use several breeding methods not normally used in rice. These methods, often called population improvement techniques, are based on large-scale crossing amongst diverse lines, in order to introduce genes from many sources into locally adapted materials, with relatively little effort.

In 1983 we planted our previously-developed M-101 genetic male sterile mutant in alternate rows with about 600 world-collection varieties from Japan, Korea, and Taiwan. Pollen from the world collection entries was blown by the wind onto the M-101 male sterile plants. We staggered the planting dates of the world collection lines and of the M-101 male sterile in an effort to synchronize heading dates and thus increase the amount of natural cross-pollination. These techniques resulted in about 10% seed set, from outcrossing, on the male sterile plants. We were successful in synchronizing the heading dates of some 400 world collection lines with the M-101 male sterile. Thus at maturity we harvested crossed seeds from 1,926 male sterile plants, from 431 rows adjacent to world collection entries. These 1,926 plants will be progeny-tested in 1984, and seeds from crosses to the world collection entries (determined by use of marker genes) will be bulked to form a germplasm composite.

b. Hybrid rice.

The Chinese reports of 14 million acres of F_1 hybrid rice have greatly stimulated research on hybrids in the rest of the world. The Chinese report that hybrids, which are produced through several labor-intensive procedures, yield 15-25% more than standard varieties. While we in the U.S. generally feel that much progress can be still achieved through conventional breeding, i.e., without hybrids, we are conducting some exploratory research on developing hybrids. Thus in 1983 we continued a study on the inheritance of the Chinese hybrid rice source of male sterility, in crosses with various U.S. lines. Information of this type is needed in order to assess the ease (or difficulty) of producing hybrids suitable for the U.S.

Seed set percentage, a measure of fertility restoration, was studied in the F_2 generation of six crosses (Fig. 2a-2f). In these crosses the first parent, either V20A or Z97A, is the Chinese cytoplasmic male sterile line. The first cross, V20A/Giza 180, was included as an internal control, since the Egyptian variety Giza 180 showed reasonably good restoring ability (60% seed set) in a previous greenhouse study. The 234 F_2 plants ranged from no seed set to 90%, and no simple genetic explanation was apparent from examination of the F_2 distribution (Fig. 2a). Among crosses with US lines, several fertile plants, i.e., 70% or higher seed set, were observed in the V20A/L-201 F_2 population (Fig. 2b). Several fertile plants were also found in the Z97A/Labelle population (Fig. 2c), and in the V20A/RU8003005 population (Fig. 2d). A few fertile plants were found in the V20A/M9 population (Fig. 2e), but none was found in the small V20A/M-401 population (Fig. 2f). The mode of inheritance of fertility restoration was not evident in any of these latter five populations. However, it was encouraging to find a few to several fertile F_2 plants in all populations except the last one, V20A/M-401. We will continue progeny testing these materials in 1984 in order to 1) elucidate the mode of inheritance and 2) to continue development of fertility restoring lines in U.S. backgrounds.

c. Innovative breeding methods.

In 1983 we attempted to germinate the very tiny "seeds" that we obtained in 1982 by pollinating male sterile rice with pollen from other grass species. These included 9 seeds from rice/rye, 1 from rice/wheat, 20 from rice/pearl millet, 7 from rice/barley, 17 from rice/corn, and 12 from rice/sorghum. None was viable. An additional 21 seeds from pollinating male sterile rice with pearl millet in 1983 also failed to germinate. It appears that these very tiny seeds lack embryos. More rice/pearl millet pollinations are planned for 1984 in order to determine what is stimulating this "pseudo-seed" formation.

We are beginning to concentrate on bridging the gap between genetic engineering techniques and traditional plant breeding. Primary emphases are on seeking mutants with resistance to physiological characters such as herbicides, through tissue culture selection, and through selection of induced mutants at the whole-plant level. Most of our 1983 efforts in this "bridging" area were on developing suitable selection techniques. For example, we developed techniques for growing callus and detached embryos on herbicide-containing agar. Since technique development has been very time consuming, we are just now ready to begin large-scale screening for useful mutants.

In 1982 we grew about 3700 irradiated rows of S-201 (X_2 generation) to prepare populations for screening for herbicide resistance. In the process we selected about 90 early maturing plants 5 days or so earlier than S-201. These were progeny-tested in the Hawaii winter nursery and again in the summer of 1983. One X_4 lines, 83:10074, which was 6 days earlier than S-201, was selected. This short grain line, which should be in the "100" (i.e., very early maturity) class, will be further evaluated.

PUBLICATIONS OR REPORTS:

Figoni, R. A., J. N. Rutger and R. K. Webster. 1983. Evaluation of wild *Oryza* species for stem rot (*Sclerotivum oryzae*) resistance. Plant Disease 67:998-1000.

McKenzie, K. S. and J. N. Rutger. 1983. Genetic analysis of amylose content, alkali spreading score, and grain dimensions in rice. Crop Sci. 23:306-313.

Moon, H. P. 1983. Inheritance of low-temperature induced-sterility and its relationship to agronomic characters in rice (*Oryza sativa* L.). Ph.D. Thesis, Univ. of Calif.

Rutger, J. N., R. K. Webster and R. A. Figoni. 1983. Weedy species of rice show promise for disease resistance. Calif. Agric. 37(1):7-9.

Rutger, J. N. 1983. Applications of induced and spontaneous mutation in rice breeding and genetics. Adv. Agron. (in press).

Rutger, J. N., C. N. Bollich and D. M. Brandon. 1983. Rice production technology and germplasm exchange with China. Report of the U.S. Rice Team visit, Sept. 17-Oct. 12, 1983.

CONCISE GENERAL SUMMARY OF CURRENT YEAR'S RESULTS:

Selection for increased seed size was highly effective, and selection for increased seed number was partially effective, but neither resulted in increased yield per plant. It was concluded that additional genetic diversity for yield components is needed in order to increase yield by this procedure.

A study to use antibiotics to induce cytoplasmic male sterility in the variety M-201 resulted in selection of 35 sterile or near-sterile plants, which will be progeny tested in 1984 to determine if the effort was successful.

A waxy M-101 mutant was found to be identical to M-101 in maturity and yield. Two marker-gene mutants, for pale-green-hull, and for yellow panicle, yielded the same as M-101. Such apparently "neutral" mutants may have value in variety identification and separation.

A study on inheritance and interspecific transfer of sheath blight resistance from weedy rice species was initiated in cooperation with Dr. R. K. Webster and with breeders at the Rice Experiment Station. The weedy species *Oryza fatua* has been identified as the best sheath blight resistant donor.

Twenty-four semidwarf selections from crosses between California varieties and tall Egyptian varieties with large panicles were yield tested in 1983, but none yielded more than M-101. The large panicle size of the Egyptian donor parent was not expressed in these semidwarf progenies.

The previously-developed M-101 genetic male sterile was wind-pollinated by some 400 world collection lines, as the first step in introducing additional genetic diversity into California-adapted backgrounds. Progeny tests will reveal how successful this effort is.

Hybrid rice studies in 1983 concentrated on inheritance of fertility restoration for the Chinese cytoplasmic male sterile source. The F_2 populations of six crosses were grown. Fertility restoration appears to be controlled by more than one gene, which means that successful production of fertile hybrids for the U.S. will be difficult. Progeny tests will help determine how many genes are involved.

Tiny seeds resulting from pollination of rice by other cereal crops (rye, wheat, pearl millet, barley, corn, and sorghum) failed to germinate. Studies on bridging the gap between genetic engineering techniques and traditional plant breeding were continued.

An early-maturity mutant was isolated from S-201. The mutant is about 6 days earlier than S-201.

Table 1. Yield components and other data on 24 genotypes grown in 10" x 12" spacings in 1983.

Line #	Pedigree	Days to Head	Plant Height,cm	Yield, g/plant	Panicles/ plant	25 seed weight,g	Seeds/ panicle	Selection Objective* B (big seeds)	Selection Objective* M (many seeds)
1	B18355/7685	100	93	66	27.3	0.61	102	-	
2	B18355/7685	100	88	59	22.7	0.96	69	+	
3	B18355/7685	98	91	70	25.4	0.62	113	-	
4	B18355/PI344042	94	82	62	21.9	0.85	85	+	-
5	B18355/PI344042	99	82	57	21.8	0.83	80	+	-
6	B18355/PI344042	101	91	59	20.4	0.85	86	+	-
7	B18355/PI344042	99	88	68	20.4	0.80	106	+	-
8	B18355/PI344042	100	80	62	30.7	0.77	67	+	-
9	B18355/PI344042	99	88	60	17.6	0.73	119	+	+
10	B18355/PI344042	102	90	64	20.5	0.73	108	+	-
11	SD7/7685	98	105	74	26.9	0.66	105	-	
12	SD7/7685	94	94	66	27.5	0.75	81	+	
13	M9/7685	96	107	67	22.3	0.86	87	+	
14	M9/7685	97	96	59	18.4	0.80	100	+	
15	SD7/PI344042 (Geno.1-1)	99	86	60	27.3	0.56	99		-
16	SD7/PI344032 (Geno.3-1)	99	95	70	27.6	0.57	111		+
18	SD7/PI344042 (Geno. 9)	103	92	62	25.5	0.62	101		-
19	SD7/PI344042 (Geno. 4)	100	99	65	21.9	0.58	128		+
20	SD7/PI344042 (Geno. 1-2)	101	92	67	25.6	0.58	114		+
21	SD7/PI344042 (Geno. 3-2)	97	93	55	21.8	0.60	108		-
17	M101/78RUN67	103	96	60	18.2	0.65	130		+
22	M9	104	98	67	30.2	0.67	83		
23	M-101	94	91	72	32.3	0.64	90		
24	M-302	103	91	68	32.0	0.65	81		
	$LSD_{.05}$	3	7	18	7.5	0.06	19		

* A plus (+) means selection was effective for the desired character; a minus (-) means selection was not effective; a blank indicates selection was not practiced for that character.

Table 2. Treatment of the rice variety M-201 with two antibiotics expected to induce cytoplasmic male sterility.

Treatment	Estimated number of plants grown	Number of near-steriles ratooned	Number of random panicles saved
Streptomycin, 800 ppm	3100	3	
Streptomycin, 1600 ppm	3100	4	
Streptomycin, 2400 ppm	3600	9	1000
Mitomycin, 100 ppm	3100	13	
Mitomycin, 500 ppm	2200	6	1000

Table 3. Days to heading and yield of four marker-gene mutants in the M-101 or closely related background.

Genotype	Days to heading	Yield, g/8 ft^2 plot
M-101 (check)	90	638
Pale-green-hull M-101	91	628
Waxy M-101	90	638
Yellow panicle ESD7	88	629
Goldhull M-101	91	565
$LSD_{.05}$	1	35

Table 4. Sheath blight reaction of two weedy species, a California check, their F_1 hybrids, and selected international lines in the greenhouse at Davis in summer 1983.

Genotype	Length of sheath blight lesion, cm*
O. rufipogon (Acc 100923)	9.79
O. fatua (PI239671)	4.17
78:18347 (California check)	11.08
O. rufipogon/78:18347 F_1	9.70
O. fatua/78:18347 F_1	4.61
IR4422-98-3-6 (PI458865)	14.65
IR10232-17-2 (PI458878)	8.87
Ai-Jiao-Nan-Te (PI401421)	12.27
Ai Nan Tsao 1 (PI401423)	12.02
Ai Nan Tsao 39 (PI401424)	12.85
Chang-Pai 5 (PI401425)	10.24
Chieh Keng 44 (PI401427)	10.65
Ching-Yu 1 (PI401432)	10.66
Hsiung Yo 613 (PI401437)	14.14
Nortai (CI9836)	11.11
$LSD_{.05}$	2.88

* Short lesion length indicates resistance; long lesions indicate susceptibility.

Table 5. Performance of semidwarf F_6 lines derived from crosses between California semidwarfs and tall Egyptian varieties in a two-replicate yield trial at Davis in 1983.

Selection number	Pedigree	Days to heading	Yield, lb/A at 14% moisture
6	M-101/Giza 171*	92	6909
7	M-101/Giza 171	92	7286
8	M-101/Giza 172	90	6532
9	M-101/Giza 172	88	6557
11	M-101/Giza 172	88	6185
13	M-101/Giza 159	94	6483
15	M-101/Giza 159	88	6240
19	M-101/Arabi	96	6286
20	M-101/Arabi	90	6757
23	M-101/Pi No. 1	95	6078
24	Pale green hull M-101	90	6111
25	Calrose 76/Giza 171	102	6426
27	Calrose 76/Giza 172	104	5850
28	M9/Giza 171	96	5793
29	M9/Giza 171	97	5185
30	M9/Giza 171	99	7059
31	M9/Giza 171	93	7401
32	M9/Giza 171	100	5435
33	M9/Giza 171	102	5696
34	M9/Giza 171	101	5924
35	M9/Giza 171	94	5882
37	M9/Giza 172	106	5402
38	M7/Giza 171	91	6798
41	M7/Giza 172	90	6769
43	M-101 (check)	88	6766
44	M-201 (check)	98	5938
45	M-302 (check)	99	6078
	$LSD_{.05}$	3	812

* Giza 171, Giza 172, Giza 159, Arabi, and Pi No. 1 are tall varieties from Egypt.

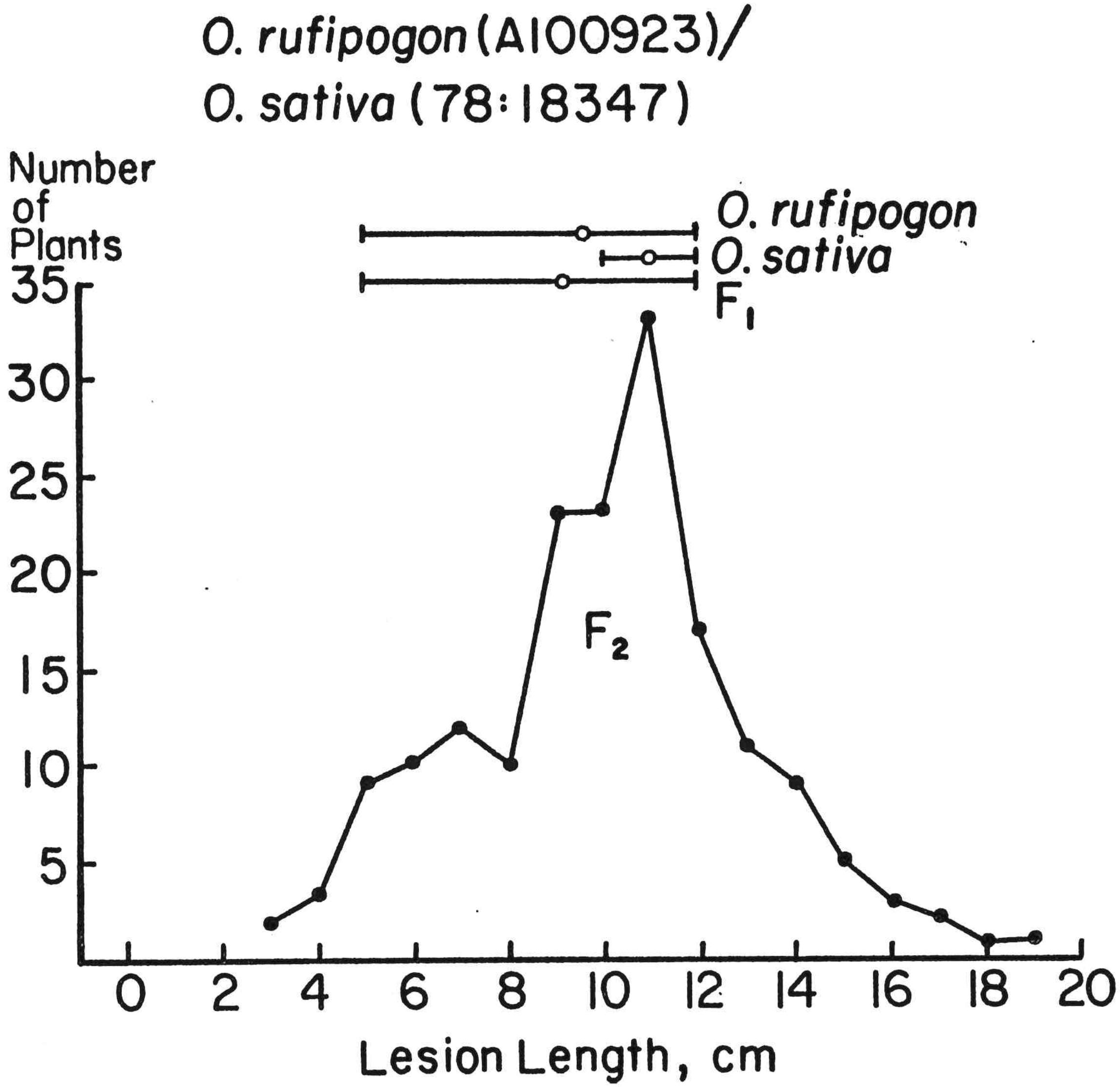
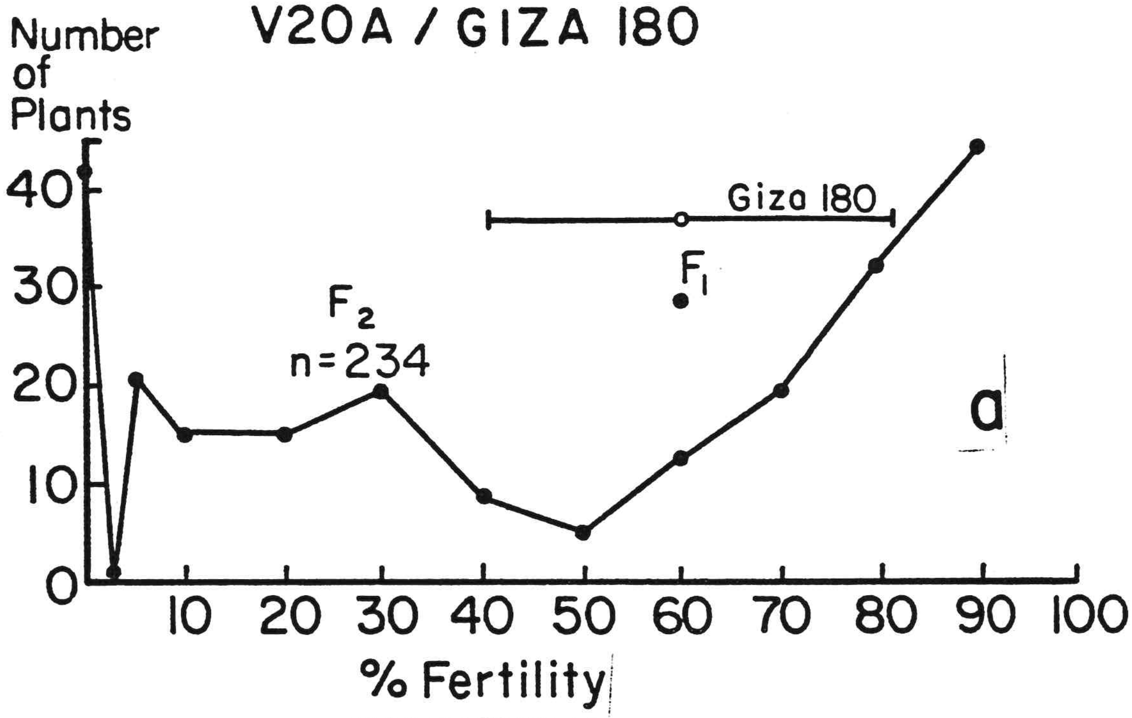


Figure 1. Distribution of sheath blight lesion lengths in the F_2 population of the cross O. rufipogon A100923/O. sativa 78:18347. Short lesion length indicates resistance; long lesion length indicates susceptibility.

Figure 2. Distribution of seed set (fertility %) in crosses between the Chinese cytoplasmic male sterile source (V20A, Z97A) and six varieties. The F_1 plants indicated in these figures was grown in the greenhouse in the winter, and the other generations in the field in the summer.

a.	V20A/Giza 180	(Giza 180 is from Egypt)
b.	V20A/L-201	(L-201 is from California)
c.	Z97A/Labelle	(Labelle is from Texas)
d.	V20A/RU8003005	(RU8003005 is from Texas)
e.	V20A/M9	(M9 is from California)
f.	V20A/M-401	(M-401 is from California)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F2
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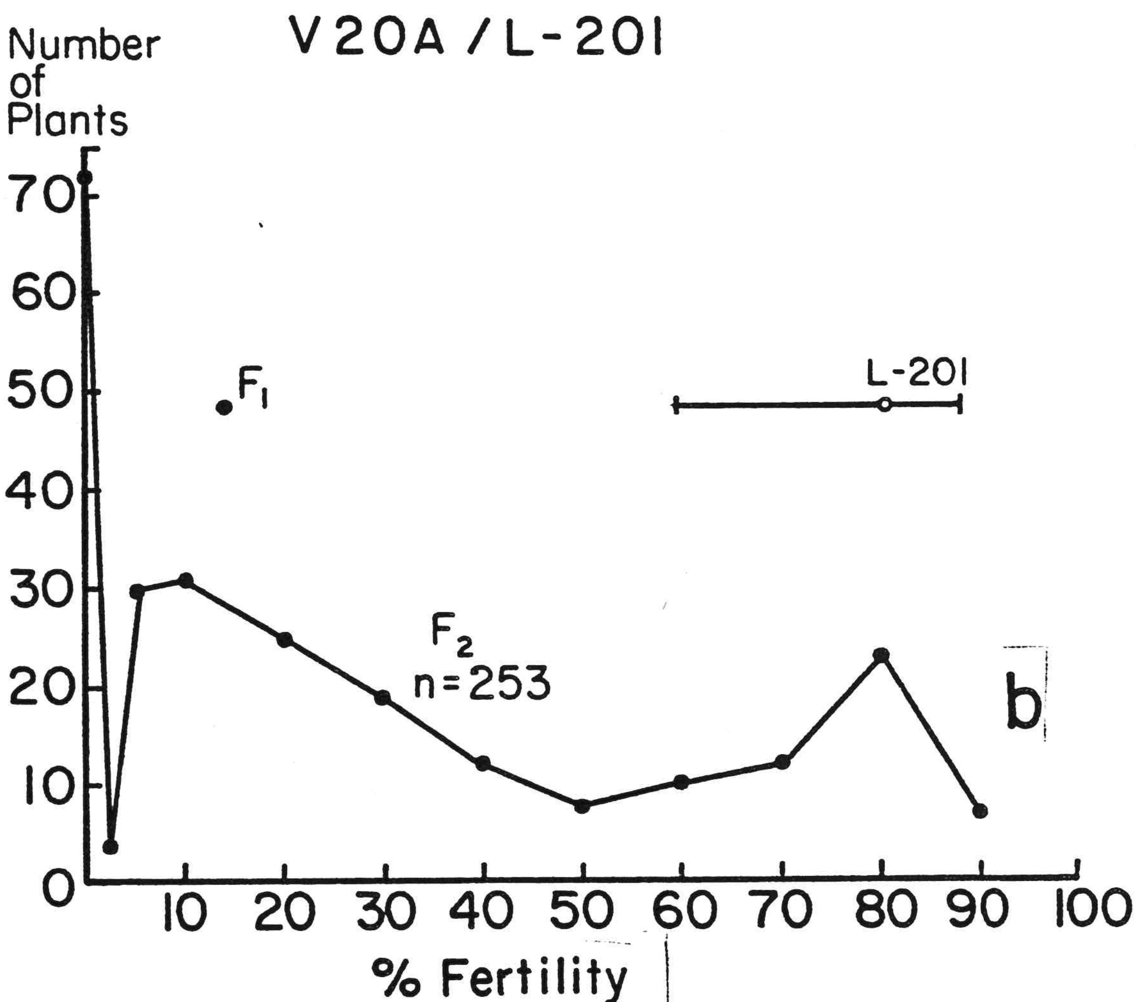
10
20
30
40
10 20 30 40 50 60 70 80 90 100
% Fertility


V20A / L-201
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L-201
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30
40
50
60
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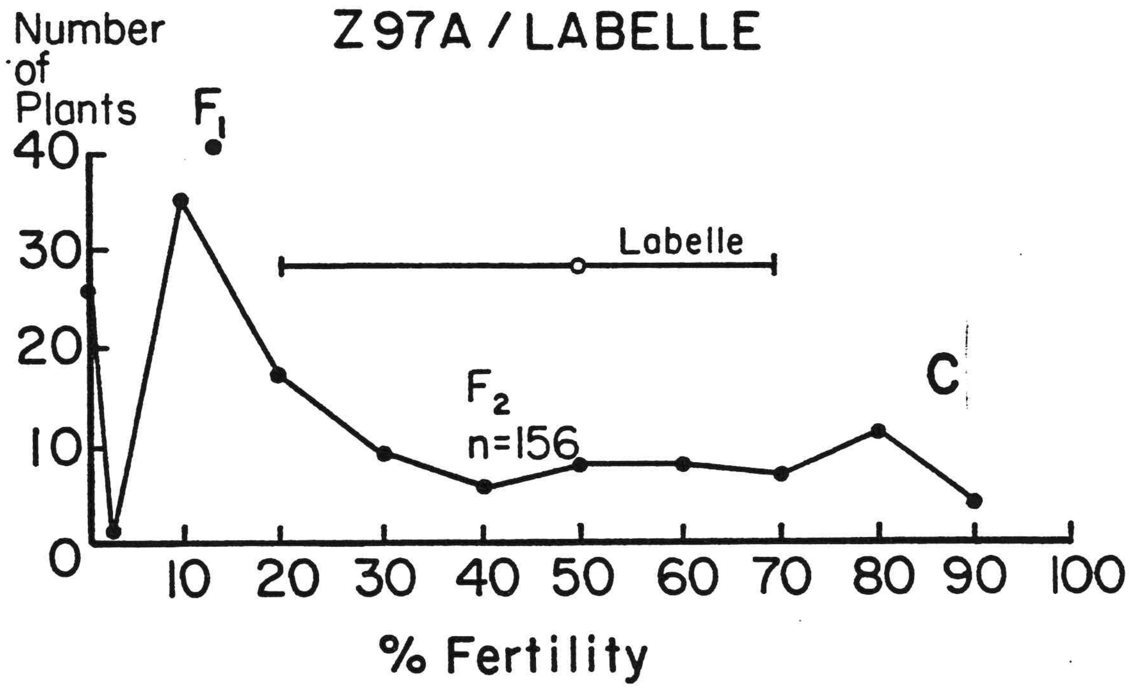
% Fertility


Z97A / LABELLE
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F1
Labelle
F2
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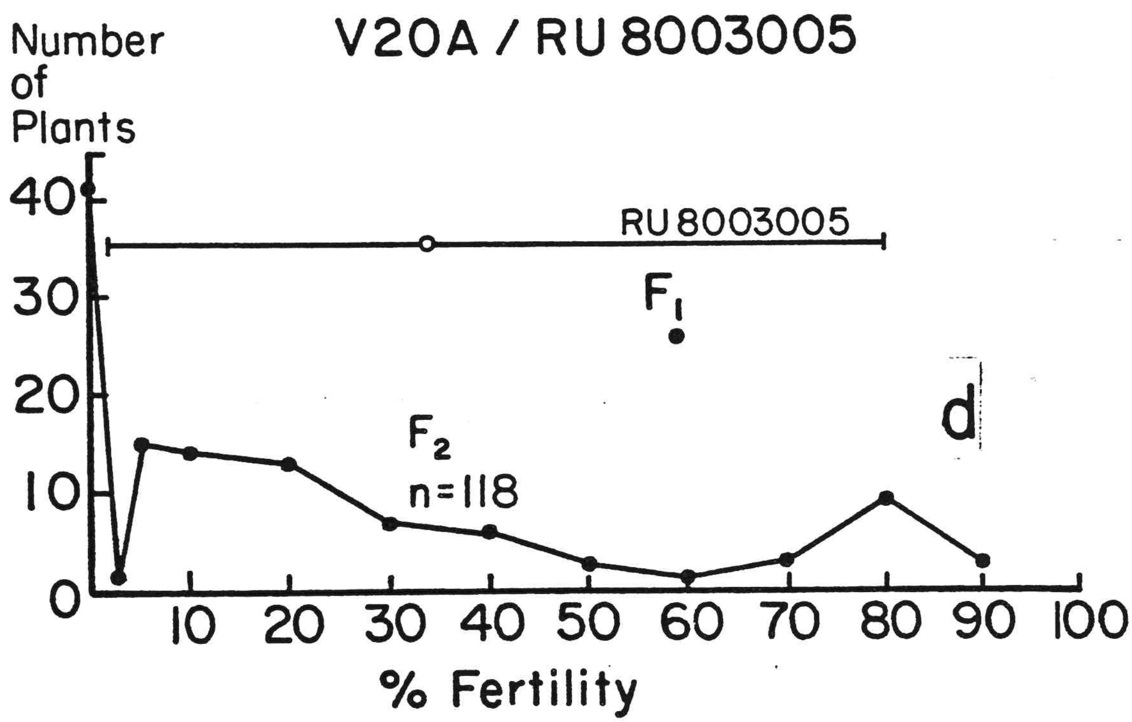
C
% Fertility


V20A / RU 8003005
Number of Plants
RU 8003005
F1
F2
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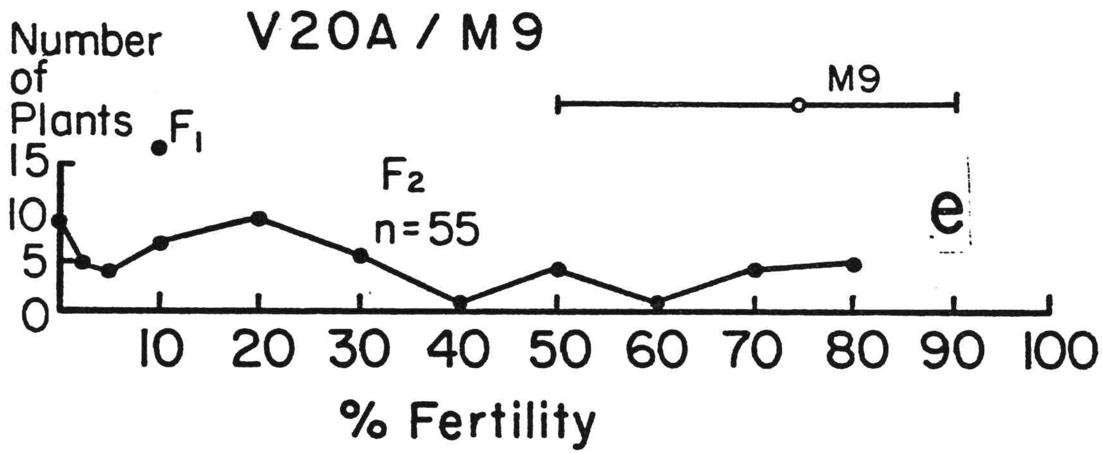
d
% Fertility


V20A / M9
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M9
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10
5
0
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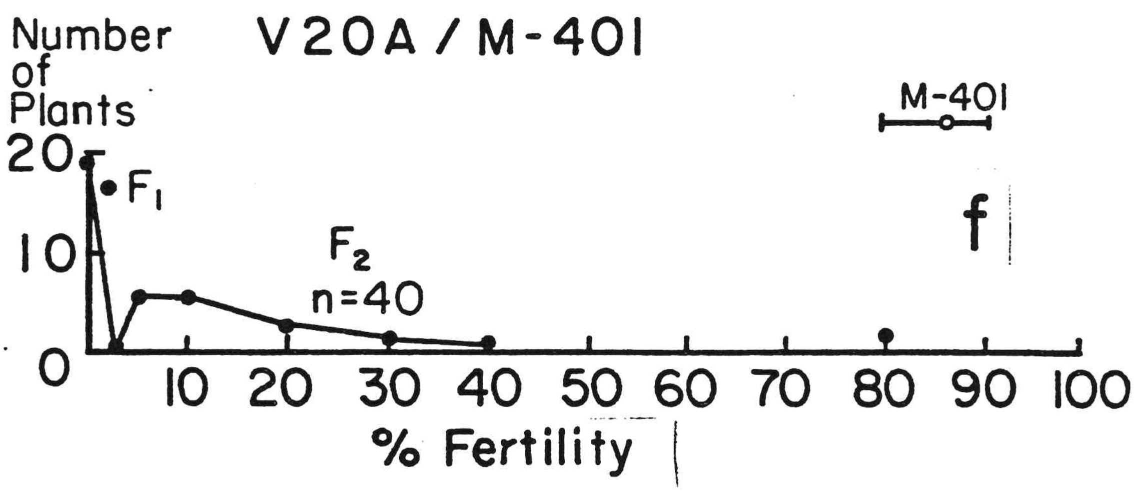
% Fertility


V20A / M-401
Number of Plants
M-401
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F1
f
10
F2
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10 20 30 40 50 60 70 80 90 100
% Fertility