Response of California rice varieties to cool temperatures

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Cool night temperature has been recognized as a major cause of floret sterility (blanking) in California rice. Surveys of 40 fields in six counties in 1971 showed an average of 12.5 percent sterility with a range from 3.8 to 25.5 percent. In 1972, sterility was determined in 59 fields. Average sterility was 12.8 percent and as high as 35 percent in some fields. Floret sterility was an important factor affecting yields in the 1978 rice crop. The rice-growing regions most affected by cool temperatures are those influenced by nightly, cool marine airflow: San Joaquin, Sacramento, and Yolo counties. The Rice Research Facility at Davis is an excellent location to study low-temperature-induced floret sterility because it is situated in one of the coolest areas in California where rice is grown.

Earlier studies—in Japan and confirmed at Davis—have revealed that temperatures of 60° F (15.5° C) or below occurring 10 to 15 days before heading can cause sterility. Since not all panicles reach this sensitive stage simultaneously the critical period is estimated to include 7 to 21 days before 50 percent heading. The period of low-temperature sensitivity for a single floret may be only the two or three days when pollen grains are formed by meiotic cell division. This is defined as the tetrad to young microspore stage. The tetrad results from two divisions of a pollen mother cell giving rise to four cells, each with half the chromosome number of the mother cell. The young microspores develop into mature pollen grains within the anthers.

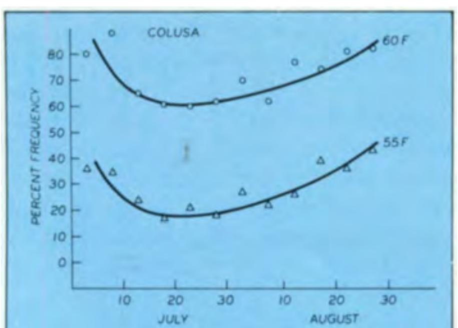

Fig. 1. Percent frequency of occurrence of minimum temperatures of 60° F and below and 55° F and below at Colusa, based on records from 1958 to 1977.

Japanese scientists have shown that cool temperature during early stages of pollen development results in an abnormally high concentration of sugars in the innermost layer of cells within the anther. These cells form a membrane called the tapetum. The tapetal cells become abnormally enlarged, and the intercellular walls break and become fused. It is presumed that the accumulation of sugars in the tapetum occurs because of transfer failures from the tapetum to developing pollen grains. As a result, nutrition of developing pollen grains is inhibited, interfering with pollen maturation. Other studies have shown that protein synthesis and respiration are reduced in cold-affected anthers. The above responses have been noted to be greater in cold-susceptible cultivars. Previous studies at Davis have shown that low night temperatures result in pollen grains either devoid of or deficient in starch. Certain biochemical disorders involved in low-temperature sterility are known, but actual causes have not been identified.

Not all sterility is caused by low temperatures. Unusually high temperatures or winds and low humidity at anthesis (flowering time) also cause sterility. Japanese scientists have observed high sterility in flowering rice plants exposed to daily maximum temperatures of only 95° F in plant-growth chambers. Sterility caused by high temperatures also has been observed in Cambodia, Thailand, Pakistan, and Egypt. Strong winds can cause sterility directly by desiccating the plant. High temperatures during flowering of some of the early-maturing varieties in California in 1978 were the probable cause of some of the sterility observed by rice growers.

Results of tests over the past few years on the low-temperature problem have shown differences in susceptibility to injury among California varieties. We also compared fertility levels among Calrose types which had been modified for earliness, short stature, and smooth leaves, thus providing further guidance to approaches for reducing sterility. Three years of intensive selection among certain crosses have given lines that are superior to the best California varieties for good grain formation (seed set) under cool conditions. These selections have been released as germplasm and made available to rice breeders.

It has proven difficult to define precise temperature and time relationships that cause sterility. We know that nightly minimum temperatures of 55° F or below over a period of several days usually induce severe sterility in some varieties. Duration of the low temperature also is a factor. Therefore minimum temperatures and their durations interact to determine the amount of sterility observed. High nitrogen fertility levels are also observed to increase sterility in some varieties.

The probability of occurrence of injurious night temperatures differs with time during the season and among regions. Weather station records over a 20-year period from 1958-1977 show mean minimum daily temperatures of 55.2° F for the month of July at Davis. Similar records for Sacramento and Colusa were 58.2° and 58.5° F respectively. Marysville and Stockton had July mean minimum temperatures of 60.8°, Willows 61.4°, and Button Willow 65.3° F. Weather station locations may not be entirely representative of surrounding rice growing areas, however.

Figure 1 shows the probability of temperatures falling below 60° F and below 55° F at Colusa during July and August based on records for the past 20 years. Each point on the figure is a 5-day mean for 20 years, or a total of 100 mean-temperature readings. The risk of low-temperature-induced floret sterility would be minimal for varieties that reached the most sensitive stage between July 10 and 30 at this location. Such a cultivar would reach 50 percent heading between July 22 and August 11, which is earlier than heading time of standard late cultivars such as Calrose. New earlier selections will pass through the sensitive stage when low temperatures are least likely.

Figure 2 presents sterility means for six standard varieties and five modified Calrose genotypes grown at Davis in 1976. The sterility means are averages for May 1 and May 19 plantings in 5-foot rows spaced one foot apart. A randomized block with 12 replications was used, making 24 separate determinations for each mean. Modified Calrose genotypes D18 and D31 are induced mutants from Cobalt-60 irradiation of Calrose. ED7 was a spontaneous mutant for early maturity from Calrose 76. SD7 is from a cross between CS-M3 and Calrose 76, made for the purposes of producing smooth-leaved, short-stature types, and 75/15070 is a slightly earlier maturing selection from SD7. SD7 has Calrose maturity and ED7, D18, and D31 show progressively increasing earliness. All were within the same general sterility range as the parental Calrose.

The table presents sterility means of 16 selections from crosses between California varieties and two sterility-resistant varieties from Japan. These 16 lines were selected as the most promising among 100 varieties and selections tested in both early and late plantings in 1974 and 1975 and in a winter nursery in Hawaii in 1975-76. Data shown in the table are averages of an early and a late planting with 12 replications each in 1976. The selections are presented in increasing order of sterility along with Calrose 76, M7, CS-M3, and Earlirose as check cultivars.

Five of the selections showed significantly less sterility than Calrose 76 which, in turn, exhibited significantly less sterility than CS-M3 and Earlirose. The resistant selections are useful as parents for crosses to produce varieties with improved fertility.

The 10 best selections from the table were averaged and are compared with eight varieties currently grown and one (CS-S4) that has been discontinued. These comparisons (see figure 3) are means of six separate trials conducted from 1974 through 1976.

One of the troublesome characteristics of research on sterility in rice is extreme variability of results among years, locations, and planting dates. Variability among replications also is large. Sources of this variability are changing weather patterns from day to day, differences in developmental stages among varieties being compared in relation to weather conditions, differences in water depth, and differences in water temperatures occasioned by flow pattern from the water inlet location. We have tried to reduce the error in sterility measurements by better control of water flow, increased replications, multiple plantings, and increased sample size from which sterility determinations are made. The data presented in figure 3 are subject to many of the above variables. However, the general patterns for the varieties shown are sufficiently similar to provide a useful guide for their performance under cool night temperature situations.

Based on these results, we suggest that rice growers in areas subject to cool night temperatures who plant early-use early-maturing varieties or sterility-resistant varieties such as M7, Calrose, and Calrose 76. New, early-maturing short-stature varieties still being developed are anticipated to be more suitable for cool areas, late planting, or double cropping after an early-maturing winter crop.

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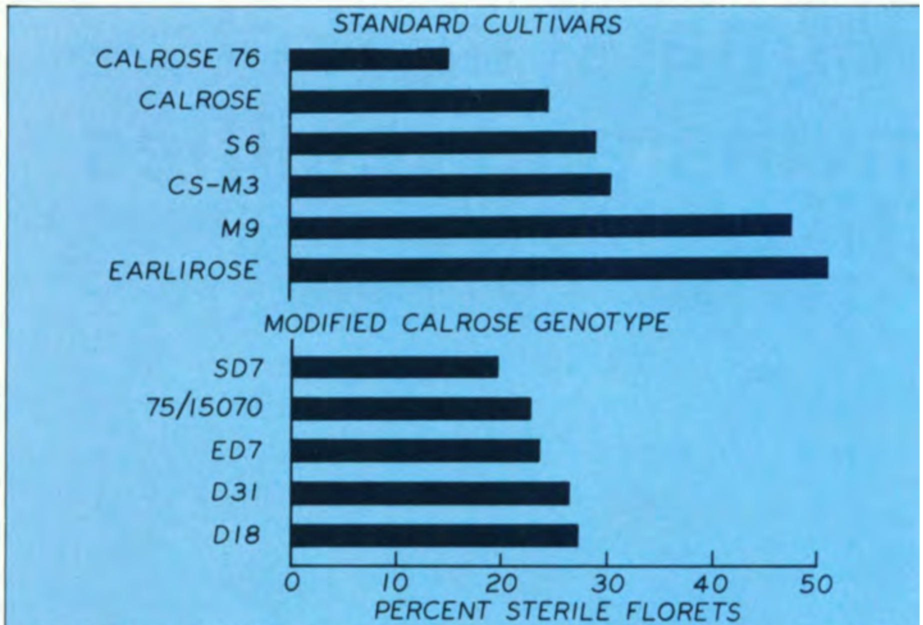

Fig. 2. Percent sterile florets of standard cultivars and modified Calrose genotypes grown at Davis, 1976. Sterility figures are means of two planting dates (May 1 and May 19), each with 12 replications.

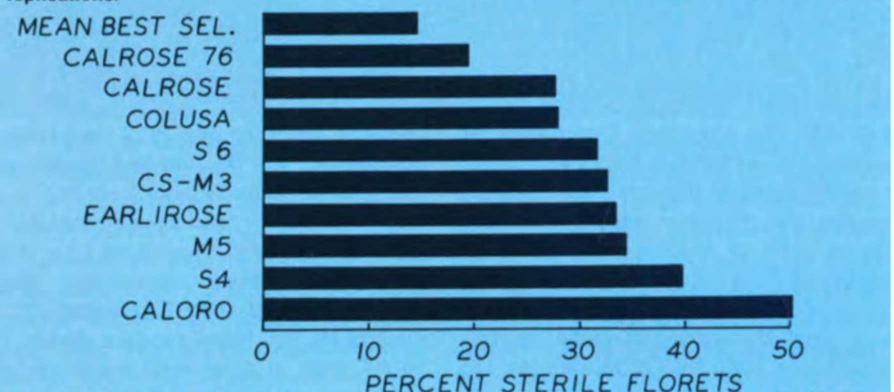

Fig. 3. Percent sterile florets of nine standard cultivars compared with the mean of the best 10 percent of 100 cultivars and selections. The sterility figures are means of five tests conducted from 1974 to 1976 at Davis and one test in Hawaii in 1975-76.

Percent Sterility of 16 Selections Compared with Four Standard Varieties at Davis in 1976

Variety or line no.	CI no.	Origin	Low temp. exposure*	Sterility†
			(hours)	(%)
82	CI 11041	Caloro/Kitaminori	45	11.8
97	CI 11040	Caloro/Kitaminori	46	12.7
56	CI 11042	Caloro/Kitaminori	43	14.8
61		Caloro/Kitaminori	37	15.2
52	CI 11039	Caloro/Kitaminori	44	15.8
65		Colusa/Kitaminori	39	17.2
53		Colusa/Kitaminori	40	17.3
25		Caloro/Kitaminori	50	19.6
92	CI 11044	Caloro/Kitaminori	48	19.7
74		Calrose/Isao Mochi	42	20.3
21		Caloro/Kitaminori	40	20.9
Calrose 76			34	21.3
43	CI 11043	Caloro/Kitaminori	39	21.5
73		Calrose/Isao Mochi	40	22.1
M7			35	24.1
91		Calrose/Isao Mochi	48	29.9
16		Caloro/Isao Mochi	39	31.4
22		Caloro/Isao Mochi	57	38.6
CS-M3			34	40.6
Earlirose			44	60.7
Mean			42.3	23.8

* No. of hours with temperatures below 60°F (15.5°C) during the 10-day period of 5 to 15 days before heading.

† These are means of two planting dates (May 1 and 19), each with 12 replications. Varieties connected by the same line do not differ from each other but are significantly different from all others at the .01 level.