COOL NIGHT TEMPERATURES CAUSE STERILITY IN RICE

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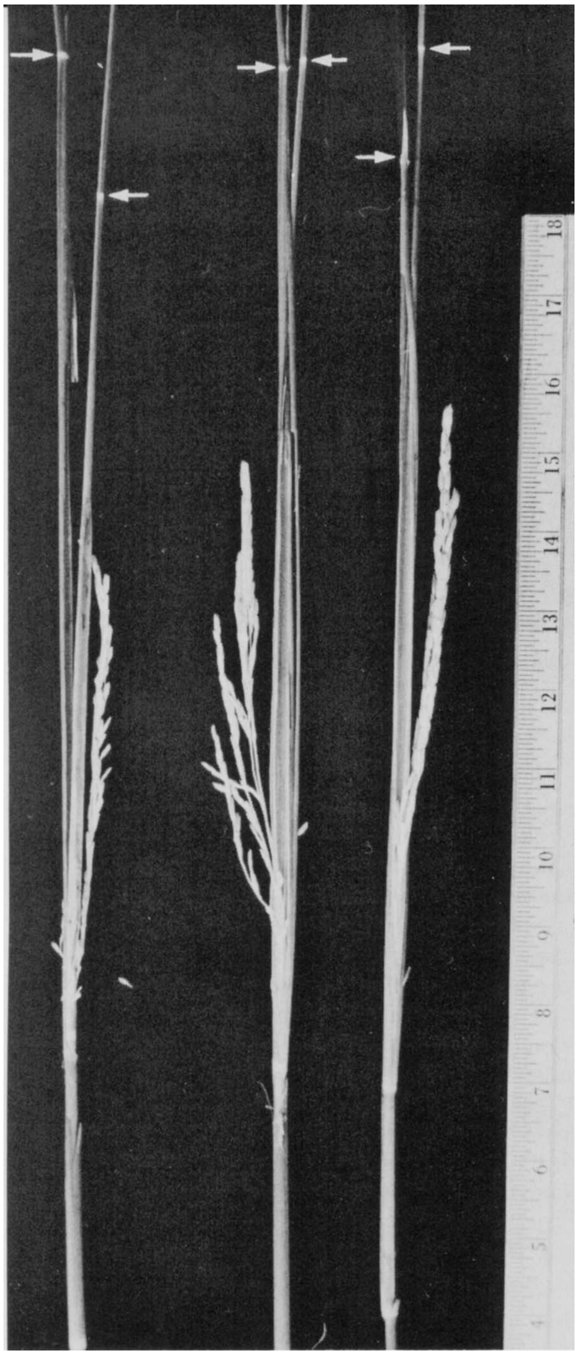


Left to right, rice stems with collars of the flag leaf below, equal, and above the collar of the next lower leaf. The center stem has a hidden panicle at the most sensitive stage to cool temperatures. The stem to the left is earlier, and the one to the right is later than the sensitive stage.

COOL NIGHT TEMPERATURES 10 to 16 days before heading cause many rice florets to be sterile. The direct cause of sterility is failure of pollen grains to germinate because they are immature, and contain little if any starch. In two successive years, 12.5 and 12.8% of the florets in rice fields grown for certification were found to be sterile, as determined by random samples of panicles taken from fields. The range in sterility in 59 fields checked in 1972 was from 2.7% to 34.8%. Rice growers have recognized the problem for many years and have correctly associated it with late planting, cold water at the inlet boxes, and heavy nitrogen fertilizer applications.

Continued research on the problem has led to the conclusion that there are two primary approaches for reducing losses from cool-temperature-induced sterility. Varieties with greater tolerance to cool temperatures would offer the simplest solution for growers. Fortunately, this solution appears possible and research is progressing at Davis and Biggs to develop varieties with greater tolerance to cool temperatures.

The other possible solution is entirely in the growers' hands. The probability of cool-temperature-induced sterility losses can be reduced by planting early, avoiding excessive nitrogen fertilization, and planting early-maturing varieties in areas more subject to cool night temperatures. Where these solutions are not sufficient, special water management a few weeks before heading may be a useful method to reduce sterility.

The Japanese have been concerned with low-temperature problems since rice was first introduced to Japan about 2000 years ago. They initiated a concerted effort to grow rice in Hokkaido in about 1875 and have continued to do research on reducing cool-temperature sensitivity of rice. Because the Japanese results were similar to the University of California conclusions, some of their data and recommendations are included in this report.

Night temperatures

Sensitivity to cool night temperature is greatest at the stage of plant development when the pollen mother cells are being formed and subsequently divide to produce pollen grains. Previous to this stage, the immature panicle is less than 6 inches long, and is protected inside the stem below the water level in the field. Formation of pollen from pollen mother cells occurs concurrently with rapid panicle enlargement and stem elongation. The developing panicle at this time draws heavily on carbohydrates produced in the leaves.

As the stem elongates the panicle enlarges, and gradually emerges from below to above the water level in the field, but is still enclosed within the stem. The air temperatures are more extreme than the water temperatures (warmer, usually, during midday and cooler at night). For a period of a critical few days, part of the panicle will be below and part above the water level. Measurements indicated the base of the panicle is about 4 inches, and the tip is about 10 inches above ground level, at the critical time of pollen formation.

Another period of low-temperature sensitivity in rice fields occurs at heading and flowering time, however, this report is concerned only with cool-temperature sensitivity at pollen formation time—believed to be the more critical period in causing sterility in California.

Three methods

Three methods can be used to determine when the cool-temperature-sensitive stage of panicle development occurs in the rice field. The stem can be split with a sharp knife or razor blade and the immature panicle located. For those varieties commonly grown in California today, the tip of the panicle will be less than 8 to 10 inches above ground level and the base 3 to 4 inches above ground level at the cool-temperature-sensitive stage. A second method is to locate the relative positions of the collars (the junction of the leaf blade and the sheath that clasps the stem) of the flag leaf and the next lower leaf. The cool-temperature-sensitive stage occurs when these two collars are at approximately the same vertical position on the stem. Earlier, the collar of the flag leaf is not visible because it is still enclosed in the leaf sheath. Later, the flag leaf collar is above the collar of the second leaf.

A little practice and observation is needed to determine whether the emerging leaf is the flag leaf or an earlier one. The photo shows the positions of the collars and panicles at this critical period. The third, and final method is simply an estimate of the number of days before heading, based on field experience (10 to 16 days before heading is the critical cool-temperature-sensitive period).

The relation between the stage of rice plant development, and cool-temperature sensitivity with Caloro rice is shown in graph 1. Temperature treatments were 59°F during a 12-hour light period and 45°F during a 12-hour dark period. Cool-temperature treatments for different durations were given at estimated mid-dates of 17, 12, and 7 days before heading. The cool-temperature treatments were established at 2, 3, 4, and 5 days. The greatest sterility occurred when cool temperatures came at an estimated 10 to 14 days (mid-date 12 days) before heading. Five days at these cool temperatures resulted in almost 50% sterility. Injury was somewhat less at 15 to 19 days (mid-date 17 days) before heading and much less at 5 to 9 (mid-date 7 days) days before heading.

Japanese studies

Studies in Japan by Hayase and coworkers also showed striking effects of both the time and duration of low temperatures. One of their graphs has been redrawn to conform with the scale of our graph 1 and is presented as graph 2. The Japanese workers used 53.6°F constant day and night temperature. Although their sterility percentages were greater, the time of greatest sensitivity to cool-temperature was nearly identical with U. C. results.

Temperatures used in these studies were within the range of those occurring in the field at night in California. Graph 3 shows the daily average minimum air temperature over a 10-year period (1964–1973) at three locations in California. The horizontal line at 60°F marks the temperature below which partial sterility is likely to occur in the field, if continued for several consecutive nights.

Madera minimum temperatures are all above the safe level, except in late August (after the sensitive stage to all but late-sown rice). Colusa minimum temperatures are cooler than at Madera by an average of 3.2°F in July and 4.7°F in August—with most minimum night temperatures below the 60°F level. Davis minimum night temperatures averaged 55.0°F in July and 53.1°F in August, making this location particularly susceptible to cool temperature injury.

There are also seasonal trends that are significant. The most important is the drop in night temperatures after about August 10th. Delayed planting dates can shift the cool-temperature-sensitivity stage into this period. If so, high sterility is likely to occur. The dip in average night temperatures in late July, and again in early August, probably are the result of chance variability—although each point on graph 3 is the average for the past 10 years.

The table presents the cool-temperature-sensitivity period for six commonly grown rice varieties in California, as determined by heading dates from field trials conducted in 1973. The interval 7 to 21 days before 50% heading was identified as the cool-temperature sensitivity period. This interval of time allows several days on either side of the peak period of sensitivity (about 10 days before heading). Varieties, locations, and time of sowing of late maturing varieties had some influence on the time of cool-temperature sensitivity in 1973. Even allowing for this variability, the first two weeks of August was the sensitive period for the late maturing varieties Calrose, CS-M3, Caloro, and CS-S4. The early maturing varieties, Earlirose and Colusa, were at the sensitive period during July (the specific time depending on the sowing date). The table provides a guide to the sensitivity period to be expected, but it should be kept in mind that variations in seeding dates, temperatures, nitrogen fertilization, and water temperatures will affect the rate of development of rice plants.

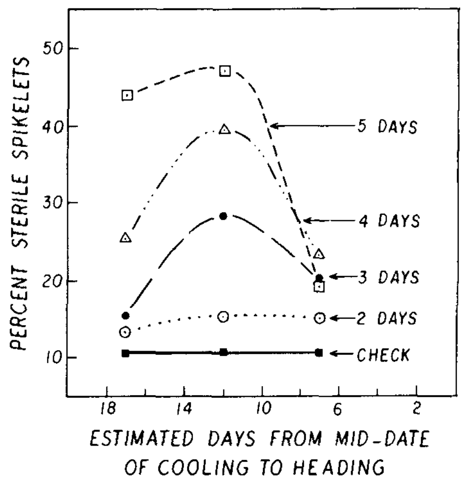
Effect of water depth

Some evidence indicates beneficial effects resulting from raising the water level in the field during the cool-temperature sensitivity period. The reason is that water temperatures are warmer than air temperatures during the night. It is not uncommon to find air temperatures 6 to 8 degrees warmer in midday and 6 to 8

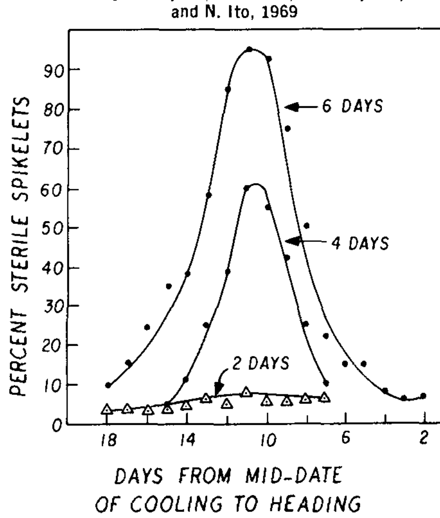
TABLE 1. ESTIMATED PERIOD OF COOL-TEMPERATURE SENSITIVITY FOR CALIFORNIA RICE VARIETIES GROWN AT DIFFERENT LOCATIONS AND PLANTING DATES IN 1973

Variety	Date: seeded	Date: headed	Days to heading	Cool-temperature sensitivity period
		LATE MATURING VARIETIES		
		Yolo Co. (Geer)		
CALROSE	4/27	8/24	119	8/3 to 8/17
CS-M3		8/23	118	8/2 to 8/16
CALORO		8/27	122	8/6 to 8/20
CS-S4		8/25	120	8/4 to 8/18
		Glenn Co. (Wylie)		
CALROSE	4/19	8/19	122	7/29 to 8/12
CS-M3		8/17	120	7/27 to 8/10
CALORO		8/23	126	8/2 to 8/16
CS-S4		8/23	126	8/2 to 8/16
		Yuba Co. (Mohammed)		
CALROSE	4/26	8/18	114	7/28 to 8/11
CS-M3		8/17	113	7/27 to 8/10
CALORO		8/21	117	7/31 to 8/14
CS-S4		8/17	113	7/27 to 8/10
		EARLY MATURING VARIETIES		
		Yolo Co. (Geer)		
EARLIROSE	5/5	8/4	91	7/14 to 7/28
COLUSA		8/6	93	7/16 to 7/30
		Yuba Co. (Hoppin)		
EARLIROSE	4/24	7/17	85	6/26 to 7/10
COLUSA		7/23	91	7/2 to 7/16

GRAPH 1. EFFECT OF COOL TEMPERATURE TREATMENTS ON CALORO RICE (59°F DURING THE LIGHT PERIOD AND 45°F DURING THE DARK PERIOD) GIVEN AT DIFFERENT TIMES AND DURATIONS BEFORE HEADING ON THE PER CENT OF STERILE FLORETS IN CALORO RICE ("DAYS" ARE LENGTH OF COOL TEMPERATURE TREATMENT AND POINTS ON THE FIGURE ARE MID-DATES FOR TEMPERATURE TREATMENTS OF SEVERAL DAYS DURATION)



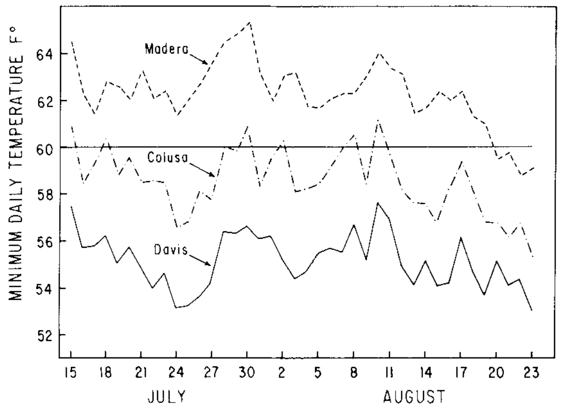
GRAPH 2. EFFECT OF COOL TEMPERATURE TREATMENTS AT 53.6°F FOR 2, 4, AND 6 DAYS AT DIFFERENT TIMES BEFORE HEADING ON RICE IN JAPAN
Data by H. Hayase, T. Patake, S. Nishiyama, and N. Ito, 1969



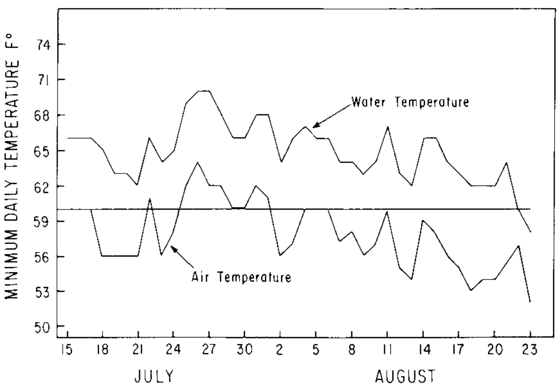
degrees cooler at the low temperature period at night than water temperatures. The maximum high temperature period occurs between 3 and 6 p.m. and the low temperature minimum from 4 to 6 a.m.

Graph 4 shows minimum night temperatures for air and water in the rice field at Davis for the last half of July and for August, 1973. All but a few of the minimum night air temperatures were below the 60 degree level, while all water temperatures were safely above

GRAPH 3. AVERAGE DAILY MINIMUM AIR TEMPERATURES OVER A 10-YEAR PERIOD (1964–1973) AT THREE LOCATIONS IN CALIFORNIA—HORIZONTAL LINE AT 60°F IS THE ESTIMATED CUT-OFF POINT BELOW WHICH RICE IS MORE SUSCEPTIBLE TO COOL-TEMPERATURE INJURY IF IT OCCURS 1- TO 3-WEEKS BEFORE HEADING



GRAPH 4. MINIMUM AIR AND WATER TEMPERATURES FOR THE LAST HALF OF JULY AND FOR AUGUST 1973 AT THE UNIVERSITY OF CALIFORNIA RICE RESEARCH FACILITY, DAVIS—MINIMUM WATER TEMPERATURES AT NIGHT WERE 6 TO 8 DEGREES WARMER THAN MINIMUM AIR TEMPERATURES



this point. As previously mentioned, part of the panicle is below and part above an average 6-inch water depth during the stage of cool-temperature sensitivity—and more of the panicle is protected from cool temperatures by raising the water level. Greenhouse studies indicated that warm water decreases, and cool water increases floret sterility. Earlier field studies in water depth have not given consistent results.

The Japanese obtained evidence of beneficial effects from raising water levels when water was warmer than the air. Nishiyama and others used warm irrigation water (23°C or 73.4°F) when air temperatures were cool (12°C or 53.6°F). As water depth was increased from 0 to 8¼ inches, sterility decreased from 80% to about 5% (graph 5). Conversely, Tsunoda and Matsushima grew rice plants in 15°C (59°F) water temperature which was below the air temperature. As water depth was increased from ¾-inch to 8 inches, sterility increased from 20% to about 95% (graph 6).

California growers located in cooler areas, or whose crops may be delayed in maturity, or who may have used very high nitrogen fertilizer levels, are encouraged to raise the water level by about 2 inches beginning three weeks before anticipated heading. It is also advisable to spill as little water as possible after raising the level to reduce the amount of water added to the field—although this only may affect water temperature near the inlet, and then only if water added is cooler than water in the rice field. Shortly before heading time (about one week) the water level can be reduced, to its original depth.

Genetic resistance to cool-temperature offers another solution to the sterility problem. Cooperative work between the plant breeders at the Rice Experiment Station and at Davis has been in progress for several years. In 1971 nearly 300 breeding lines were sown on April 28 and again on May 7 at the Rice Research Facility at Davis. The average sterility for all lines from the two plantings was 30.1% for the earlier and 35.2% for the later planting. The range in sterility between lines was from 3.6% to 81.6% for the first planting and 4.6% to 96.8% for the later planting. Temperature differences between two planting dates at the cool-temperature-sensitivity stage were only 1 or 2 degrees, but were enough to increase sterility for the later planting.

In 1973 961 lines were tested from the Rice Experiment Station. These were sown at Davis on May 3. The average sterility of these lines was 26.2% and the range was from 10% to 90%. The check variety Colusa showed 17.4% sterility, and Earlirose averaged 25.5%.

Graph 7 shows the number of breeding lines which fell within a series of sterility classes. On the basis of these results, the rice breeders have eliminated lines showing high sterility from further consideration in the breeding program.

Research is being continued along three lines: (1) to discover lines showing a very high level of fertility under low temperature conditions; (2) to devise more precise methods for evaluating temperature sensitivity; and (3) to discover the physiological reason for low night-temperature induced sterility.

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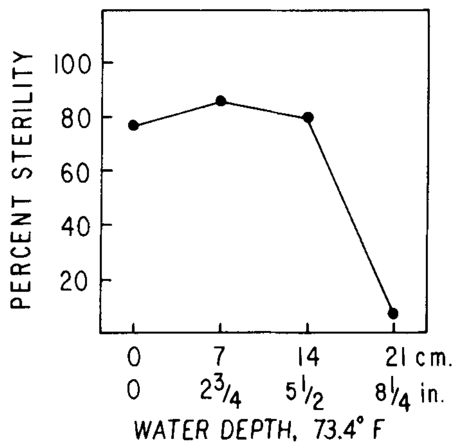
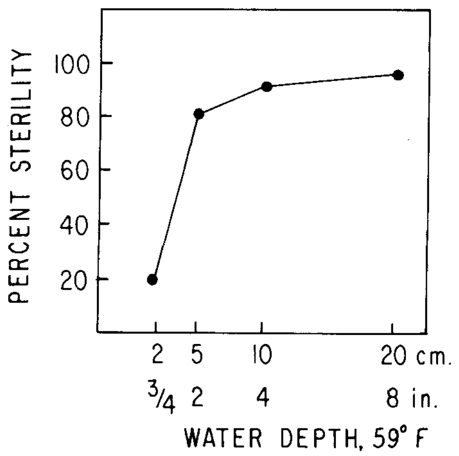
GRAPH 5. EFFECT OF DEPTH OF WARM WATER AT 73.4°F OVER A 4-DAY PERIOD AT BOOTING ON STERILITY PERCENTAGES OF RICE WHOSE SHOOTS WERE KEPT IN A COOL 53.6°F TEMPERATURE (CONDITION APPLIES TO FIELD CONDITIONS IN CALIFORNIA)
Data by I. Nishiyama, N. Ito, H. Hayase, and T. Satake. 1969



GRAPH 6. EFFECT OF DEPTH OF COOL WATER AT 59°F OVER A 15-DAY PERIOD AT BOOTING ON STERILITY OF RICE WHEN THE SHOOTS WERE AT NORMAL TEMPERATURE (CONDITION USUALLY WOULD NOT APPLY TO FIELD CONDITIONS IN CALIFORNIA)
Data by K. Tsunoda and S. Matsushima. 1962



GRAPH 7. FREQUENCY DISTRIBUTION FOR PERCENTAGES OF STERILE FLORETS AMONG 961 BREEDING LINES GROWN IN THE FIELD AT DAVIS