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# PROCEEDINGS

## SYMPOSIUM OF STUDIES ON THE CAUSES OF LOW YIELD OF RICE IN TROPICAL AND SUB-TROPICAL REGIONS

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# PREFACE

The reason for the yield of rice in tropical countries being generally low has been a subject which attracts our interest. We have started on studies of this problem in March 1959, under the kind grant (RF 59029) from the Rockefeller Foundation. We have executed our research plan in the fields of Soil Science, Agronomy, Plant Disease and Genetics with cooperation of experts in and outside this Institute, aiming at a solution of various problems related to the cause of low yield in sub-tropical countries. In the past two years, we had two symposia on our research activities with attendance of our staff members and guests from outside. Records of our discussions in the last one and data obtained from various experiments are briefly described in this report. This is then a tentative report of our researches which are still under way.

*Shoei-chuan Hsu*
Director,
Taiwan Agricultural
Research Institute

March, 1961

## Attendants of the Symposium held on February 8, 1961:

| | |
|---|---|
| S. C. Hsu | Director, Taiwan Agricultural Research Institute |
| H. I. Oka | Member, National Genetics Institute, Japan |
| Y. L. Ku | Professor, National Taiwan University |
| T. T. Yen | Professor, National Taiwan University |
| T. S. Miu | Head of Agrnomy Dept., TARI |
| C. L. Liang | Head of Agr. Chemistry Dept., TARI |
| T. S. Hung | Head of Plant Pathology Dept., TARI |
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| C. F. Chiu | Associate Agr. chemist, TARI |
| S. C. Hsieh | Associate Agronomist, TARI |
| C. N. Wu | Associate Agronomist, TARI |
| C. S. Hwang | Senior Agronomist, TARI |
| Y. T. Yao | Instructor, National Taiwan University |
| W. T. Chang | Instructor, Taiwan Provincial Chung-hsin University, Taichung |
| K. M. Lin | Senior Agronomist, Taichung District Agricultural Improvement Station |
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| L. T. Lin | Associate Agr. chemist, TARI |
| C. C. Chien | Associate Plant pathologist, TARI |
| S. H. Lin | Junior Agronomist, TARI |
| T. M. Chang | Junior Agronomist, TARI |

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# I. SOIL SCIENCE: STUDIES ON NUTRIENT UPTAKE OF RICE PLANTS IN RELATION TO THE PROPERTY OF SOILS

## a. EFFECT OF TEMPERATURE ON NUTRIENT UPTAKE OF RICE

Shoei-chuan Hsu, Tsai-fua Chiu & Sien Lian

(Laboratory of Plant Nutrition, TARI)

The effect of temperatures on nutrient absorption levels were studied by rice plants grown in pots. One of the glass-houses with closed windows and the other opened windows are considered as the high and low temperature plots, respectively. In 1959, a Japonica variety, Taichung No. 65 was used. In 1960, both a Japonica and an Indica variety, Taichung no. 65 and Pai-mi-fun, were studied to examine how nutrient absorption and other agronsmic characters behave under the two conditions of temperature. In 1961, the effects of fertilization and different soils will be dealt with. The results of experiments in the past two years are presented below.

### Experiment in 1959

The growth habit and nutrient absorption of Taichung no. 65 under different temperatures were investigated in this year. The average temperatures during the growing period in the two glass-houses were as follows.

Table 1. Average temperature in two glass-houses

| | 1st crop, 1959 (Mar. 26-Aug. 8) | 2nd crop, 1969 (Aug 13-Dec. 18) |
|---|---|---|
| High temp. plot | 30.9°C | 29.8°C |
| Low temp. plot | 27.9°C | 27.0°C |
| Difference | 3.0°C | 2.8°C |

Culm length, tiller number and dry plant weight were measured at various growing stages successively. The characters measured at maturity are shown in table 2.

Culm lengths in the first and sccond crops in the high temperature plot were apparently longer than those in the low temperature plot, but tiller number did not show a significant difference. It was found also that high temperatures advanced heading; heading date in the high temperature plot was 7 days earlier than that in the low temperature plot in the first crop, and 4 days earlier in the secoond crop. Total dry weights in the high temperature plot were higher than those in the low temperature plot, especially in the first crop.

Table 2. Growth and yield of rice plants grown under two different temperatures

| | 1st crop, 1959 | | 2nd crop, 1959 | |
|---|---|---|---|---|
| | High temp. plot | Low temp. plot | High temp. plot | Low temp. plot |
| Plant height (cm) | 116.6 | 104.0 | 117.4 | 111.8 |
| Tiller number | 26.6 | 26.2 | 26.4 | 26.8 |
| Total yield (g/pot) | 92.2 | 76.9 | 101.7 | 98.1 |
| Grain (g/pot) | 13.7 | 27.2 | 40.8 | 31.3 |
| Straw (g/pot) | 78.5 | 49.7 | 60.9 | 66.3 |
| Grain/Straw ratio | 17/100 | 55/100 | 67/100 | 48/100 |

However, grain yields appeared to be more complicated. As shown in table 2, grain/straw ratios in the high and low temperature plots were 17% and 55% in the first crop and 67% and 48% in the second crop respectively. In the first crop, high temperatures decreased grain yield, but in the second crop increased on the contrary. This might be because that the high temperature plot in the first crop occasionally had maximum temperatures over 40°C which might have disturbed pollination. In fact, a high proportion of sterile grains resulted, 60% being empty. Grain yield would be thus reduced in the high temperature plot.

It was also found that the ripenning of grains was delayed for more than 10 days in the high temperature plot, letting the plants continue to grow vegetatively. The metabolism in the ripening period of rice plants Murayama (1957) stated that after heading, nutrients were translocated to panicles and the existence of panicles will cause yellowing of leaves and weakening of root activity. If the panicles are removed, the plant may continue to grow up and increase the dry matter weights of other organs to compensate for the loss of panicles.

In the second crop, the grain yields in the high temperature plot were higher than those in the low temperature plot. In the later stage of growth in November and December, since the temperature was too low for the fruiting process of rice, the high temperature plot might have a rather adequate condition for grain production.

The N, P and K contents in plants gradually increased after transplanting. The highest nutrient contents were reached about 50 days after transplanting in the first crop and 25 days in the second crop, and then the figures made a slow dropping till maturity. It was found that the K contents in the high temperature plot, especially in the first crop, were evidently higher than that in the low temperature plot.

In general, the absorption of the three elements by rice plants, especially of potassium, was greatly promoted under high temperatures. Moreover, potassium absorption was larger in the second crop than that in the first crop. This fact is of

interest with regard to the favourable availability of potash fertilizers in the second crop season in which the temperatures are high.

Table 3. Inorganic nutrient contents of rice plants at successive growing stages (% on oven dry basis), 1959

| | High temp. plot | | | | Low temp. plot | | | |
|---|---|---|---|---|---|---|---|---|
| | Date | N% | $P_2O_5$% | $K_2O$% | Date | N% | $P_2O_5$% | $K_2O$% |
| 1st crop | Mar. 26 (planting) | 1.14 | 0.868 | 1.56 | | 1.14 | 0.368 | 1.56 |
| | Apr. 28 | 3.21 | 0.860 | 4.30 | | 3.74 | 0.875 | 2.80 |
| | May 15 | 4.21 | 0.808 | 4.56 | | 4.41 | 0.390 | 2.35 |
| | June 1 | 3.23 | 0.800 | 3.65 | | 3.71 | 0.938 | 1.58 |
| | June 29 | 1.79 | 0.657 | 1.94 | July 28 | 1.55 | 0.701 | 0.91 |
| | Aug. 8 (maturity) | 1.31 | 0.580 | 1.64 | | 1.12 | 0.550 | 0.88 |
| | Grain | 1.32 | 0.615 | 0.64 | | 1.32 | 0.611 | 0.62 |
| | Stem | 0.75 | 0.803 | 1.20 | | 0.73 | 0.840 | 1.30 |
| | Leaf | 1.46 | 0.521 | 1.97 | | 1.10 | 0.423 | 0.94 |
| 2nd crop | Aug. 13 (planting) | 2.86 | 0.958 | 3.65 | | 2.86 | 0.958 | 3.65 |
| | Sep. 8 | 3.64 | 0.985 | 4.94 | | 3.74 | 0.943 | 5.04 |
| | Oct. 1 | 3.50 | 0.938 | 4.42 | | 3.18 | 0.825 | 3.65 |
| | Oct. 21 | 2.20 | 0.782 | 3.50 | | 2.28 | 0.792 | 2.98 |
| | Nov. 9 | 1.45 | 0.660 | 25.2 | | 1.52 | 0.644 | 2.09 |
| | Dec. 18 (maturity) | 1.18 | 0.558 | 1.83 | | 1.33 | 0.527 | 1.61 |
| | Grain | 1.40 | 0.702 | 0.65 | | 1.58 | 0.698 | 0.67 |
| | Stem | 0.66 | 0.682 | 3.84 | | 0.92 | 0.534 | 2.50 |
| | Leaf | 1.22 | 0.355 | 2.04 | | 1.37 | 0.394 | 1.85 |

Table 4. Amounts of inorganic nutrients absorbed by rice plants at successive growting stages (mg/pot)

| | High temp. plot | | | | Low temp. plot | | | |
|---|---|---|---|---|---|---|---|---|
| | Date | N | $P_2O_5$ | $K_2O$ | Date | N | $P_2O_5$ | $K_2O$ |
| 1st crop | Mar. 26 (planting) | 1.0 | 6.7 | 1.3 | | 1.0 | 0.7 | 1.3 |
| | Apr. 28 | 31.1 | 8.3 | 42.1 | | 24.7 | 5.8 | 18.5 |
| | May 15 | 275.7 | 52.9 | 298.7 | | 231.5 | 46.7 | 123.4 |
| | June 1 | 699.9 | 170.7 | 778.9 | | 671.8 | 169.9 | 286.1 |
| | June 29 | 1,036.8 | 380.4 | 1,123.6 | | 730.8 | 307.9 | 399.7 |
| | Aug. 8 (maturity) | 1,107.0 | 492.2 | 1,380.8 | July 28 | 775.1 | 385.9 | 613.6 |
| 2nd crop | Aug. 13 (planting) | 1.6 | 0.5 | 2.1 | | 1.6 | 0.5 | 2.1 |
| | Sep. 8 | 65.9 | 17.8 | 93.8 | | 93.5 | 23.6 | 126.0 |
| | Oct. 1 | 568.4 | 152.3 | 717.2 | | 562.5 | 145.9 | 645.3 |
| | Oct. 21 | 870.8 | 309.5 | 1,386.9 | | 888.7 | 308.7 | 1,160.0 |
| | Nov. 9 | 910.6 | 414.4 | 1,582.6 | | 936.9 | 397.0 | 1,287.0 |
| | Dec. 18 (maturity) | 1,059.6 | 499.9 | 1,642.1 | | 1,137.6 | 449.4 | 1,371.7 |

The average amounts and indices of N, $P_2O_5$, $K_2O$ absorbed (per pot) were estimated as follows; N 1,019 mg. (100), $P_2O_5$ 457 mg. (45), $K_2O$ 1,252 mg. (123).

## Experiment in 1960

In 1960, the pot experiment was continued in the same two glasvouses in order to find differences in the effect of temperatures on nutrient absorption between two rice varieties. A Japonica variety, Taichung 65 and an Indica variety pai-mi-fun were comparatively investigated.

Table 5. Average temperature in two glass-houses

| | 1st crop, 1960 (Feb. 24-July 12) | 2nd crop, 1960 (July 30-Dec. 5) |
|---|---|---|
| High temp. plot | 26.6°C | 27.9°C |
| Low temp. plot | 24.2°C | 25.5°C |
| Difference | 2.4°C | 2.4°C |

Table 6. Yield and other measurements at maturity

| | | Japonica (Taichung 65) | | Indica (Pai-mi-fen) | |
|---|---|---|---|---|---|
| | | High temp. plot | Low temp. plot | High temp. plot | Low temp. plot |
| 1st crop | Plant height (cm) | 128.6 | 120.6 | 153.6 | 146.0 |
| | Tiller number | 22.0 | 27.4 | 24.8 | 26.6 |
| | Total yield (g/pot) | 105.2 | 102.3 | 102.9 | 97.2 |
| | Grain (g/pot) | 39.6 | 40.9 | 45.6 | 39.8 |
| | Straw (g/pot) | 65.6 | 61.4 | 57.3 | 57.4 |
| | Grain/Straw ratio | 60/100 | 67/100 | 79/100 | 69/100 |
| 2nd crop | Plant height (cm) | 123.5 | 124.3 | 168.3 | 162.5 |
| | Tillers number | 21.5 | 17.9 | 22.0 | 21.7 |
| | Total yield (g/pot) | 82.9 | 79.9 | 102.7 | 93.3 |
| | Grain (g/pot) | 36.9 | 33.5 | 44.1 | 37.9 |
| | Straw (g/pot) | 46.0 | 46.4 | 58.6 | 55.8 |
| | Grain/Straw ratio | 80/100 | 72/100 | 75/100 | 68/100 |

Elongation was apparently promoted in the high temperature plot, and the dry matter weight of plants was always larger than that in the low temperature plot. This trend was more significant in the first crop than in the second crop.

In the first crop, the high temperatures decreased both grain yield and grain/straw ratio in the Japonica variety, Taichung 65, but in the second crop the high temperatures increased them, in the same manner as in 1959. However, the grain yield of the Indica variety Pai-mi-fun was promoted under high temperatures in both the first and second crops; the two varieties thus seem to differ in temperature response.

The high temperature promoted heading of both varities in the first crop, but did not in the second crop.

Table 7. Heading date under different temperatures

| | | 1st crop, 1960 Heading date | 2nd crop, 1960 Heading date |
|---|---|---|---|
| Japonica variety | High temp. | June 8-16 | Oct. 17-22 |
| | Low temp. | June 16-25 | Oct. 17-22 |
| Indica variety | High temp. | June 2- 6 | Oct. 15-22 |
| | Low temp. | June 5- 9 | Oct. 15-21 |

The amount of nutrients absorbed by the plants in the high temperature plot was larger than that in the low temperature plot, as shown in Table 9. In Pai-mi-fun, the increasing of nutrient absorption under high temperatures appeared to result in an increased transmission of nutrients to grains, but in Taichung No. 65, it did not. In this respect, the Japonica varity seemed to be less adaptive to high temperatures than the Indica variety.

Table 8a. Inorganic nutrient contents (% on oven dry basis), 1st crop, 1960

| Varutty | Date | High temp. plot | | | Low temp. plot | | |
|---|---|---|---|---|---|---|---|
| | | N% | $P_2O_5$% | $K_2O$% | N% | $P_2O_5$% | $K_2O$% |
| Japonica, Taichung No. 65 | Feb. 22 (planting) | 4.628 | 2.280 | 4.464 | 4.628 | 2.280 | 4.464 |
| | Mar. 17 | 4.324 | 1.055 | 5.904 | 4.660 | 1.297 | 5.930 |
| | Mar. 31 | 4.280 | 1.075 | 6.048 | 4.420 | 1.010 | 5.520 |
| | Apr. 14 | 3.898 | 1.048 | 5.222 | 3.892 | 1.062 | 5.356 |
| | Apr. 28 | 3.803 | 1.196 | 5.254 | 4.278 | 1.119 | 4.835 |
| | May 12 | 2.579 | 0.866 | 3.233 | 3.101 | 0.862 | 3.334 |
| | June 2 | 1.592 | 0.643 | 2.155 | 1.604 | 0.758 | 1.818 |
| | June 21 | 1.207 | 0.494 | 1.445 | 1.251 | 0.570 | 1.395 |
| | July 12 (harvesting) | 1.086 | 0.427 | 1.223 | 1.039 | 0.454 | 1.187 |
| | Grain | 1.341 | 0.610 | 0.592 | 1.371 | 0.581 | 0.594 |
| | Stam & Sheath | 0.630 | 0.330 | 1.368 | 0.609 | 0.396 | 1.440 |
| | Leaf Blade | 1.564 | 0.288 | 2.202 | 1.338 | 0.311 | 1.902 |
| Indica, Pai-mi-fun | Feb. 22 (planting) | 4.639 | 2.160 | 4.128 | 4.639 | 2.160 | 4.128 |
| | Mar. 17 | 4.346 | 1.102 | 5.856 | 4.476 | 1.155 | 6.144 |
| | Mar. 31 | 4.492 | 1.085 | 6.000 | 4.422 | 1.165 | 6.384 |
| | Apr. 14 | 3.574 | 0.950 | 5.201 | 3.798 | 0.999 | 5.821 |
| | Apr. 28 | 3.482 | 0.994 | 4.239 | 3.724 | 0.988 | 4.630 |
| | May 12 | 2.448 | 0.752 | 2.673 | 2.254 | 0.808 | 2.656 |
| | June 2 | 1.381 | 0.485 | 1.722 | 1.528 | 0.650 | 2.098 |
| | June 21 | 1.144 | 0.471 | 1.370 | 1.115 | 0.452 | 1.314 |
| | July 4 (harvesting) | 1.152 | 0.479 | 1.302 | 1.112 | 0.450 | 1.269 |
| | Grain | 1.591 | 0.790 | 0.560 | 1.532 | 0.798 | 0.568 |
| | Stem & Sheath | 0.621 | 0.253 | 2.060 | 0.585 | 0.207 | 1.886 |
| | Leaf Blade | 1.151 | 0.192 | 1.572 | 1.362 | 0.211 | 1.401 |

Table 8b. Inorganic nutrient contents (% on oven dry basis), 2nd crop, 1960

| Variety | Date | High temp. plot | | | Low temp. plot | | |
|---|---|---|---|---|---|---|---|
| | | N% | $P_2O_5$% | $K_2O$% | N% | $P_2O_5$% | $K_2O$% |
| Japonica, Taichung No. 65 | July 30 (planting) | 3.000 | 0.846 | 3.360 | 3.000 | 0.846 | 3.360 |
| | Aug. 29 | 3.576 | 0.814 | 4.903 | 3.127 | 0.785 | 5.238 |
| | Sep. 20 | 3.146 | 0.650 | 3.855 | 3.121 | 0.651 | 3.926 |
| | Oct. 12 | 2.324 | 0.739 | 2.886 | 2.254 | 0.712 | 2.920 |
| | Nov. 1 | 1.674 | 0.651 | 2.072 | 1.623 | 0.569 | 2.020 |
| | Dec. 5 (harvesting) | 1.581 | 0.580 | 1.730 | 1.414 | 0.531 | 1.707 |
| | Grain | 1.690 | 0.740 | 0.552 | 1.650 | 0.708 | 0.588 |
| | Stem & Sheath | 1.260 | 0.495 | 2.808 | 1.010 | 0.448 | 2.628 |
| | Leaf Balde | 2.080 | 0.345 | 1.730 | 1.800 | 0.299 | 2.244 |
| Indica, Pai-mi-fun | July 30 (planting) | 3.310 | 0.958 | 3.984 | 3.310 | 0.958 | 3.984 |
| | Aug. 29 | 3.995 | 0.590 | 5.771 | 3.734 | 0.471 | 5.279 |
| | Sep. 20 | 3.128 | 0.593 | 3.715 | 2.891 | 0.858 | 3.142 |
| | Oct. 12 | 1.672 | 0.506 | 2.391 | 1.591 | 0.575 | 2.008 |
| | Nov. 1 | 1.196 | 0.484 | 1.654 | 1.145 | 0.543 | 1.676 |
| | Nov. 22 (harvesting) | 1.107 | 0.411 | 1.412 | 0.974 | 0.425 | 1.298 |
| | Grain | 1.470 | 0.602 | 0.576 | 1.370 | 0.685 | 0.600 |
| | Stem & Sheath | 0.700 | 0.279 | 2.352 | 0.580 | 0.270 | 1.992 |
| | Leaf Blade | 1.130 | 0.244 | 1.356 | 0.960 | 0.243 | 1.272 |

Table 9a. Distribution of inorganic nutrients in the plant, 1st crop, 1960

| Variety | Plot | Part | N | $P_2O_5$ | $K_2O$ |
|---|---|---|---|---|---|
| | | | mg/pot (Index) | mg/pot (Index) | mg/pot (Index) |
| Japonica, Taichung No. 65 | High temp. plot | Grain | 531.0 (47) | 241.5 (54) | 234.4 (18) |
| | | Stem & Sheath | 281.0 (25) | 147.2 (33) | 610.1 (47) |
| | | Leaf Blade | 328.4 (29) | 60.5 (13) | 442.6 (35) |
| | | Total (Index) | 1,140.4(100) (100) | 449.2(100) (39) | 1,287.1(100) (113) |
| | Low temp. plot | Grain | 550.5 (52) | 237.6 (51) | 242.9 (20) |
| | | Stem & Sheath | 258.2 (24) | 167.9 (36) | 610.6 (50) |
| | | Leaf Blade | 254.2 (24) | 59.1 (13) | 331.4 (30) |
| | | Total (Index) | 1,062.9(100) (100) | 464.6(100) (44) | 1,214.9(100) (114) |
| Indica, Pai-mi-fun | High temp. plot | Grain | 725.5 (61) | 360.2 (73) | 255.4 (19) |
| | | Stem & Sheath | 234.1 (20) | 95.4 (19) | 776.6 (58) |
| | | Leaf Blade | 225.6 (19) | 37.6 (8) | 308.1 (23) |
| | | Total (Index) | 1,185.2(100) (100) | 493.2(100) (42) | 1,340.1(100) (113) |
| | Low temp. plot | Grain | 609.7 (56) | 317.6 (73) | 226.1 (18) |
| | | Stem & Sheath | 233.4 (22) | 82.6 (19) | 762.5 (62) |
| | | Leaf Blade | 238.4 (22) | 36.9 (8) | 245.1 (20) |
| | | Total (Index) | 1,081.5(100) (100) | 437.1(100) (40) | 1,233.7(100) (114) |

Table 9b. Distribution of inorganic nutrients in the plant, 2nd crop, 1960

| Variety | Plot | Part | N | $P_2O_5$ | $K_2O$ |
|---|---|---|---|---|---|
| | | | mg/pot (Index) | mg/pot (Index) | mg/pot (Index) |
| Japonica, Taichung No. 65 | High temp. plot | Grain | 632.6 (48) | 273.1 (56) | 203.7 (14) |
| | | Stem & Sheath | 414.2 (32) | 162.7 (34) | 923.1 (64) |
| | | Leaf Blade | 273.0 (21) | 45.3 (9) | 307.1 (21) |
| | | Total (Index) | 1,310.8(100) (100) | 481.1(100) (37) | 1,433.9(100) (109) |
| | Low temp. plot | Grain | 552.1 (49) | 236.9 (56) | 196.7 (14) |
| | | Stem & Sheath | 329.5 (29) | 146.2 (34) | 857.5 (63) |
| | | Leaf Blade | 247.7 (22) | 41.1 (10) | 308.8 (23) |
| | | Total (Index) | 1,129.3(100) (100) | 424.2(100) (38) | 1,363.0(100) (121) |
| Indica, Pai-mi-fun | High temp. plot | Grain | 647.5 (57) | 265.2 (63) | 253.7 (17) |
| | | Stem & Sheath | 282.3 (25) | 112.5 (27) | 948.4 (65) |
| | | Leaf Blade | 207.1 (18) | 44.7 (10) | 248.5 (17) |
| | | Total (Index) | 1,136.9(100) (100) | 422.4(100) (37) | 1,450.6(100) (128) |
| | Low temp. plot | Grain | 560.3 (58) | 269.1 (64) | 254.4 (20) |
| | | Stem & Sheath | 234.8 (24) | 109.3 (26) | 806.3 (63) |
| | | Leaf Bade | 171.8 (18) | 43.5 (10) | 227.7 (18) |
| | | Total (Index) | 966.9(100) (100) | 421.9(100) (44) | 1,288.4(100) (133) |

## DISCUSSION

Oka: It might be desired to investigate the assimilation rate of plants to find whether or not there are varietal differences in such specific growing characters between the two varieties and between temperature treatments. The method of measuring assimilation rate, so called "growth analysis" was reported in detail by J. Tsunoda (Agr. & Hort, Janan, Vol. 33, 1958)

Hsu: Mr. Chiu and Mr. Wu may adopt the growth analysis method as suggested in future.

Oka: I wonder why the growing periods were so long, especially, in the second crop the maturity in the middle of December. The date obtained could not be applied for explaining of those from field experiments.

Chiu: According to our experiences, pot culture in a glass-house brings about a longer growing period than field culture. I will try to start experiments earlier in future.

Ku: The temperatures in the glass-house, even in the low temperature plot, were higher than those in the field condition. The temperatures in the high temperature plot were extremely high, which might be undoubtedly an abnormal condition for plant growth. The installation of air-conditioner, or water spraying on the roof of glasshouse, would be necessary for realizing field temperatures.

Chiu: Owing to the lack of installations for lowering temperature, we could only

used the present two glass-houses.

Tan: You didn't give any statististical analysis of the data for interpretation, Differences in absorbed nutrients between temperature treatments may be doubtful if no statistical methods are taken.

Chiu: We haven't had enough time. I wish you can help me.

Hsu: Your experiment showed that high temperatures increased dry weights and nutrient absorption, but the absorbed nutrients might be consumed for straw formation leaving little for the production of grains. That is a point of interest in relation to low yield of rice in tropical countries. I hope that more penetrating researchs on the mechanism of yield determination from the view-point of nutriophysiology be carried out.

Chiu: High temperatures are harmful for grain formation in the Japonica variety, Taichung no. 65. However, the Indica variety, Pai-mi-fun appeared to be adapted to higher temperatures. Transmission of absorbed nutrients under high temperatures should be studied.

Hsu: The status of nutrients in soils under different temperatures is also important to be investigated in future.

# b. EXPERIMENTS ON THE DECREASE OF TOTAL AND AMMONIUM NITROGEN IN FLOODED SOILS AT DIFFERENT TEMPERATURES

Tsang-taur Yen

(Laboratory of Soil Science, National Taiwan University)

## 1. Influence of temperature on the decrease of total nitrogen in flooded soils

Fifteen gram samples of the soils of Taipei, Pinchen, Ilan, Yuanlin, Hsinyin, and Pintung-series taken in beakers, were supplied each with 5 mg of ammonium-nitrogen and were flooded. They were then incubated at 10°, 20°, 30°C and at room temperature, and were analyzed for total nitrogen including nitrate-nitrogen at 1-month intervals, for 2 or 4 months. The results are presented in Tables 1 and 2.

The data in Table 1 indicate that the loss of nitrogen is generally large at high temperatures and in soils having high pH-values, and it is rapid in the early period of flooding.

Table 2 shows that the loss of nitrogen in acidic soils increases when they are limed to a neutral pH-value, and that though the loss is generally rapit in the early period of flooding, in the soil of Taipei series, the loss continues longer. It is also found in the table that the loss is larger in the months of the first crop than in those of the second crop and is the least in winter months.

Table 1. The amount of decrease in total nitrogen in flooded soils supplied with 0.33 gr. $NH_4$-N per kgr. soil at 10°, 20° and 30°C (gr. N per Kgr. soil, mean for 8 replications)

| Temperature | 10°C | | 20°C | | 30°C | |
|---|---|---|---|---|---|---|
| Period of flooding (Month) | 1 | 2 | 1 | 2 | 1 | 2 |
| Soil series | | | | | | |
| Taipei | 0.08 | 0.09 | 0.25 | 0.35 | 0.30 | 0.39 |
| Taipei+L | 0.29 | 0.34 | 0.34 | 0.43 | 0.48 | 0.47 |
| Pinchen | 0 | 0.04 | 0.01 | 0.03 | 0.01 | 0.02 |
| Pinchen+L | 0.16 | 0.23 | 0.20 | 0.24 | 0.28 | 0.35 |
| Ilan | 0.10 | 0.14 | 0.25 | 0.29 | 0.28 | 0.36 |
| Yuanlin | 0.23 | 0.26 | 0.26 | 0.33 | 0.33 | 0.40 |
| Hsinyin | 0.06 | 0.09 | 0.09 | 0.14 | 0.15 | 0.20 |
| Pintung | 0.11 | 0.11 | 0.22 | 0.27 | 0.30 | 0.37 |
| Mean | 0.129 | 0.163 | 0.203 | 0.260 | 0.266 | 0.320 |

Remarks: (1) PH-value of the soils:

| Taipei | Pinchen | Ilan | Yuanlin | Hsinyin | Pintung |
|---|---|---|---|---|---|
| 5.6 | 4.6 | 5.8 | 6.8 | 6.8 | 7.0 |

(2) "+L" means liming to pH 7.0.

Table 2. The amount of decrease in total nitrogen in flooded soils supplied with 0.33 gr. $NH_4$-N per Kg. soil, at room temperature in different season (gr. N per Kg. soil, mean of 8 replications)

| Season | 1st crop | | | | 2nd crop | | | | Winter | |
|---|---|---|---|---|---|---|---|---|---|---|
| Period of flooding (Month) | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 |
| Name of month | Apr. | May | June | July | Aug. | Sep. | Oct. | Nov. | Dec. | Jan. |
| Temp. range (°C) | 16-29 | 22-29 | 25-33 | 28-32 | 29-33 | 25-32 | 23-29 | 23-25 | 23-25 | 20-25 |
| Soil series (pH) | | | | | | | | | | |
| Taipei (5.6) | 0.12 | 0.24 | 0.37 | 0.41 | 0.12 | 0.16 | 0.29 | 0.33 | 0.06 | 0.15 |
| Taipei+L (7.0) | 0.40 | 0.49 | 0.56 | 0.59 | 0.26 | 0.39 | 0.50 | 0.51 | 0.28 | 0.40 |
| Ilan (5.8) | 0.26 | 0.36 | 0.45 | 0.48 | 0.37 | 0.31 | 0.43 | 0.44 | 0.18 | 0.20 |
| Ilan+L (7.0) | 0.37 | 0.50 | 0.54 | 0.58 | 0.39 | 0.44 | 0.46 | 0.43 | 0.30 | 0.44 |
| Yuanlin (6.8) | 0.27 | 0.41 | 0.44 | 0.43 | 0.23 | 0.31 | 0.36 | 0.36 | 0.19 | 0.30 |
| Pintung (7.0) | 0.20 | 0.31 | 0.34 | 0.38 | 0.25 | 0.26 | 0.33 | 0.30 | 0.14 | 0.18 |
| Mean | 0.246 | 0.359 | 0.414 | 0.444 | 0.266 | 0.300 | 0.380 | 0.379 | 0.179 | 0.261 |

Remarks: "+L" means liming soil to pH 7.

The principal cause of nitrogen loss may probably be the process of denitrification, as the amount of loss due to the evolution of free ammonia was found to be too small to account for the total amount of loss; nitrification may proceed in flooded soils, and nitrate ion may be readily reduced in them.

## 2. Influence of temperature on the decrease of ammonium-nitrogen in flooded soils

To 30-gm samples of the soils of Taipei, Yuanlin, and Pintung-series, 21 mgr. of ammonium-nitrogen were supplied, and after flooding they were incubated at 10°, 20° and 30°C for 9 weeks. The soils were analyzed for ammonium and nitrate-nitrogen at one-week intervals. The results are shown in Table 3, and the change in the content of ammonium-nitrogen is presented in Figures 1, 2 and 3.

The result shows the following facts:

(1) The content of ammonium-nitrogen decreases in flooded soils.

(2) The decrease is slower in acidic soils of Taipei-and Ilan-series than in those of Yuanlin and Pintung-series which have a neutral pH-value. The application of lime to these acidic soils promotes the decrease.

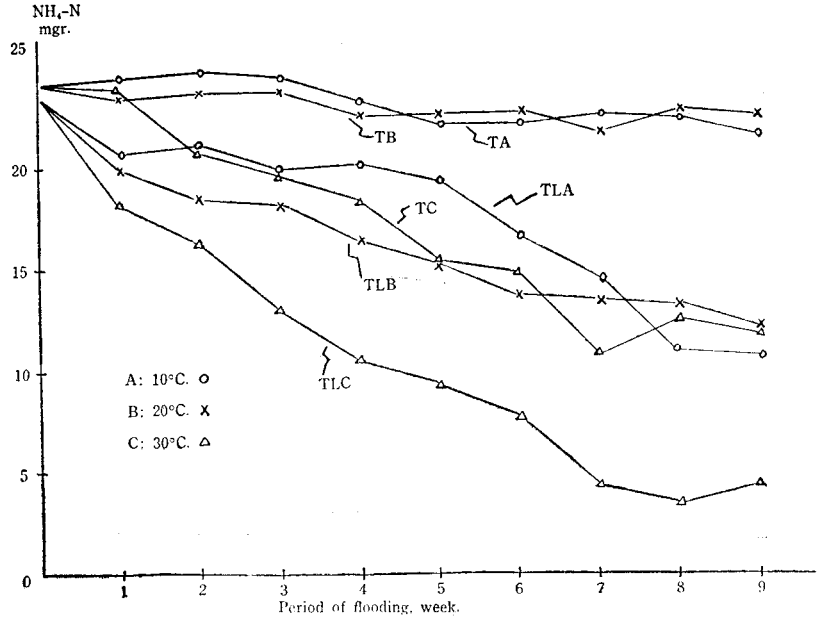
(3) The decrease in the content of ammonium-nitrogen is rapid at high temperature (30°C) while the rate of decrease is about the same at 10° and 20°C.

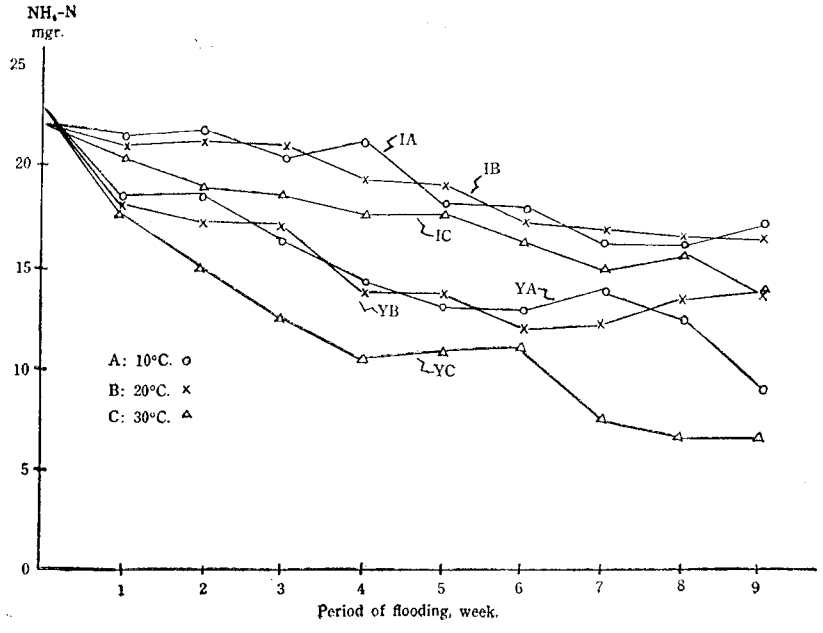
(4) The content of nitrate-nitrogen in flooded soil usuall low, less than 1 mgr. in 30 gr. soil supplied with 21 mgr. ammonium nitrogen. But in the soils of Ilan and Pintung-series some nitrate can be accumulated in the later period of flooding. This indicates that nitrification can proceed even in flooded soils. Thus it is found that the process of denitrification is possible in flooded soils, though nitrate-nitrogen has not been supplied.

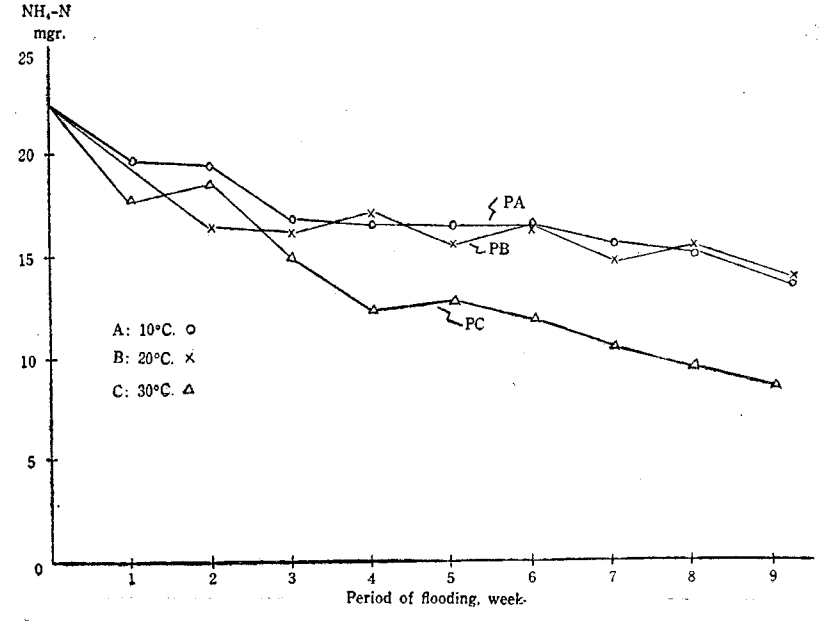
Table 3. Change in the content of $NH_4$-N and $NO_3$-N in flooded soils at 10°, 20° and 30°C (mgr. N in 30 gr. soil)

| Soils eries | | Taipei | | | Taipei+L | | | Ilan | | | Yuanlin | | | Pintung | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temp., °C | | 10 | 20 | 30 | 10 | 20 | 30 | 10 | 20 | 30 | 10 | 20 | 30 | 10 | 20 | 30 |
| | | | | | | | | $NH_4$-N | | | | | | | | |
| Period of flooding (week) | 0 | 24.2 | 24.2 | 24.2 | 23.4 | 23.4 | 23.4 | 22.2 | 22.2 | 22.2 | 23.1 | 23.1 | 23.1 | 22.5 | 22.5 | 22.5 |
| | 1 | 24.5 | 23.6 | 24.5 | 20.8 | 20.0 | 18.1 | 21.7 | 21.2 | 20.5 | 18.7 | 18.1 | 18.2 | 19.7 | 19.5 | 17.9 |
| | 2 | 24.8 | 23.8 | 20.8 | 21.2 | 18.4 | 16.3 | 22.0 | 21.5 | 19.1 | 18.7 | 17.4 | 15.1 | 19.5 | 16.5 | 18.7 |
| | 3 | 24.5 | 23.8 | 19.5 | 19.8 | 18.4 | 13.0 | 20.6 | 21.1 | 18.8 | 16.6 | 17.2 | 12.8 | 16.9 | 16.1 | 15.0 |
| | 4 | 23.2 | 22.6 | 18.2 | 20.1 | 16.3 | 10.5 | 21.5 | 19.5 | 17.8 | 14.5 | 13.9 | 10.8 | 16.6 | 17.1 | 12.3 |
| | 5 | 22.1 | 22.6 | 15.3 | 19.3 | 15.4 | 9.3 | 18.4 | 19.3 | 17.9 | 13.3 | 13.8 | 11.0 | 16.5 | 15.4 | 12.8 |
| | 6 | 22.1 | 22.8 | 14.9 | 16.6 | 13.8 | 7.8 | 18.2 | 18.4 | 16.5 | 13.1 | 12.1 | 11.2 | 16.5 | 16.5 | 11.9 |
| | 7 | 22.6 | 21.7 | 10.9 | 14.4 | 13.4 | 4.2 | 16.6 | 17.0 | 15.1 | 14.0 | 12.3 | 7.7 | 15.4 | 14.7 | 10.5 |
| | 8 | 22.6 | 22.8 | 12.6 | 10.9 | 13.3 | 3.2 | 16.6 | 16.8 | 15.8 | 12.4 | 13.5 | 6.8 | 15.1 | 15.3 | 9.6 |
| | 9 | 21.7 | 22.6 | 11.9 | 10.7 | 12.2 | 4.4 | 17.4 | 17.0 | 14.0 | 10.1 | 14.0 | 6.7 | 13.6 | 13.8 | 8.6 |
| | | | | | | | | $NO_3$-N | | | | | | | | |
| Period of flooding (week) | 0 | 0.6 | 0.6 | 0.6 | 0.7 | 0.7 | 0.7 | 0.1 | 0.1 | 0.1 | 1.3 | 1.3 | 1.3 | 0.7 | 0.7 | 0.7 |
| | 1 | 0.7 | 0.4 | 0.7 | 0.7 | 0.6 | 0.3 | 0.4 | 0.7 | 0.3 | 0.5 | 0.6 | 0.4 | 0.3 | 0.7 | 0.2 |
| | 2 | 0.6 | 0.6 | 0.3 | 0.3 | 0.6 | 0.4 | tr. | 0.6 | 0.8 | 0.8 | 0.3 | 0.7 | 0.9 | 0.6 | 0.7 |
| | 3 | 0.5 | 0.3 | 0.5 | 1.0 | 0.4 | 0.7 | 0.6 | 0.8 | 1.0 | 0.7 | 0.6 | 0.6 | 0.5 | 0.6 | 0.2 |
| | 4 | tr. | 0.4 | 0.5 | tr. | 0.7 | 0.5 | tr. | 0.6 | 1.1 | 0.3 | 0.5 | 0.7 | 0.4 | 0.6 | 0.3 |
| | 5 | 1.2 | 0.5 | 0.2 | 0.5 | 0.2 | 0.6 | 0.2 | 0.4 | 1.1 | 0.4 | 1.1 | 0.5 | 0.4 | 1.4 | 0.4 |
| | 6 | 0.4 | tr. | 0.9 | — | 0.4 | 0.7 | 0.4 | 1.3 | 1.8 | 1.6 | 0.2 | 0.5 | 0.2 | 1.2 | 0.5 |
| | 7 | 0.3 | 0.4 | 0.2 | 0.2 | 0.5 | 0.4 | 1.3 | 2.7 | 4.2 | tr. | 1.5 | 2.2 | 2.5 | 2.9 | 0.5 |
| | 8 | tr. | 0.2 | tr. | tr. | — | 0.3 | tr. | 0.9 | 4.4 | tr. | tr. | 0.5 | 0.2 | 0.4 | 0.4 |
| | 9 | — | 0.7 | 0.2 | 0.5 | 0.4 | 0.5 | 0.2 | 0.5 | 4.2 | 0.4 | 0.2 | tr. | 0.2 | tr. | 2.1 |

Remarks: (1) The soils were supplied with 21 mgr. of $NH_4$-N.
(2) "+L" means liming soil to pH 7.0.




NH4-N
mgr.
25
20
15
10
5
0
IA
IB
IC
YA
YB
YC
A: 10°C. o
B: 20°C. ×
C: 30°C. Δ
1
2
3
4
5
6
7
8
9
Period of flooding, week.


NH4-N
mgr.
25
20
15
10
5
0
PA
PB
PC
A: 10°C. o
B: 20°C. ×
C: 30°C. Δ
1
2
3
4
5
6
7
8
9
Period of flooding, week.

## DISCUSSION

Hsu: Loss of other elements in addition to nitrogen and loss of inorganic nutrients by leaching should also be investigated.

Yen: I am going to carry out a lysimeter experiment for the purpose of investigating nutrient loss in soil leaching solution.

Ku: How is the relationship between nitrogen loss and soil microbes?

Yen: In my experiments, the principal cause of nitrogen loss is probably denitrification which is caused by soil microbes.

Chiu: If the nitrogen loss is caused by denitrification, sterilized soil samples may not show denifrification. Did you make a check plot of sterilized soils to acertain that nitrogen loss in your experiment is due to denitrification?

Yen: I did not try the sterilized soil samples.

Hsu: The loss of nitrogen is increased as temperature gets higher. That is probably one of the causes of low yield of rice in tropical soils.

# c. EXPERIMENT ON THE METHODS OF FERTILIZER APPLICATION UNDER DIFFERENT TEMPERATURES

Kuo-chien Lin and Lan-ti Lee

(Laboratory of Fertilizer Research, TARI)

It is known that yield of rice differs according to the method of fertilizer application, while the effects of different fertilizing methods may differ according to temperatures. Experiments were carried out in order to look into this respect.

## First year experiment

The experiment was made with a Ponlai variety (Taichung no. 65) in two greenhouses, one keeping higher temperatures than the other. Fertilizer treatments were 1) basic application by deep placement, 2) basic application (before transplanting) by surface placement, 3) basic application and top-dressing, 4) basic application of fertilizer ball, 5) basic application of soybean cake and 6) no fertilizer. The rates N, $P_2O_5$ and $K_2O$ were 1.0 0.8 and 0.6 g per plot, respectively. Rice plents were taken at the intervals of 25 days for C/N determination. The results are showen in the Table 1.

Table 1. Effects of fertilizer-application method on agronomic characters of rice under a high and a low temperatures (1959)

Unit: g/pot

| Crop | Temperature | High Temperature | | | | | | Low Temperature | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Treatment | I | II | III | IV | V | VI | I | II | III | IV | V | VI |
| 1st crop | Date of heading | 25/6 | 1/7 | 29/6 | 26/6 | 26/6 | 7/6 | 28/6 | 3/7 | 27/6 | 27/6 | 29/7 | 16/6 |
| | Straw yield | 71.2 | 71.7 | 76.8 | 81.8 | 73.7 | 40.8 | 48.8 | 52.8 | 46.8 | 50.6 | 47.5 | — |
| | Grain yield | 5.9 | 4.2 | 5.3 | 8.2 | 8.0 | 6.7 | 23.4 | 22.2 | 12.8 | 23.3 | 34.1 | — |
| | Sterile grain | 2.3 | 2.7 | 1.7 | 1.0 | 2.0 | 0.8 | 1.1 | 1.1 | 3.2 | 0.9 | 0.5 | — |
| 2nd crop | Date of heading | 4/11 | 2/11 | 30/10 | 3/11 | 4/11 | 13/10 | 7/11 | 8/11 | 4/11 | 3/11 | 7/11 | 25/10 |
| | Straw yield | 46.8 | 42.1 | 47.5 | 50.6 | 52.5 | 33.0 | 57.8 | 53.1 | 43.8 | 50.0 | 50.8 | 37.5 |
| | Grain yield | 26.2 | 27.8 | 28.6 | 37.0 | 28.9 | 26.4 | 24.4 | 24.3 | 14.4 | 22.0 | 23.9 | 19.0 |
| | Sterile grain | 2.1 | 2.2 | 1.9 | 2.1 | 2.9 | 1.2 | 2.8 | 2.4 | 2.8 | 2.4 | 2.9 | 1.4 |

Note: *I. Basic application by deep placement
II. Basic application by surface placement
III. Basic application by top-dressing
IV. Ball fertilizer as base manure
V. Soybean cake as base manure
VI. No nitrogen
** Grain yield represented by the average for 4 replications

Table 2. Effect of temperatures on C/N ratio (1959)

| | | First crop | | | Second crop | | |
|---|---|---|---|---|---|---|---|
| | | Sampling date | High temp. | Low temp. | Sampling date | High temp. | Low temp. |
| 1st | C | 20/4 | 35.840 | 36.910 | 12/9 | 37.420 | 37.560 |
| | N | | 2.979 | 3.411 | | 3.549 | 3.306 |
| | C/N | | 12.3 | 10.9 | | 10.6 | 11.5 |
| 2nd | C | 15/5 | 40.300 | 38.070 | 17/10 | 39.970 | 39.560 |
| | N | | 2.880 | 3.123 | | 2.597 | 2.642 |
| | C/N | | 14.2 | 12.6 | | 16.18 | 16.0 |
| 3rd | C | 9/6 | 43.100 | 43.560 | 11/11 | 40.380 | 42.500 |
| | N | | 1.930 | 1.910 | | 1.761 | 1.810 |
| | C/N | | 22.6 | 23.0 | | 23.5 | 24.2 |
| 4th | C | 4/7 | 40.550 | 41.040 | 4/12 | 41.290 | 40.600 |
| | N | | 1.332 | 1.336 | | 1.504 | 1.543 |
| | C/N | | 31.0 | 30.87 | | 27.8 | 26.8 |
| 5th | C | 29/7 | 40.240 | 40.470 | 18/12 | 40.850 | 40.420 |
| | N | | 1.155 | 1.074 | | 1.277 | 1.411 |
| | C/N | | 34.9 | 38.0 | | 32.4 | 28.9 |

From the results shown in the above tables, it may be said that:

1. The low temperature plot gave higher grain yield than the high temperature plot in the first crop, but in the second crop this relation was reversed.
2. Straw yield was higher in the high temperature plot than in the low temperature plot in the first crop, and in the second crop no significant difference was found.
3. The differences among fertilizer treatments were not significant.
4. C/N ratio increase with the growth, but was little affected by other factors.

## Second year experiment

Two varieties, two kinds of fertilizer (organic manure and chemical fertilizer), two different rates (1 g and 2 g per plot) of nitrogen and two temperature plots were examined in an experiment of factorial design with four replications. The rates of $P_2O_5$ and $K_2O$ were evenly 0.8 g and 0.6 g per plot, respectively. Rice plants were taken at the interval of 25 days for C/N ratio determination. The results are shown in Table 3.

Table 3. Effects of fertilizer application methods on agronomic characters of rice under different temperature (1960)

Unit: g/pot

| Crop | Character | Ponlai Variety (Taichung No. 65) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | High temperature | | | | Low temperature | | | |
| | | I | II | III | IV | I | II | III | IV |
| 1st crop | Date of heading | 22/6 | 22/6 | 29/6 | 24/6 | 24/6 | 26/6 | 4/7 | 30/6 |
| | Straw yield | 63.9 | 74.1 | 88.0 | 74.2 | 46.6 | 48.8 | 81.1 | 65.7 |
| | Grain yield | 24.0 | 26.3 | 34.7 | 28.4 | 24.0 | 26.6 | 35.3 | 35.7 |
| | Sterile grain | 1.0 | 2.0 | 3.0 | 1.7 | 0.3 | 0.6 | 4.1 | 1.7 |
| 2nd crop | Date of heading | 24/10 | 22/10 | 3/11 | 24/10 | 22/10 | 22/10 | 28/10 | 30/10 |
| | Straw yield | 50.0 | 45.0 | 69.3 | 81.3 | 40.0 | 35.0 | 65.6 | 55.6 |
| | Grain yield | 10.1 | 10.9 | 4.9 | 7.2 | 4.5 | 3.6 | 5.1 | 5.6 |
| | Sterile grain | 3.9 | 2.9 | 4.5 | 5.0 | 2.3 | 2.4 | 4.8 | 3.6 |
| Crop | Character | Native Variety (Pai-mi-fun) | | | | | | | |
| | | High temperature | | | | Low temperature | | | |
| | | I | 11 | III | IV | I | II | III | IV |
| 1st crop | Date of heading | 11/6 | 11/6 | 12/6 | 13/6 | 13/6 | 13/6 | 14/6 | 13/6 |
| | Straw yield | 44.5 | 39.6 | 80.4 | 69.7 | 39.8 | 40.5 | 68.1 | 59.1 |
| | Grain yield | 28.4 | 21.0 | 54.1 | 44.6 | 30.6 | 27.5 | 48.7 | 42.2 |
| | Sterile grain | 1.4 | 1.3 | 2.8 | 1.4 | 1.9 | 1.4 | 2.3 | 1.2 |
| 2nd crop | Date of heading | 23/10 | 24/10 | 28/10 | 30/10 | 24/10 | 25/10 | 28/10 | 25/10 |
| | Straw yield | 61.7 | 55.3 | 71.8 | 69.0 | 41.7 | 40.6 | 73.4 | 57.6 |
| | Grain yield | 28.7 | 22.4 | 31.6 | 31.5 | 20.0 | 19.8 | 32.2 | 22.1 |
| | Sterile grain | 4.5 | 2.0 | 3.8 | 4.8 | 1.6 | 1.6 | 4.6 | 3.6 |

Note: I. 2g of N with organic manure
II. 1g of N with organic manure
III. 2g of N with chemical fertilizer
IV. 1g of N with chemical fertilizer

Table 4. Effect of temperature on C/N ratio of plant (1960)

| Crop | | | 1st crop | | | |
|---|---|---|---|---|---|---|
| Temperature | | | High temp. | | Low temp. | |
| Varity | | | Ponlai | Native | Ponlai | Native |
| 1st | 5/4 | C | 35.67 | 34.72 | 36.06 | 36.51 |
| | | N | 2.10 | 1.99 | 2.17 | 1.95 |
| | | C/N | 17.00 | 17.40 | 16.60 | 18.70 |
| 2nd | 30/4 | C | 39.87 | 37.57 | 37.45 | 36.06 |
| | | N | 1.96 | 1.84 | 1.69 | 1.70 |
| | | C/N | 20.30 | 20.40 | 22.20 | 21.20 |
| 3rd | 25/5 | C | 34.95 | 35.72 | 36.73 | 1.36 |
| | | N | 1.25 | 1.22 | 1.56 | 1.36 |
| | | C/N | 28.00 | 29.30 | 23.50 | 26.60 |
| 4th | 19/6 | C | 28.25 | 37.61 | 37.65 | 38.25 |
| | | N | 1.19 | 1.10 | 1.24 | 1.15 |
| | | C/N | 32.10 | 34.20 | 30.40 | 33.50 |
| 5th | 14/7 | C | 37.68 | 37.00 | 38.59 | 38.69 |
| | | N | 0.98 | 0.88 | 0.90 | 0.89 |
| | | C/N | 38.40 | 42.10 | 42.80 | 43.50 |

From the results in the above tables, it may be said that:

1. In the first crop no marked difference in grain yield arose between the high and low temperatures, though, in the second crop, the high temperature plot showed higher yield than the low temperature plot.
2. In the first crop, grain yield was higher in the plots of chemical fertilizers than in those of organic manures.
3. Straw yield in the high temperature plot was higher than that in the low temperature plot.
4. Straw yield in plots of chemical fertilizers was higher than those in organic manure plots.
5. C/N ratio increased with growth, but was little affected by other factors.

Note on the third year experiment:

The third year experiment will be made similarly as in the second year.

## DISCUSSION

Yen: The grain yields in treatment III in the low temperature plot shown in Table 1 are markedly low in both the first and second crops. I wonder why?

Lee: We have no good explanation for this. Perphaps it is due to error.

Hsu: Soybean cake was the only organic nitrogen used in this experiment. It seems necessary to test other kind of organic manures, and to evaluate the effects in relation with the rate of decomposition.

Ku: In the first year, the high temperature plot showed a low grain yield especially in the first crop, but did not in the second year experiment, How is your explanation for this?

Lee: In the first year the high temperature reached so high that the pollination might be affected but in the second year regulation was made to avoid such a failure.

Yen: Please explain the reason for the low yield in the second crop of Ponlai variety in the second year.

Lee: The temperature became too low after the heading stage.

Hsu: Statistical analysis should be conducted.

Lee: Yes, we are doing it now.

Hsu: Temperature of soil layer should be investigated.

# d. STUDIES ON THE DEVELOPMENT OF ROOT SYSTEM AND CARBON ASSIMILATION OF PADDY RICE AS INFLUENCED BY TEMPERATURES.

Chen-Neng Wu

(Laboratory of Plant Physiology, TARI)

The production of rice grain is due to synthetic results of water and mineral absorptions, transpiration, assimilation, respiration and transmission of assimilation product to panicles. Generally speaking, these actions may be promoted with the rise of temperature within the limit of 15°C to 33°C. The mode of temperature changes differ between the two rice seasons of Taiwan; from low to high in the first crop and from high to low in the second crop. It is possible that the high temperatures at the heading stage of first crop and the low temperatures at the heading stage of second crop, reduce yield to some extent.

The present studies were aimed to investigate the root development, the changes in net assimilation rate under changing temperatures and the effect of temperatures on seed sterility.

## Materials and Methods

Taichung No. 65 (Ponlai rice, Japonica type) and Pai-mi-fun (Native rice, Indica type) were used as materials, and the pot culture was applied. The root-examination-boxes were also used in addition to pots.

Each pot, filled with 27 Kgr. of soil which was taken from the experimental field of this Institute, was dressed with 1 gr. of ammonium sulphate, calcium superphosphate and potassium chloride. 30 pots for each variety were set in each plot respectively, so that those were 120 pots in total. The root-examination-boxes, one for each variety, were set in each plot. Three seedlings were planted in each pot and box. The experiments were carried out in a greenhouse divided into two parts, the one with most windows being closed except some pivoted one (taken as the high temperature plot) and the other with wire-windows (taken as the low temperature plot). The difference in night temperature between the two plots was below 1°C.

During the growing period, the pots in each plot were rearranged several times so as to remove the difference in environmental factors among them. Ordinary meteorological measurement and the temperatures of water and soil in pots were recorded six times a day during the growing season. The development of straws and roots, the leaf area and these oven dry weight, were measured at the intervals of 2-weeks, using plants in three pots each time. The rate of carbon assimilation was shown by "Net Assimilation Rate" (NAR) according to the "Growth analysis method". The development of root system was also investigated by using root-examina-

tion-boxes. The dates of transplanting and harvest were shown in Table 1.

Table 1. Dates of transplanting and harvest of two crop seasons

| Plots | Items | 1st crop | | 2nd crop | |
|---|---|---|---|---|---|
| | | Ponlai rice | Native rice | Ponlai rice | Native rice |
| High temp. plot | Transplantation | 10, March | 10, March | 10, August | 10, August |
| | Harvest | 23, July | 5, July | 17, December | 17, December |
| | Total days | 135 | 117 | 129 | 129 |
| Low temp. plot | Transplantation | 10, March | 10, March | 10, August | 10, August |
| | Harvest | 23, July | 5, July | 17, December | 17, December |
| | Total days | 135 | 117 | 129 | 129 |

## Experimental Results

### 1. Effect of temperatures on the plant height and dry weight

It was found that the plant height in the high temperature plot was higher than that in the low temperature plot both in the first and second crops. However, this difference was relatively small in the second crop.

The oven dry weight of plants excluding root, was apparently promoted by high temperature in Taichung No. 65 (Ponlai rice), both in the first and the second crops, but the difference between two plots was relatively small in Pai-mi-fun (Native rice). The difference of dry weight which was measured at harvest time, in Taichung No. 65, in first crop was 1.7 times to that of second crop in high temperature plot, and 2.2 times in low temperature plot. Pai-mi-fun in first crop showed 1.7 and 1.8 times of difference to second crop for respective high and low temperature plots.

### 2. Effect of temperatures on the development of root

In the first crop, the oven dry weight of root in both varieties in high temperature plot was larger than that in the low temperature plot and the difference between two plots was significant. In the seconp crop, no remarkable difference between the two plots was found in both varieties of Pai-mi-fun and Taichung No. 65.

The process of root development between the first and second crop was compared with regard to the temperature effect. No difference in the root weight was found at the early stage of each crop, but from the tillering stage to the heading stage, it was larger in first crop than in second crop both of varieties as well as in the high and low temperature plots, after the heading stage it was larger in second crop than in first crop. The root weight of Pai-mi-fun was generally larger than that of Taichung No. 65 in both high and low temperature plots as well as in the first and the second crops, except that measured near the harvest time in the low temperature plot of second crop.

The changing mode of the "Relative Growth Rate" (RGR) of root as influenced by the change of temperatures through the growing stage was investigated at the

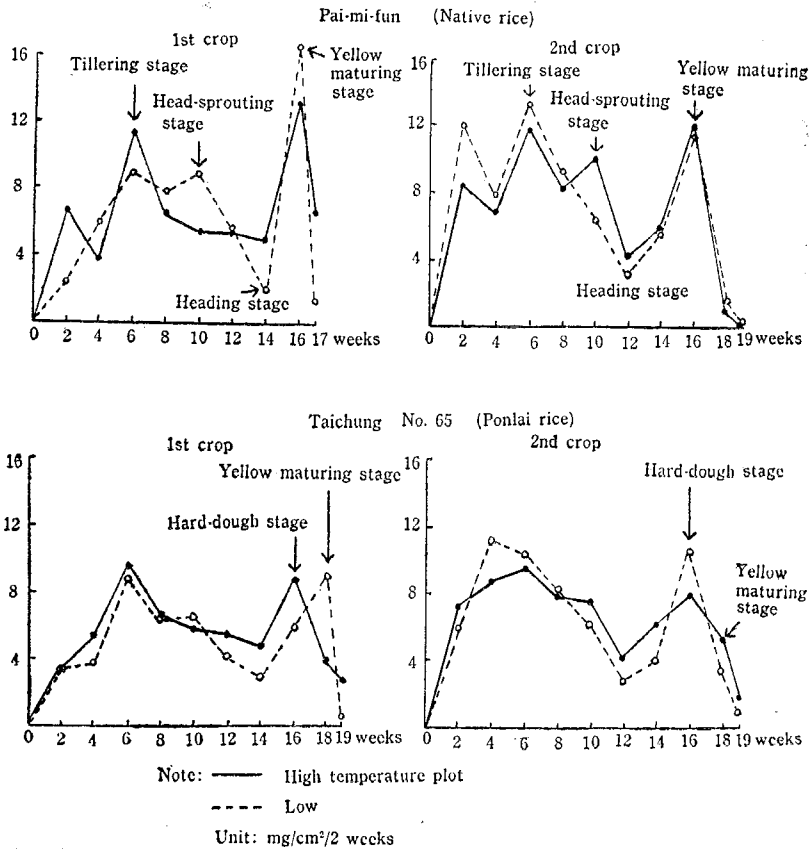
intervals of two weeks. In the first crop, the "Relative Growth Rate" was found to be very high in the first half of growing stage in both varieties of Pai-mi-fun and Taichung No. 65. In the high temperature plot, the highest peak of RGR was seen at the tillering stage. In the low temperature plot, however, two peaks one at tillering stage and the other at head-sprouting stage, in parallel with the rise and drop of temperatures was observed. It may be due to the extremly high temperature at head-sprouting stage which brought about to reduce RGR in the high temperature plot. The sharp drop of RGR at the beginning of heading stage, in the low temperature plot may be affected by the low temperature.

In the second crop, the RGR of the two varieties were larger than that in the first crop. The high RGR was found in the first and the last stage of growth in both varieties. Pai-mi-fun showed three peaks at eary stage (two weeks after transplanting), tillering and yellow maturity stage, while Taichung No. 65, showed two peaks, one at the tillering stage and the other at hard-dough stage. The RGR in the earliest growing stage of high temperature plot of Pai-mi-fun was apparently lower than that in the low temperature plot, because of extremly high temperature. The similar tendency was also found at the tillering stage of Taichung No. 65.

### 3. The changes of "Net Assimilation Rate" (NAR)

The changes of "Net Assimilation Rate" under the different temperatures were also observed at the intervals of two weeks. The results are shown in Fig 1.

Fig. 1. Change of Net Assimilation Rates under different temperatures



As seen in Fig 1, in the first crop, the NAR measured in the head-sprouting stage of the low temperature plot was higher than that of high temperature plot, in contrast to this, relatively high NAR was found in high temperature plot of both varieties in the second crop. It seems that these facts brought the good yield for respective plot of each season.

**4. Effect of temperature on various Agronomic characters**

The various agronomic characters in relation to the temperature effect were observed at maturity. The results are shown in Table 3.

Table 3.

| Crop | Items | Taichung No. 65 | | Pai-mi-fun | |
|---|---|---|---|---|---|
| | | High temp. plot | Low temp. plot | High temp. plot | Low temp. plot |
| 1st crop | Plant height (cm) | 143.0(110) | 130.0(100) | 180.0(111) | 162.0(100) |
| | Number oftillers | 21.0(108) | 19.5(100) | 22.5(105) | 21.5(100) |
| | Total yield (gr/pot) | 117.6(104) | 113.1(100) | 149.7(109) | 137.2(100) |
| | Unripen grain | 3.9(673) | 0.6(100) | 6.3(334) | 1.9(100) |
| | Grain | 27.6 (59) | 46.5(100) | 45.4 (69) | 65.4(100) |
| | Straw | 86.1(130) | 66.1(100) | 98.0(140) | 69.9(100) |
| | Migration coefficient (%) | 20.6 (55) | 37.5(100) | 26.1 (64) | 40.8(100) |
| 2nd crop | Plant height (cm) | 125.7(107) | 117.3(100) | 162.3(101) | 161.0(100) |
| | Number of tillers | 16.8(117) | 14.3(100) | 13.0(100) | 13.0(100) |
| | Total yield (gr/pot) | 69.4(133) | 52.3(100) | 87.5(102) | 85.4(100) |
| | Unripen grain | 0.5 (71) | 0.7(100) | 1.2 (48) | 2.5(100) |
| | Grain | 34.0(152) | 22.3(100) | 43.6(104) | 41.8(100) |
| | Straw | 34.9(119) | 29.3(100) | 42.7(104) | 41.1(100) |
| | Migration coefficient (%) | 37.1(122) | 30.3(100) | 42.2(108) | 39.1(100) |

Note: Migration coefficient were shown by the rate of grain dry weight per total dry weight.

As the data in table 3 show, the growth in dry weight was apparently promoted by high temperature, but the grain yield was not always promoted. In the first crop, the grain yield in the high temperature plot was less than that in the low temperature plot, but in the second crop the high temperautre plot gave higher yield.

As shown in table 3, in the first crop, the coefficient of transmission of assimilation product was apparently lower in the high temperature plot than the low temperature plot, but it was just reversed in the second crop.

Further, the pollination as well as seed setting were greatly obstructed by extremly high temperature of first crop and extremly low temperature of the second crop after the flowering time. The percentage of seed sterility due to temperature effect is shown in Table 4.

Table 4. Comparison of seed sterility between high and low temperature plots

| Crop | Taichung No. 65 | | Pai-mi-fun | |
|---|---|---|---|---|
| | High temp. plot | Low temp. plot | High temp. plot | Low temp. plot |
| 1st crop | 44.48(465) | 9.56(100) | 47.75(402) | 11.89(100) |
| 2nd crop | 12.50 (72) | 17.40(100) | 18.20 (55) | 33.20(100) |

As table 4 shows, in the first crop, the rate of seed sterility in high temperature plot was four times higher than that of low temperature plot, in both varieties. But in the second crop, that of low temperature plots were 28–45 percent higher than high temperature plots.

Further, the native variety, Pai-mi-fun, in the high temperature plot grew many tillers from the node on high position of straw. This also suggested that the transmission of assimilation produdct to panicles was blocked under high temperature of the first crop.

## Consideration

The effect of temperatures on the increase of root dry weight through the growing season was observed in this study. In the first crop (temperature changed from low to high), the development of root was promoted by the temperature but not clear in the second crop (temperature changed from high to low). The "Relative Growth Rate" of root at various growing stages was distinctly affected by the change of temperature. The changing mode of the "Net Assimilation Rate" affected by the change of temperatures, was quite similar to that of RGR of roots. It was found that both the RGR of root and the NAR were relatively high at the head-sprouting stage of the low temperature plot in the first crop and in the high temperature plot of the second crop. It is infered from these facts together with the facts that the water absorption and the nutrient absorption reached the climax at the head-sprouting stage, and brought the good yield for respective plot of each season.

On the other hand, the grain yield was apparently affected by the assimilation after heading, because it had been found by Togari (1954) that the two thirds of starch stored in the panicles were produced after 10 th day of heading. In the first crop, both the RGR of root and NAR during the heading stage in the high temperature plot were higher than that of low temperature plot, and the number of panicle was also more in high temperature plot. Theoretically these phenomena should be beneficial to the production of grain but the low yield was observed in high temperature plot on the contrary. The extremly high temperature after heading apparently obstracted the transmission of assimilation product to panicle and caused high rate of seed sterility may be its important reason. Further in the native rice "Pai-mi-fun" in high temperature plot grew many ineffective tillers from the node of high positions of straw. These ineffective tillers let to make the further drop of the migration

coefficient.

In the second crop, both the RGR of root and the NAR, from the head-sprouting stage till the hard-dough stage were always lower than that under the high temperature, these facts can be considered that the important reasons of the low yield of the second crop. Further, the seed sterility under the low temperature condition were very high, it may be due to both the average and minimum temperatures after head-sprouting stage were lower than 25°C which is the limit of minimum temperature let to increase the sterility. Moreover, the migration coefficient was low, this is also the major cause of the low yield in the second crop.

## DISCUSSION

Hsu: Have you made an experiment on the transmission of synthesized substance in the plant by chemical analysis ?

Wu: It has not been made yet, but the migration coefficient was expressed by the grain/total weight ratio as shown in table 3.

Chiu: You used three replications, but it seem to me not enough.

Wu: Because, the investigations on the leaf area and total dry weight of plant in various plots were quite laborous, if the replication was increased the investigation can not be finished in the same day, so that the records might be uncertainly.

Lin: I would like to suggest you to make chemical analysis by using leaf system to determine the assimilation.

Wu: The growth analysis was used in this experiment instead of chemical analysis. Because to study the process of plant growth in respect to the assimilation rate, the growth analysis method is better than chemical analysis method. For study the growth analysis, it is necessary to investigate the dry weights of straws and roots, and the areas of leaves.

# II. AGRONOMY: STUDIES ON YIELDING CAPACITY OF RICE VARIETIES UNDER HIGH TEMPERATURE

## a. COMPARISON OF FERTILIZER-RESPONSE OF VARIETIES UNDER HIGH AND LOW TEMPERATURE

Tsin-san Miu

(Department of Agronomy, TARI)

Three places at different sea levels, i. e. Taipei (15 M above the sea level) Wu-lai (220 M, 1–2°C lower than in Taipei) and Chu-tsu-fu (660 M, 3–4°C lower than in Taipei) were selected as the sites of the experiment. During 1959, five varieties were planted in pots in order to evaluate the effect of temperatures on fertilizer response. The plants were grown in pots filled with the same soil with the same amount of fertilizers and were investigated. The results of this experiment indicated that Wu-lai, at a relatively low temperature showed the highest yield on the average, while Taipei (high temperature) gave the lowest yield. Chu-tsu-fu being intermediate. In straw yield the highest was Chu-tsu-fu, and at Wu-lai the lowest. In the weight of 1,000 grains the highest was Chu-tsu-fu, and lowest was Taipei, These figures are shown in Table 1.

Table 1. Measurements of three characters of rice grown at different sea-levels

| Sea level | Grain yield (%) | Straw yield (%) | 1,000 grain wt. |
|---|---|---|---|
| 1st crop (1959) | | | |
| 660 M | 109.14 | 111.51 | 25.6 |
| 220 M | 120.02 | 69.51* | 24.1 |
| 15 M | 100.00 | 100.00 | 22.9 |
| 2nd crop (1959) | | | |
| 660 M | 0** | 68.88 | 26.9 |
| 220 M | 105.51 | 97.40 | 26.9 |
| 15 M | 100.00 | 100.00 | 26.3 |

Note: * The low straw yield was due to the infection of rice blast disease.
** No grains were harvested on account of low temperatures in the fall.

In the second crop, Wu-lai showed the highest yield again, Taipei being lower, but no grains could be harvested at Chu-tsu-fu on acount of low temperature in the fall, and all of the grains are sterile.

It was found that the high yield at Wu-lai was related to the large number of effective tillers, and the high 1,000 grain weight. So far as varieties used (Japonica type) are concerned, it seems that a high yield results when the plants were grown

at a relatively low temperature. It was suggested that the relatively low temperatures at Wu-lai may induce a high fertilizer response.

Secondly, for looking into the effect of planting time to heading time, rice seedlings at the age of 15 days were planted at 10-day intervals from June 1 to August 11, 1959. It was found from the results that varieties of the Japonica type were mostly insensitive to photoperiod, though they may be sensitive to temperature. When the varieties were planted so late as on August 11, the yield was nearly normal, though it declined after this date. Taichung No. 65 and Kaoshiung No. 53 showed the lowest photoperiodic sensitivity. In 1960, the comparative test at different sea levels was continued. In addition to three levels of fertilizer treatment, four Japonica and two Indica varieties were used so as to make the experiment more complete. The results are shown in Table 2.

Table 2.

| Sea level | Fertilizer applied | Grain yield (g) (with Index) | Total | Straw yield (g) (with Index) | Total | 1,000 grain wt. | Average |
|---|---|---|---|---|---|---|---|
| 1st crop (1960) | | | | | | | |
| 660 M | (A) 0 | 121.50 (85.60) | 387.8 | 1,179.40 (70.43) | 4881.6 | 25.5 | 24.7 |
| | (B) Normal | 141.90 (100.00) | | 1,674.50 (100.00) | | 24.7 | |
| | (C) 2 times | 124.40 (87.70) | | 2,027.70 (121.00) | | 23.8 | |
| 220 M | (A) 0 | 208.20 (186.30) | 701.5 | 1,200.60 (87.20) | 4,109.5 | 26.9 | 25.9 |
| | (B) Normal | 241.10 (100.00) | | 1.376.30 (100.00) | | 26.0 | |
| | (C) 2 times | 252.20 (104.60) | | 1,532.60 (111.30) | | 24.7 | |
| 15 M* | (A) 0 | 202.90 (106.50) | 570.5 | 890.69 (70.60) | 3,662.4 | 26.8 | 25.9 |
| | (B) Normal | 190.50 (100.00) | | 1,260.70 (100.00) | | 25.8 | |
| | (C) 2 times | 177.10 (92.90) | | 1,511.40 (119.80) | | 25.0 | |
| 2nd crop (1960) | | | | | | | |
| 660 M | (A) 0 | 158.50 (100.60) | 460.5 | 737.50 (66.50) | 3,006.6 | 25.3 | 22.8 |
| | (B) Normal | 157.50 (100.00) | | 1,109.10 (100.00) | | 23.5 | |
| | (C) 2 times | 144.50 (91.70) | | 1,160.00 (104.50) | | 19.5 | |
| 220 M | (A) 0 | 145.20 (55.10) | 687.4 | 437.80 (49.40) | 2,367.8 | 27.6 | 26.8 |
| | (B) Normal | 263.30 (100.00) | | 884.50 (100.00) | | 26.7 | |
| | (C) 2 times | 278.90 (105.90) | | 1,045.50 (118.20) | | 26.0 | |
| 15 M | (A) 0 | 144.90 (61.60) | 650.2 | 449.90 (63.30) | 2,103.0 | 25.8 | 25.8 |
| | (B) Normal | 235.00 (100.00) | | 710.30 (100.00) | | 26.1 | |
| | (C) 2 times | 270.30 (115.00) | | 942.80 (132.70) | | 25.4 | |

* Lower yield due to the damage of stem borer.

From the results shown above, we find that the grain yield in both first and second crops was again highest at Wu-lai due to the greater number of effective tillers and higher 1,000 grain wt.. The fertilizer response is then more effective at Wu-lai where the temperature is 1–2°C lower than Taipei.

After 2 year's research, we also find that the varieties of cultivated rice in Taiwan seem to be more adapted to the lower temperature condition as at the place of 220 M over the sea level, and is not so tolerate high temperature on the plain. Thus it should be better to use tropical varieties (as Southern Island system) as one of the parents during cross-breeding in order to make new system of Ponlai varieties to raise the yielding capacity of rice varieties in this Island.

## DISCUSSION

Oka: Your experiment has been made in pots. I think you can do the same experiments in the field.

Miu: Yes, I can. In order to eliminate the difference in soil, pot culture was used. After the pot experiments is over, field experiments will be carried on as suggested.

Oka: Five varieties used are almost the same in agronomic characters. You had better use varieties possessing different agronomic characters so as to evaluate varietal differences.

Miu: Yes, we will do in the next year.

# b. RESEARCH ON THE AGRONOMIC MERIT OF PHOTO-SENSITIVENESS IN RICE

Yun-te Yao

(Laboratory of Plant Physiology, National Taiwan University)

## 1. Comparitive studies of critical day-lengths in photosensitive rice varieties

A number of photosensitive rice varieties were grown in the second crop season of 1960 with five photoperiods, namely 12.0, 12.5, 13.0, 13.5, 14.0 hours, to investigate their critical photoperiods.

The results obtained show that 38 out of 63 varieties had their critical photoperiods between 12.0 and 12.5 hours, 12 between 12.5 and 13.0, 2 between 13.0 and 13.5, 5 between 13.5 and 14.0. The remaining 6 varieties showed no significant difference among the above-mentioned photoperiods. Previous records showed that when grown under 9-hour photoperiod, these 6 varieties had a significantly earlier heading-date than those grown under a 24-hour photoperiod. Since these varieties have been proved sensitive to photoperiod, their critical photoperiod may be between 14 and 24 hours.

The critical day-length has been found to vary with the temperature in some plant species. Experiments will be carried on in this year to investigate whether such a variation in critical daylength is also found in rice.

## 2. Studies on various agronomic characters in relation to growing seasons, growing periods and the amount of mineral nutrients

The varieties used in this experiment was Taitung No. 24, a photosensitive "Ponlai" rice.

Before starting the short-day treatment, all plants were grown under a long-day condition (16-hours). Thus delaying floral initiation, the vegetative growth could be continued irrespective of the seeding season. A short-day treatment of 9 hour-day was then made in each of three seeding-season groups (seeded on June 10 and there after at the intervals of 30 days) with the seedlings at the age of 30, 45, 60 and 75 days. The treatment was continued to heading.

At the advent of treatment, the flower primordia were initiated in the growing point immediately. Panicles appeared after continuing the treatment for about 40 days if the temperature and other environs were suitable.

Mixture in four different dosages of chemical fertilizers were applied in order to evaluate the effects of growing seasons, and growing periods on fertilizer response and yield. The fertilizers were used at a 15-day interval from the day of seeding to the beginning of short-day treatment, but since then was not used. Thus the longer

the days of vegetative growth was, the larger was the amount of fertilizer applied.

Results of this experiment may be summarized as follows:

1) Temperature had a significant effect on heading date. The number of days from the beginning of treatment to heading was markedly prolonged if the treatment was started later than August 24. Too late floral initiation also decreased the amount of yield.

2) Fertilizers had a little effect on the number of days of growing period. Within a certain limit of temperatures, the amount of fertilizers showed positive correlations with plant height, effective number of tillers, panicle length, panicle weight, grain number per panicle, panicle weight per plant, and straw weight. Percentage of seed setting and weight of 1000 grains showed a negative correlation with the amount of fertilizers.

3) The measurements of these agronomic characters varied with the number of days of growing period. When the duration of growing period was less 95 days, it showed positive correlations with plant height, effective number of tillers, length and weight of panicle, number of grains per panicle, and panicle weight per plant. If the duration was longer than 95 days, however, negative correlations were found, with the increase of growing period from 95 days to 105 days, dry weight of straw increased. Panicle weight per plant also showed the same tendency. Although the grain and straw yield increased with the increase of growing period, the increase in straw weight was not proportional to that in grain weight and the former often gets more than the latter. Therefore, the relation between growing period and grain straw ratio was negative.

4) It may be emphasized that growing season and growing period are important factors which modity fertilizer response and yielding.

## DISSCUSSIONS

Oka: Is the purpose of this experiment genic analysis?

Yao: Not only the genic analysis, but I have studied varietal variation in photosensitiveness of rice as in my previous experiment. I used an index number to express photosensitiveness which was denoted by a formula, $a/a+b$ (where "a" represents the days of growing period needed for heading under a long-day condition, and "b" represents those under a short day condition). For instance, when $a/a+b \geq 0.5$, the plant was taken to be photosensitive. Using this standard, I observed 185 varieties collected from various districts of the world with regard to photosensitiveness. I found that photosensitiveness can be classified into three groups.

Oka: How about the definition of photosensitivity? We can't gain a clear definition of photosensitivity from the index.

Yao: The effect of temperature and photoperiodism could be estimated in some varieties which showed no heading in the first crop and headed only in the second crop. This phenomenon might be related to temperature and photoperiodism.

# c. CHANGE OF GENOTYPES OF THE HYBRID POPULATIONS IN RESPONSE TO FERTILIZER AND OTHER ENVIRONMENTAL FACTORS

Chuan-in Chao

(Cytogenetics Laboratory, National Taiwan University)

In this study, the following two hybrid combinations have been used,

1) Nungling No. 11×Century Patna No. 52
2) Taipei Black Glumes×Chianungyu No. 280

After the $F_3$ seeds of each of the two hybrid combination were throughly mixed, they were divided into 12 equal portions for planting in three different localities, namely Pintung, Taichung, and Taipei. From agricultural point of view, these three localities represent three marked regions in Taiwan. In each of the three localities two crop of rice are grown. Each of the two crops is applied with two different levels of fertilizer, one at the conventional rate (80 N, 40 $P_2O_5$, 40 $K_2O$ kg/ha) and the other at double rate (160 N, 80 $P_2O_5$, 80 $K_2O$ kg/ha). Thus, there are 12 treatments for each of the two hybrid combinations, making a total of 24 treatments in all. Seeds obtained from each of the twenty four treatments are kept separate. But seeds of each individual treatment are throughly mixed and a portion of which taken at random is used for planting of next crops. This will be continued until $F_5$ or $F_6$ generation. Comparisons of various agronomic characters among different treatments shall be made from a number of ecotypes of $F_5$ or $F_6$ generation of each treatment.

In the past two years, $F_3$ and $F_4$ generations were obtained in the seasons of first crop and second crop. For the purpose of making preliminary studies, 100 such $F_3$ plants of the first crop from Taipei region were taken at radom and their height and number of tillers were measured. The results are given in Table 1.

Table 1. Mean of plant height and number of tillers of the $F_3$ plants grown at different levels of fertilizer

| Hybrid combination | Characters | Fertilizer level | |
|---|---|---|---|
| | | Double rate | Conventional rate |
| Nungling No. 11 × Centary Patna No. 52 | Number of tillers | 8.70 | 7.26 |
| | Height of plant in cm | 95.71 | 97.82 |
| Taipei Black Glume × Chianungyu No. 280 | Number of tillers | 9.77 | 8.87 |
| | Height of plant in cm | 107.41 | 110.74 |

From the above table, it can be seen that the plant height was taller in the individual plants of those populations which received conventional rate of fertilizer than those received double rate. But their number of tillers was smaller in the former than in the latter. These hold true for both hybrid combinations.

Means of plant height and of tiller number were also measure from 100 $F_4$ plants of the second crop from Taipei region. They are presented in Table 2.

Table 2. Mean of plant height and number of tillers of the $F_4$ plants grown at different levels of fertilizer

| Hybrid combination | Characters | Fertilizer level | |
|---|---|---|---|
| | | Double rate | Conventional rate |
| Nungling No. 11 × Centary Patna No. 52 | Number of tillers | 5.81 | 5.62 |
| | Height of plant in cm | 86.70 | 79.77 |
| Taipei Black Glume × Chianungyu No. 280 | Number of tillers | 7.06 | 7.14 |
| | Height of plant in cm | 100.98 | 95.90 |

From the above figures it may be seen that the plant height was shorter in individual plants of those populations received conventional rate of fertilizer than those received double rate of fertilizer. No difference in tiller number between the populations received different rate of fertilizer was observed in both hybrid combinations.

The differences in plant height and tiller number among plants from populations of same generation but received different rate of fertilizer and between the $F_3$ and $F_4$ generations could be due to hereditary as well as environmental factors.

## DISCUSSION

Oka: Number of samples taken from $F_3$ or $F_4$ generation and method of analysis of the results seem to be very important.

Miu: According to Dr. Chao's original design, we would not make final test until $F_5$ or $F_6$ generation from which about 50-100 random samples will be taken from each treatment for comparison of various agronomic characters under different condition.

Hsieh: Blast disease could be very serious in those populations received double rate of fertilizer. If so, other agronomic characters would be affected.

Miu: So far we have not met serious blast disease in our experimental field. If so, ceresan-lime would be used.

# III. PLANT PATHOLOGY

## a. INVESTIGATION OF PHYSIOLOGICAL RACES OF THE BLAST FUNGUS

Chang-shiung Hung and Chin-chung Chien

(Department of Plant Pathology, TARI)

### 1. Isolation and culture of rice blast fungus

In order to demonstrate the existence of physilogical races of blast fungus, which is assumably an important factor that leads the resistance of a variety to differ in different localities, 151 cultures of *Piricularia oryzae* were isolated from diseased plants of various rice varieties collected from Kaoshung, Chiayi, Taichung, and Iran areas in 1959. The cultures were primarily classified into seven groups according to the coloration substrate, spore formation and other cultural characteristics of colonies. No sporulation was found in some cultures. The cultures which appeared to be more stable were selected for single-spore isolation. They were classified into four distinct groups on the basis of their morphological characteristics as shown in Table 1. In addition to these, two cultures, G-2, G-7, were isolated from diseased weeds collected from a field near our Institute. The cultural characteristics of G-2 were similar to those of Group 4, while G-7 differed from any of the four groups.

Table 1. Characteristics of the groups of isolates of *Piricularia oryzae*

| Group | Colony appearance | | Isolate No.* |
|---|---|---|---|
| | colour of colony | aerial hyphae | |
| 1 | dark-green | 2 mm height, abundant | 886, 111, K67 |
| 2 | white | 1 mm height, sparse | 891, 1155 |
| 3 | brown-grey | 1-1.5 mm height, velvet | 288, 1134 |
| 4 | grey-green | 1 mm height, rather abundant | 1127, 1124, 529 |

| * Isolate No. | Original variety | Place of collection |
|---|---|---|
| 886 | Taichung line No. 33 | Chiayi |
| 111 | Chianung No. 242 | Kaoshung |
| K67 | Chianung No. 242 | Kaoshung |
| 891 | Cutsugulcule | Chiayi |
| 1155 | Chianung No. 242 | Tungshu Taichung |
| 233 | Taichung line No. 33 | Chiayi |
| 1134 | Kwang-Fu No. 1 | Tungshu Taichung |
| 1129 | Kwang-Fu No. 1 | Tungshu Taichung |
| 1124 | Kwang-Fu No. 1 | Tungshu Taichung |
| 529 | Kwang-Fu No. 1 | Tungshu Taichung |

Some isolates showed different reactions to temperatures, nutrients in medium and pH values, as shown in Tables 2, 3 and 4.

Table 2. Cultural characteristics upon rice-polished agar medium of *Piricularia oryzae* influenced by temperature

| Isolate | Temperature | | | | |
|---|---|---|---|---|---|
| | 13°C | 19°C | 25°C | 28°C | 34°C |
| 886 | d. 42 mm, black-green, hyphae radial | d. 60.5 mm, black-green, hyphae radial | d. 69 mm, black-green, hyphae radial | d. 84.5 mm, black-green, hyphae radial | d. 10.7 mm, black-green, hyphae radial |
| 891 | d. 50.3 mm, white, hyphae minute | d. 69.2 mm, white, hyphae minute | d. 75 mm, white, hyphae minute | d. 84.0 mm, white, hyphae rather sparse | d. 11.5 mm, white, hyphae rather sparse |
| 288 | d. 45.5 mm, grey-brown, hyphae velvet | d. 63.3 mm, grey-brown, hyphae velvet | d. 69.5 mm, grey-brown, hyphae velvet | d. 83.5 mm, grey-brown, hyphae velvet | d. 10.9 mm, grey-brown, hyphae velvet |
| 1124 | d. 43.5 mm, green-gray, with a rim of 0.5 cm wide white hyphae | d. 63.1 mm, green-gray, with a rim of 0.5 cm wide white hyphae | d. 68.9 mm, green-gray | d. 81.5 mm, green-gray | d. 10.9 mm, green-gray |
| G-7 | d. 29.5 mm, grassy-green, center rather dark | d. 45.5 mm, grassy-green, center rather dark | d. 51.0 mm, grassy-green, center rather dark | d. 58.5 mm, grassy-green, center rather dark | d. 5.1 mm, grassy-green, center rather dark |

Note: 1. 10 days culturing.
2. "d" represents the diameter of colony.

Table 3. Influence of nutrient on the growth of *Piricularia oryzae*

| Isolate No. | Media | | | |
|---|---|---|---|---|
| | Rice-polished Agar | Sorghum-agar | Czapek-agar | Corn-meal-agar |
| 886 | 7.5×7.5 cm, black-green, hyphae radial | 7.9×7.9 cm, black-green, hyphae radial | 6.0×6.5 cm, black-green, hyphae rather sparse | 7.0×7.0 cm, grey-green |
| 891 | 9.0×8.9 cm, white | 9.0×9.0 cm, white | 6.0×6.5 cm, grey-white hyphae sparse | 8.0×9.0 cm, white |
| 288 | 8.5×8.0 cm, grey-brown, hyphae fine velvet | 8.9×8.5 cm, grey-brown, hyphae fine velvet | 7.8×6.5 cm, grey-brown, hyphae rather sparse, coarse | 8.0×7.5 cm, light-brown, hyphae sparse |
| 1124 | 8.5×8.5 cm, grey-green, with a rim of 0.5 cm wide white hyphae | 8.0×7.5 cm, grey-green, with a rim of 0.5 cm wide white hyphae | 6.0×6.0 cm, deep-grey-green, hyphae rather coarse | 8.0×8.0 cm, with a rim of 0.5 cm wide white hyphae |
| G-7 | 6.0×6.0 cm, grassy-green, with a rim of 1 cm wide white hyphae | 6.5×6.5 cm, grassy-green, with a rim of 1 cm wide white hyphae | 5.0×5.0 cm, grassy-green, with a rim of 1 cm wide white hyphae | 6.0×6.0 cm, grassy-green, with a rin of 1 cm wide white hyphae |

Note: The fungi were cultured at 28°C for 2 weeks.

Table 4. Influence of pH values upon cultural characteristics of *Piricularia oryzae* (On Czapek agar at 28°C)

| Isolate | pH value | | | | |
|---|---|---|---|---|---|
| | 4.5 | 5.5 | 6.5 | 7.5 | 8.5 |
| 886 | 4×4.5 cm, dark-olive, center rather dark, rim few hyphae | 4.8×4.5 cm, dark-olive, center rather dark, rim few hyphae | 5.3×5.3 cm, dark-olive, hyphae rather coarse, center rather dark, rim few hyphae | 5.0×5.2 cm, dark-olive, hyphae rather coarse, center rather dark, rim few hyphae | 4.2×4.0 cm, dark-olive, hyphae gery coarse, center rather dark, rim few hyphae |
| 891 | 6.2×6.0 cm, white-grey, hyphae minute | 5.8×6.0 cm, white-grey, hyphae minute | 5.6×5.8 cm, white-grey, hyphae minute | 5.5×5.3 cm, white-grey, hyphae minute | 5.0×5.0 cm, grey-brown, aerial hyphae velvel, fine |
| 288 | 5.0×5.2 cm, grey-brown, aerial hyphae velvet, fine | 5.6×6.0 cm, grey-brown, aerial hyphae velvet, fine | 6.5×6.5 cm, grey-brown, aerial hyphae velvet, fine | 5.5×5.5 cm, grey-brown, aerial hyphae velvet, fine | 5.0×5.0 cm, grey-brown, aerial hyphae velvet, fine |
| 1124 | 4.5×4.5 cm, green-grey, with a rim of 0.5 cm wide white hyphae | 5.2×5.2 cm, green-grey, with a rim of 0.5 cm wide white hyphae | 5.0×5.0 cm, green-grey, with a rim of 0.5 cm wide white hyphae | 5.0×5.0 cm, green-grey, with a rim of 0.5 cm wide white hyphae | 5.0×5.0 cm, green-grey, with a rim of 0.5 cm wide white hyphae |
| G-7 | 5.5×5.5 cm, grassy-green | 4.5×4.5 cm, grassy-green, outer hyphae rather coarse | 4.0×4.3 cm, rather deep, grassy-green | 3.3×3.3 cm, grassy-green, aerial hyphae rather coase | 2×2.5 cm, grassy-green |

Note: 10 days culturing.

## 2. Reactions of sixteen standard varieties of rice to "rice blast" pathogenes

### (*1*) *Inoculum Supply*

Spore inocula used for inoculation were obtained from the culture of rice grain medium. The fungi performed a certain amount of vegetative growth but formed few conidia. This phenomenon may be due to the inhibitiory action of ammonia produced by the fungi as staling product, as reported previously. Then in order to improve this situation, airiation equipments were employed. After 9-10 days culture at 25°C, the conidia were gathered from the substrate by washing the whole culture in distilled water and spore suspension containing a large quantity of conidia was obtained by this method the amount of conidia was increased for example, in isolate 886, from the initial 1,600 per ml. to 870,000 per ml. The sporulation was affected by temperatures. Isolate 886 produced less than 1,000 per ml. at temperatures bellow 20°C. When the temperature was higher than 30°C, it showed relatively fine vegetative growth but little sporulation and produced less than 10,000 spores per ml.

Proper infection may occur by the application of spore suspension which contains spores at the rate of 50 million per sq. ft or more. Spore suspensions were prepared from various isolates, and they were adjusted so as to keep the same density of

conidia, because an excessive amount of conidia in suspension will induce a severe infection and make the observation difficult.

(*2*) ***Inoculation***

In order to identify physilogical races of *Piricularia oryzae*, seedlings of sixteen standard varieties of rice were inoculated with the spore suspensions in a greenhouse. After the inoculation the plants were placed in a chamber with controlled humidity and temperature for 12 to 24 hours. Investigation was made as soon as the infected leaves could be distinquished, usually 4 to 9 days after inoculation.

The isolates used and their origines are as follows:

| Isolate No. | Original variety | Place of collection |
|---|---|---|
| 529 | Kwang-fu No. 1 | Tungshu, Taichung |
| 886 | Taichung Line No. 33 | Chiayi |
| 891 | Custugulcule | Chiayi |
| 1124 | Kwang-fu No. 1 | Tungshu, Taichung |
| 1127 | Kwang-fu No. 1 | Tungshu, Taichung |
| 1125 | Chianung No. 242 | Tungshu, Taichung |

Infection types were determined according to the following varietal reaction types:

S: (Susceptible): Characterized by a rapid enlargement of large and spindle-shaped lesions.

The color of lesion center was grey, being rimmed by a brownish colored inner edge, and also surrounded by a yellow-brownish outer edge. Small lesions of acute infection type as the whole grey in colour, also belonged to this type.

M: Various types of brown lesions, slowly expanding, restricted in size.

R: (Resistant): Infection is readily established but the lesion remain as black-brown flecks on the leaves.

I: (Immune): No lesions appear.

Reactions of sixteen rice varieties to the isolates used are shown in Table 5.

Comparing the reactions of sixteen rice varieties, five kinds of isolates could be distinguished. They were designated as A, B, C, D, E types and were considered to be different physiological races. They are described as follows:

(A) The isolate 886 gave the most serious infection to eight rice varieties, i. e, Taichung No. 65, Kun-shau-wu-shan-ken, Chianung No. 242, Custugulcule, Chianung-yu 280, Taichung No. 171, Taichung Line No. 33, Kwan-fu No. 1. Kaoshung Ta-li-chen-yu, Nung-lin No. 21, and Sensho appeared to be immune, while other varieties, Kao-chio-lin-chou, Pai-kan-tao, Taichung-ti-chio-chien, Natala were moderately susceptible to this isolate.

(B) The isolate 1127 gave the second serious infection to the test varieties. Four rice varieties, Taichung No. 65, Kun-shan-wu-shan-keng, Custugulcule, Nung-lin No.

Table 5. Reactions of sixteen Standard varieties of rice to seven isolates of rice blast pathogen

| Variety | Isolate | | | | | | |
|---|---|---|---|---|---|---|---|
| | 529 | 886 | 891 | 1124 | 1127 | 1155 | G-11 |
| Taichung No. 65 | M | S | M | I | S | I | I |
| Kao-chio-lin-chou | I | M | M | I | M | I | I |
| Kun-shan-wu-shan-keng | R | S | S | M | S | M | I |
| Kaoshung-ta-li-chen-yu | I | I | I | I | I | I | I |
| Pai-kan-tao | I | M | I | I | I | I | I |
| Kanto No. 51 | I | I | I | I | I | I | I |
| Chianung-yu No. 280 | I | S | I | I | I | I | I |
| Taichung No. 171 | I | S | I | I | I | I | I |
| Taichung Line No. 33 | I | S | I | I | I | I | I |
| Kwang-fu No. 1 | I | S | I | I | I | I | I |
| Chianung No. 242 | I | S | I | I | I | I | I |
| Custugulcule | R | S | I | I | S | I | I |
| Taichung-tichio-wu-chien | I | M | I | I | Sr | I | I |
| Nung-lin No. 21 | I | I | I | I | S | I | I |
| Sensho | I | I | I | I | I | I | I |
| Natala | M | M | I | I | M | I | I |

Note: Temperature 28°C.

21, were susceptible to this. Taichung-ti-chio-wu-chien, also showed susceptible reaction. Natala and Kao-chio-lin-chou showed the same intermediate reaction as that found after the inoculation with (A) race. All other test varieties showed immune types to this race.

(C) The isolates 1,124, 1,155 showed the weakest infecting ability to the test varieties. Only Kung-shan-wn-keng showed medium degrees of reaction, while all other fifteen test were immune.

(D) The isolate 891 gave a weak infection to the test varieties, Kung-shan-wu-shan-keng was susceptible to this isolate and Taichung No. 65 and Kao-liu-chou were moderately susceptible, while all other test varieties were immune to this race.

(E) The isolate 529 gave the weaker infection. Even Kung-shan-wu-shan-keng, the most susceptible variety, showed a resistance. Custugulcle was also. Natale and Taichung No. 65 were intermediate, while all of others test varieties were immune.

### (3) *Differential reactions of rice varieties affected by temperatures*

In order to find the effect of temperatures on the inoculation reaction of rice varieties, the inoculation trial were made under different temperatures. The result are shown in Table 6.

As Table 6 shows, the reaction of rice varieties to the isolates seems to be modified by temperatures. At 25°C, Kaoshung-ta-li-chen-yu Kanto 51 and Nung-lin No. 21

Table 6. Reactions of test rice varieties to four isolates of blast pathogen under different temperature

| Variety | Isolate No. | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 886 | | K67 | | 891 | | G-7 | |
| | 25°C | 20°C | 25°C | 20°C | 25°C | 20°C | 25°C | 20°C |
| Taichung No. 65 | S | I | S | I | R | R | I | I |
| Kao-chio-liu-chou | S | M | S | S | I | I | I | I |
| Kun-shan-wu-shan-keng | S | S | S | S | I | I | I | I |
| Kaoshung-ta-li-chen-yu | R | R | S | M | I | I | I | I |
| Pai-kan-tao | S | I | S | S | I | I | I | I |
| Chianung-yu No. 280 | S | S | M | M | R | R | I | I |
| Kanto No. 51 | R | I | M | I | I | I | I | I |
| Taichung No. 171 | S | I | R | R | I | I | I | I |
| Taichung Line No. 33 | S | R | I | I | I | I | I | I |
| Kwang-fu No. 1 | S | I | M | M | I | I | I | I |
| Chianung No. 242 | S | I | M | R | R | I | I | I |
| Custugulcule | S | I | M | R | I | I | I | I |
| Taichung-tichio-wu-chien | S | I | S | S | R | I | I | I |
| Nung-line No. 21 | R | R | S | S | I | R | I | I |
| Sensho | M | I | M | M | I | R | I | I |
| Natala | S | R | M | S | R | I | I | I |
| Weeds | I | I | I | I | I | I | I | I |

| Isolate No. | Original variety | Place of collection |
|---|---|---|
| 886 | Taichung line No. 33 | Chiayi |
| K-67 | Chianung No. 242 | Kaoshung |
| 891 | Cutsugulcule | Chiayi |
| G-7 | Weed | Taipei |

were resistant. Sensho was moderately resistant, and all other test varieties were susceptible to isolate 886. At 20°C however, only Kun-shan-wu-shan-keng was susceptible, and Taichung No. 65 and other seven varieties were resistant or immune. It is apparent that the infection ability of isolate 886 decreases at low temperature. The reaction of test varieties to the isolates K67 and 891 however, showed small differences between the temperature treatments.

## DISCUSSION

Hsu: What is the object of your experiment?

Hung: The prevalence of blast disease in Taiwan markedly differ from year to year. Besides environmental factors, physiological races in the pathogene may also play an important role in this phenomenon. The number of races, the relation between their occurrence and environment, and the reaction of rice varieties to different races should be investigated. These have been our main object of experiment.

Oka: When two or more races were inoculated in mixture, different races may compete each other. Such may be a method of study if the races can be distinguished from each other by some characteristcs. How do you think about that?

Hung: I think it is a very good idea.

Wu: The prevalence of blast disease is closely related to the chemical component, of rice plants. I think you should make chemical analysis of rice plants.

Hung: Yes, but owing to limited activity, this line of study cannot be done at this time.

Hsu: How about the optimum temperature for the growth of blast pathogenes?

Hung: Usually 28°C.

Hsieh: Pathogenic races which attack leaves may differ from those for neck and node blasts. Have you conducted any such experiment to clarify this point?

Hung: We don't know yet whether the blast pathogen on leaves is the same as that on neck and node. We are isolating single spore cultures from different parts of plant to answer this problem.

Ku: In wheat, pathogenic reactions to seedlings and adult plants are different how about the blast disease in rice.

Chien: It's different.

Oka: How about the statistical methods to look into the physiological races?

Hung: It is to be tried in our future studies.

# b. SURVEY OF INTERVARIETAL VARIATION IN THE RESISTANCE TO BLAST DISEASE

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## 1. Varietal difference in blast resistance

119 Cultivated rice varieties and 204 wild or "primitive" strains from tropical and sub-tropical Asian countries collected by Dr. H. I. Oka, and various mutants induced by irraditions, were planted in an experimental field at Tun-shu, Taichung prefecture, where natural infection occurs in both the first and the second crop seasons. The degree of damage by leaf blast was graded into 12 classes on the basis of the proportion of lesion area to total leaf area.

### (*1*) *Experiment with cultivated varieties collected from various Asian countries.*

The varieties tested varied in a wide range of resistance as shown in Table 1.

Table 1. Variation in blast resistance of varieties from different countries

| | Localities | Disease index Number | | | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 8.5 | 8.8 | 9 | |
| 1st crop 1959 | Indochina | 5 | 5 | | | | | | 1 | | | | | 11 |
| | India & Siam | 10 | 6 | | | | | | 1 | | | | | 17 |
| | Celebes | 1 | 3 | 2 | | 1 | | | 1 | | | | | 8 |
| | Indonesia | 1 | 2 | 1 | | | 1 | 2 | | | | | | 7 |
| | Philippines | 3 | 6 | | | | 1 | 2 | 1 | | | | | 12 |
| | Formosa (Native) | 4 | 2 | | 2 | 1 | | | 1 | | | | | 10 |
| | Formosa (Ponlai) | | | | | | | 1 | 5 | 4 | | | | 10 |
| | China mainland | 1 | 5 | 1 | | 1 | | | 2 | 4 | 1 | | | 15 |
| | Japan | 1 | 1 | | | 1 | 2 | | 4 | 2 | | | | 11 |
| | Indochina | 12 | 1 | | | | | | 1 | | | | | 14 |
| 1st crop 1960 | India & Siam | 11 | 2 | 1 | | | 1 | 2 | | | | | | 17 |
| | Celebes | 4 | 2 | | | | | | 1 | | | | | 7 |
| | Indonesia | 4 | 2 | | | | | | | 1 | | | | 7 |
| | Philippines | 3 | 2 | | | 1 | 3 | | | | | | | 9 |
| | Formosa (Native) | 6 | | 1 | | 2 | 2 | 1 | | | | | | 12 |
| | Formosa (High land) | 4 | | | | | | 2 | | | | | | 6 |
| | China mainland | 15 | 1 | 2 | | | 1 | 2 | 3 | 5 | | | | 29 |
| | Japan | 1 | 1 | | | 2 | 1 | 1 | 1 | 2 | | | | 9 |
| 2nd crop 1960 | Indochina | 2 | 4 | 3 | 1 | 3 | 1 | 1 | 1 | | 1 | | | 17 |
| | India & Siam | 1 | 2 | 3 | 1 | 2 | 2 | 1 | 3 | | | | 1 | 16 |
| | Celebes | | 2 | | | | 1 | | 2 | | | | 1 | 6 |
| | Indonesia | | | 1 | | | 1 | 1 | | | | | | 3 |
| | Philippines | | 2 | | | 1 | 2 | 3 | 1 | | 1 | | | 10 |
| | Burma | | 1 | | | | | | 1 | | | | | 2 |
| | Ceylon | | | | 2 | | | | | | | | | 2 |
| | Formosa (Native) | 3 | 4 | | 1 | 1 | 2 | | 1 | 1 | | | | 13 |
| | Formosa (High land) | | | 1 | | 2 | 1 | 1 | 1 | | 1 | | | 7 |
| | China mainland | | 5 | 6 | 2 | 3 | | | 2 | 1 | 2 | 5 | 3 | 29 |
| | Japan | | | | | 1 | 1 | 1 | | 1 | 2 | | 3 | 9 |

Note: In the 2nd crop of 1959, the infection was not serions enough. The data from this crop were excluded.

As the table shows, varieties from different countries appeared to differ in the resistance to blast. Resistant varieties were mostly found among those from low latitudes, while the susceptible ones mostly from high latitudes. However, both resistant and susceptible varieties could be found in the same country. The Continental (or Indica) type tended to be more resistant than the Insular (or Japanica) type. According to Oka (1953), the Insular type can be further classified into Tropical and Temperate types. More resistant varieties were found in the Tropical Insular group than in the Temperate Insular group, as shown in Table 2.

Table 2. Intervarietal variations in leaf blast resistance in different variety groups

| | Variety groups | Didease index number | | | | | | | | | | | | Total number of varieties |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 8.5 | 8.8 | 9 | |
| 1st crop 1959 | Continental | 12 | 14 | 1 | 1 | 2 | | | 2 | | | | | 32 |
| | Insular Tropical | 2 | 5 | 1 | | | | 4 | 2 | 3 | | | | 17 |
| | Insular Temperate | 1 | 1 | 1 | | | 1 | | 6 | 2 | | | | 12 |
| 1st crop 1960 | Continental | 41 | 4 | 4 | | 2 | 4 | 2 | 1 | 1 | | | | 59 |
| | Insular Tropical | 6 | 5 | | | 3 | 3 | 3 | 1 | 2 | | | | 23 |
| | Insular Temperate | 2 | | | | 1 | 1 | 3 | 4 | 4 | | | | 15 |
| 2nd crop 1960 | Continental | 5 | 15 | 11 | 6 | 9 | 5 | 2 | 7 | 1 | 1 | 2 | | 64 |
| | Insular Tropical | | 1 | 1 | | 1 | 4 | 4 | 4 | 1 | 4 | | 3 | 23 |
| | Insular Temperate | | | | | 1 | 1 | 2 | 1 | | 1 | 3 | 4 | 13 |

Note: Continental=Indica type, Insular=Japonica; Oka (1953).

### (2) *Experiments with irradiated progeny.*

70 mutant lines derived from irradiated populations of five rices were planted at Tun-shu Experimental field together with their original stock. The results for blast resistance are shown in Table 3. As the table shows, the majority of mutant lines did not differ so much from the unirradiated control in the resistance. However, one line of Taichung No. 65, (thermal neutron treatment, 20 hours) appeared to be highly resistant.

This resistant line was then back crossed with the original stock of Taichung No. 65, The $F_1$, $F_2$, and $F_3$ were grown and the segregation for resistance was studied. The results are also shown in Table 3. As the table shows, the range of variation is fairly wide in both $F_2$ and $F_3$ generations. 6 resistant lines were selected from the $F_3$.

Table 3. Variations in blast resistance in a resistant mutant, its original stock of Taichung No. 65 and their $F_2$ and $F_3$

| | Crosses | Didease index number | | | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 8.5 | 8.8 | 9 | |
| 1st crop 1960 | Mutant | 5 | 33 | 6 | 7 | 6 | | | | | | | | 57 |
| | $F_2$ | | 10 | 3 | 3 | 11 | 19 | 3 | 1 | | | | | 50 |
| | Taichung No. 65 | | | 1 | 3 | 18 | 48 | 30 | | | | | | 100 |
| 2nd crop 1960 | Mutant | | 6 | 7 | 14 | 34 | 33 | 6 | | | | | | 100 |
| | $F_3$ | | 2 | 4 | 9 | 26 | 60 | 52 | 42 | 5 | | | | 200 |
| | Taichung No. 65 | | | | | | | | | 13 | 59 | 2 | 6 | 80 |

### (*3*) *Experiments with wild and "primitive" rice varieties.*

The wild rice strains collected from India and Tailand were tested for blast resistance in 1959, and those collected from Africa were tested in 1960. The results are shown in Table 4.

Table 4. Frequency distribution in leaf blast resistance among wild and "primitive" strains

| Origin | Crop | Disease index number | | | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 8.5 | 8.8 | 9 | |
| India | 1st crop 1959 | 68 | 44 | 15 | 7 | 8 | 3 | 7 | 13 | 2 | | | | 167 |
| | 1st crop 1960 | 79 | 44 | 20 | 9 | 14 | 18 | 20 | 4 | 3 | | | | 211 |
| | 2nd crop 1960 | 7 | 8 | 7 | 2 | 5 | 3 | 3 | | 1 | | | | 36 |
| Tailand | 1st crop 1959 | 35 | 6 | 1 | 1 | | | | | | | | | 43 |
| | 1st crop 1960 | 2 | 1 | | | | | 1 | | | | | | 2 |
| | 2nd crop 1960 | | | 1 | | | | | 1 | | | | | 2 |
| Africa | 1st crop 1950 | 9 | 4 | 1 | 1 | | | | | | | | | 15 |
| | 2nd crop 1960 | 2 | 4 | 4 | 1 | 4 | 4 | 3 | | | | | | 22 |

As the table shows, the strains from India varied in a wide range. Those collected from Tailand were mostly resistant. About half of those from Africa were resistant while the other half showed medium resistance.

### (*4*) *Experiment with different Oryza species.*

A wide variation in leaf blast resistance was found among the *Oryza* species tested as shown in Table 5,

Table 5. Interspecific differences in leaf blast resistance

| Name of species | Disease index number | Name of species | Disease index number |
|---|---|---|---|
| O. brevitigulata | 5 | O. glaberrima (W025) | 2 |
| O. lichinger | 0 | O. glaberrima (W026) | 0 |
| O. alta (Suriram) | 0 | O. glaberrima (W027) | 8 |
| O. perennis (Burmis) | 1 | O. glaberrima (W028) | 0 |
| O. longistaninata | 4 | O. glaberrima (038) | 8 |
| O. Perennis (Cubensis) | 0 | O. glaberrima (039) | 7 |
| O. minuta | 0 | O. glaberrima (W040) | 5 |
| O. sativa f spontanea | 8 | O. glaberrima (W041) | 0 |
| O. glaberrima (W024) | 8 | O. glaberrima (W055) | 3 |

## 2. Introduction of resistant genes into the Ponlai or Japonica Rice

(A) Progeny test of the cross Taichung No. 65×Kanto No. 55.

In both first and scond crop seasons of 1960, $F_3$ and $F_4$ plants were planted together with their parents. Variations in blast reaction in the materials are shown in Table 6. As Table 6 shows, in the first crop of 1960, the majority of $F_3$ lines showed resistance. 100 lines were then selected from them and the $F_4$s were grown. In the $F_4$ generation all selected lines were susceptible or intermediate. Nevertheless, the materials were used for yield trial.

Table 6. Frequency variation in leaf blast resistance in Taichung No. 65×Kanto No. 55

| | Crosses | Diseade index number | | | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 8.5 | 8.8 | 9 | |
| 1st crop 1959 | Taichung No. 65 | | 1 | 2 | | 3 | | | | | | | | 6 |
| | $F_3$ Taichung No. 65 ×Kanto No. 55 | 3 | 36 | 15 | 22 | 20 | 4 | | | | | | | 100 |
| | Kanto No. 55 | | 1 | 4 | | | | | | | | | | 5 |
| 2nd crop 1959 | Taichung No. 65 | | | | | | | | | 13 | 59 | 2 | 6 | 80 |
| | $F_3$ Taichung No. 65 ×Kanto No. 55 | | | | | 5 | 15 | 40 | 111 | 28 | 1 | | | 200 |
| | Kanto No 55 | | | | | | | | 8 | 91 | 1 | | | 100 |

(B) Progeny test in the bulked population of $F_5$ in the cross of Taichung No. 65×C. I. 1955.

In the 1st crop of 1959, 9 lines from $F_5$ were bulked and were tested with regard to blast resistance. The susceptible ones were discarded.

(C) Progeny test in the cross between resistant varieties and Ponlai varieties. The progeneis of 11 crosses between Indica and Ponlai varieties and 6 crosses between resistant varieties were surveyed with regard to blast resistance. The cross combinations employed are as follows:

1. JC 148-4 (India)×Chianun-yu No. 242
2. JC 148-4 (India)×Tainan No. 1
3. JC 148-4 (India)×Nunshu No. 20
4. JC 148-4 (India)×Kaoshung No. 27

5. Katakutara (India)×Chianun-yu No. 242
6. Katakutara (India)×Tainan No. 1
7. Katakutara (India)×Kaoshung No. 27
8. Taichung No. 65×JC 148-4
9. Taichung No. 65×JD 73 (Siam)
10. Taichung No. 65×Katakutara
11. Taichung No. 65×JC 178-2 (India)

(b) Crosses between resistant varieties.

1. Maratelli (Italy)×Nunlin No. 12 (Japan)
2. Maratelli (Italy)×CI 9155 (U. S. A.)
3. Maratelli (Italy)×Pi No. 4 (Japan)
4. Noling No. 12×CI 9155
5. Noling No. 12×Pi No. 4
6. CI 9155×Pi No. 4

Table 7. Frequency distribution in leaf blast resistance in crosses between resistant varieties and susceptible Ponlai varieties

| Generation | Crosses | Disease indes Number | | | | | | | | | | | | Total | No. of plant selected |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 8.5 | 8.8 | 9 | | |
| $Bc_1F_1$ | Jc148×Chianun-yu No. 242 | 6 | 20 | 13 | 5 | 2 | 1 | | | | | | | 47 | 5 |
| | Jc148×Nunshu No. 20 | | 10 | 10 | 4 | 6 | 10 | 8 | 4 | 5 | 3 | | | 60 | 3 |
| | Jc148×Tainan No. 1 | | 1 | 1 | 1 | 2 | 3 | 3 | 1 | | | | | 12 | 3 |
| | Jc148×Kaoshung No. 27 | | 27 | 8 | 4 | 10 | 3 | 3 | 1 | | | | | 57 | 5 |
| | Katakutara× Chianun-yu No. 242 | | 5 | 3 | 8 | 4 | 2 | 1 | | | | | | 23 | 3 |
| | Katakutara× Tainan No. 1 | 1 | 4 | 10 | 7 | 10 | 2 | 1 | | | | | | 35 | 2 |
| | Katakutara× Kaoshung No. 27 | | 2 | 4 | 4 | 7 | 6 | 5 | 4 | | | | | 32 | 2 |
| $F_2$ | Jc148×Chianun-yu No. 242 | 39 | 37 | 9 | 4 | 7 | 10 | 11 | 12 | 3 | | | | 132 | 4 |
| | Jc148×Tainan No. 1 | 10 | 35 | 28 | 4 | 17 | 25 | 11 | 2 | | | | | 132 | 8 |
| | Jc148×Numshu No. 20 | 22 | 47 | 18 | 3 | 8 | 12 | 9 | 7 | 1 | | | | 127 | 4 |
| | Jc148×Kaoshung No. 27 | | 5 | 10 | 3 | 13 | 56 | 24 | 14 | 4 | | | | 129 | 5 |
| | Katakutara× Chianun-yu No. 242 | 19 | 53 | 22 | 3 | 4 | 7 | 3 | 2 | 5 | 2 | 1 | | 121 | 3 |
| | Katakutara× Tainan No. 1 | 11 | 44 | 11 | 1 | 6 | 17 | 3 | 7 | 1 | | | | 101 | 4 |
| | Katakutara× Kaoshung No. 27 | 6 | 46 | 28 | 24 | 14 | 9 | 3 | 1 | 1 | | | | 132 | 6 |
| | Taichung No. 65× Jd73 | 5 | 24 | 24 | 2 | 25 | 39 | 13 | 11 | 2 | | | | 145 | 2 |
| | Taichung No. 65× Jc148-4 | 2 | 17 | 20 | 21 | 33 | 41 | 16 | 6 | 3 | | | | 159 | 12 |
| | Taichung No. 65× Katakutara | 54 | 26 | 11 | 12 | 12 | 17 | 6 | 3 | | | | | 141 | 7 |
| | Taichung No. 65× Jc178-2 | 104 | 19 | 13 | 9 | 7 | 5 | 0 | 2 | 1 | | | | 160 | 5 |
| Ck | Jc148-4 | | | | | | | * | | | | | | | |
| | Katakutara | | * | | | | | | | | | | | | |
| | Jd73 | * | | | | | | | | | | | | | |
| | Jc178-2 | | | | | | * | | | | | | | | |
| | Taichung No. 65 | | | | | | | | * | | | | | | |
| | Chianun No. 242 | | | | | | * | | | | | | | | |
| | Tainan No. 1 | | | | | | | * | | | | | | | |
| | Numshu No. 20 | | | | | | | | * | | | | | | |
| | Kaoshung No. 27 | | | | | | | | * | | | | | | |

Note: *……based on lines.

In the first crop of 1960, the $F_1$ plants of the above listed crosses were back crossed with their parental lines. In the second crop of 1960, the $F_1$s, $F_2$s and $Bc_1$s were planted and resistant ones were selected for the second back-crossing. The results are shown in Table 7.

As Table 7 shows, the resistant plants were more frequently found in $F_2$ than in $Bc_1$ and $F_1$ plants. The resistant plants were selected and were back-crossed again with their parents. The results are shown in Table 8. Crosses between two resistant lines were highly resistant in 4 crosses, but in the other two crosses an intermediate resistance was found, indicating that the genotypes of the parents differed regarding resistance.

Table 8. Variation in blast resistance in the progeny of cross between resistant varieties

| Crosses | Disease index number | | | | | | | | | | | | Total | No. of plant selected |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 8.5 | 8.8 | 9 | | |
| Maratelli×Noling No. 12 | 51 | 56 | 22 | 14 | 9 | 7 | 2 | 5 | 2 | | | | 168 | 3 |
| Maratelli×C. I. 9155 | 49 | 16 | 2 | | | | | | | | | | 67 | 3 |
| Maratelli×Pi No. 4 | 31 | 36 | 5 | 4 | 7 | 3 | 2 | 2 | | | | | 90 | 4 |
| Noling No. 12×C. I. 9155 | | 1 | 2 | | 2 | 7 | 35 | 52 | 60 | 9 | 4 | 6 | 178 | 2 |
| Noling No. 12×Pi No. 4 | 1 | 6 | 5 | 4 | 25 | 50 | 31 | 32 | 9 | | | 1 | 164 | 2 |
| C. I. 9155×Pi No. 4 | 43 | 32 | 5 | | 1 | 2 | 2 | 3 | | | | | 88 | 6 |
| Ck Maratelli | | * | | | | | | | | | | | | |
| Ck Noling No. 12 | | | | | * | | | | | | | | | |
| Ck C. I. 9155 | * | | | | | | | | | | | | | |
| Ck Pi No. 4 | * | | | | | | | | | | | | | |

Note: *……based on lines.

## DISCUSSION

Lin: I think the system for determining the degree of infection should be re-examined. The percentage of lesion area has been used up to present. In Japan, the degree of infection is in most cases determined on the basis of lesion type. Therefore, in our future experiments these two systems should be compared.

Hung: I think the system now in use in Japan is a good one. Different types of lesion show characteristics of reaction type, and it is not necessary to take the number of lesions into consideration. I recomend you to use this system in your future studies.

Chiu: Mr. Lin used a number of varieties collected from South-east Asian countries and tested their reactions to blast disease. Is it possible to compare the damage of blast disease on yield of rice in various sub-tropical districts?

Oka: Though the materials used in this experiment covered various counties of tropical Asia, the growing conditions in respective countries are quite different from one another, therefore, can not be compared in one experimental field.

Hsieh: According to your report the index numbers for some varieties are zero. Are these varieties immune to the blast disease?

Lin: According to the definition of index number, zero means immunity but in the present study, slightly infected plants only with a trace of lesion was counted as zero. Therefore, strickly speaking, no immune varieties would be found in this study.

Hsieh: Is there any immune species in wild rice?

Lin: In some species, no trace of infection was found in the first year. I thought, they were immune from blast disease, but in the second year, very small brown spores appeared on the leaves. Generally speaking, most wild species show a high resistance to blast but no real immune type was found within the scope of present study.

# IV. GENETICS: ANALYSIS OF GENES FOR BLAST DISEASE RESISTANCE AND OTHER CHARACTERS

## a. ANALYSIS OF GENES FOR BLAST DISEASE RESISTANCE CAUSED *BY PIRICURARIA ORYZAE*

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The blast disease caused by *Piricularia Oryzae* is the most important in most rice growing countries. It seriously damages rice when nitrogen fertilizer is heavily applied. Therefore, breeding for blast disease resistance is urgently needed and a number of promising resistant varieties have been selected in various countries. However, knowledges on the genetics of disease resistance are still limited.

In order to get more knowledges on the inheritance of blast disease resistance in rice, the writer has conducted genetic experiments on resistances to leaf as well as neck blast disease. Fourty-six rice varieties from Japan, U. S. A. and Taiwan were used as the cross parents.

### 1. Inheritance of resistance to blast disease in seedlings

Studies on seedling reaction to blast disease was conducted during the period March to July in 1958. Five resistant, four intermediate and seven susceptible varieties were used as cross parents. 13 $F_2$ crosses together with their parental strains were planted in a specially designed greenhouse, in where artificial inoculation of blast fungus onto the seedlings was made. The inoculum was composed of a number of isolates taken from infected leaves collected from various parts of Taiwan. Single lesion was cultured in artificial media and the inoculum was applied in the form of a conidial suspension. The rice seedlings were grown in fungus free soil in iron flats (30 cm×30 cm in size), placed in the green house. About 40–50 seedlings are planted in separated blocks in the same flat. Prior to the inoculation, 2% ammonium sulfate solution was topdressed to the flats twice, at the rate of 25 cc per flat for each application. When the seedlings reach at the height of 15 cm, the conidial suspension was sprayed onto the leaves of seedlings. The inoculation was repeated 3-4 times so as to minimize the chance of escaping from infection. The flats were then placed in an inoculation chamber where the moisture (80-90%) and temperature (25–28°C) were controlled. A week after inoculation, the flats were moved out of the inoculation chamber into either a wire cage or in a greenhouse, depending on the air tem-

perature outside. Three to four days later, the inoculated seedlings were examined and records with regard to the types of lesions were taken according to the following six grades. O, A and B types were considered as resistant, while, C, D and E type were considered as susceptible.

| Grade | Degree of resistance | Lesion type | Description |
|---|---|---|---|
| O | HR | Immune | No visible sign of infection. |
| A | R | Brown spot | Small brownish-dark brown lesions or spots. |
| B | MR | Brown margin | Brownish lesions with a distinct border which would not increase in size. |
| C | MS | Grayish white center | Slowly expanding, lesions restricted in size. |
| D | S | Large lesions with dark green center | Large lesions surrounded by brownish bands, expanding. |
| E | HS | Large lesions with grayish center | Water soacked appearance, often without well defined border, variable in size, lesions are expanded drastically. |

Note: HR: Highly resistant
R: Resistant
MR: Moderately resistant
MS: Moderately susceptible
S: Susceptible
HS: Highly susceptible

Variation in seedling reaction to blast disease of the parental strains and $F_2$s are shown in Table 1.

As the table shows, crosses between resistant and susceptible strains, the $F_2$ segregated into 3 resistant and 1 susceptible plants in the majority of the crosses, showing the resistance being controlled by a single dominant gene. The result agrees with what Sasaki (1922) as well as Oka (1957) reported.

In the cross between a susceptible variety J-302 (Nakamura, Japonica type) and a resistant variety T-234 (Wukao, Indica type), the susceptible plant being smaller in number than expected and the chi-square value did not show a good fit to the 3:1 ratio. Since seed fertility in the $F_1$ plant of this cross was 20%, gametic selection due to hybrid sterility may be one of the disturbing factors for such a deviation. It is also possible that excessive plants may also be due to "disease escaping."

The $F_2$s of the crosses, P-123×M-503, P-123×P-130, P-123×7114 and P-124×T-215 segregated into 9 resistant and 7 susceptible plants. The chi-square value showed good fits to the expected ratio. When we classify the degree of resistance into three classes, resistant (O+A), intermediate (B+C) and susceptible (D+E), a 9:3:4 ratio was observed in P-123×P-130 and P-123×7114. These facts indicate that at least two genes are concerned with regard to blast resistance. This assumption was confirmed by the second series of experiment conducted in the field condition.

Table 1. Variations in seedling resistance to leaf blast disease in parental lines and $F_2$s in green house experiment

| | Parents and crosses | Type of lesion | | | | | | Resistant | Susceptible | Total | Segregation ratio | $X^2$ | P |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | O | A | B | C | D | E | (O+A+B) | (C+D+E) | | | | |
| 1960 | P-123 | | | | | 115 | | | | 115 | | | |
| | P-123×M-503 | 15 | 8 | 12 | 18 | 10 | | 35 | 28 | 62 | 9 : 7 | 0.013 | 0.8-0.9 |
| | M-503 | 1 | 3 | 8 | | | | | | 12 | | | |
| | P-123×T-208 | 59 | 9 | 43 | 20 | 11 | | 111 | 31 | 142 | 3 : 1 | 0.760 | 0.3-0.5 |
| | T-208 | 54 | 46 | | | | | | | 100 | | | |
| | P-123×P-167 | 72 | 28 | 19 | 14 | 13 | | 119 | 27 | 146 | 3 : 1 | 3.297 | 0.05-0.1 |
| | P-167 | 64 | 17 | 10 | | | | | | 91 | | | |
| | P-138 | | | | | 12 | 10 | | | 22 | | | |
| | P-138×7101 | 18 | 12 | 26 | 9 | 12 | | 56 | 21 | 77 | 3 : 1 | 0.212 | 0.5-0.7 |
| | P-163 | 116 | 39 | 5 | 1 | 15 | 1 | | | 177 | | | |
| | P-163×7245 | 23 | 86 | 23 | 13 | 28 | | 132 | 41 | 173 | 3 : 1 | 0.156 | 0.5-0.7 |
| | 7245 | 99 | 16 | 1 | 1 | | | | | 117 | | | |
| | P-163×9781 | 30 | 61 | 15 | 7 | 19 | | 106 | 26 | 132 | 3 : 1 | 0.980 | 0.1-0.2 |
| | 9781 | 15 | 21 | 13 | 1 | | | | | 22 | | | |
| | P-163×9783 | 42 | 67 | 7 | 6 | 39 | | 116 | 45 | 161 | 3 : 1 | 0.748 | 0.3-0.5 |
| | P-163×A-73 | 31 | 50 | 8 | 1 | 32 | | 89 | 33 | 122 | 3 : 1 | 0.273 | 0.5-0.7 |
| | J-302×T-234 | 102 | 32 | 23 | 16 | 6 | | 157 | 22 | 179 | 3 : 1 | 15.421 | 0.01 |
| | P-141×P-167 | 67 | 23 | 23 | 17 | 11 | | 113 | 28 | 141 | 3 : 1 | 1.988 | 0.1-0.2 |
| | P-141 | | | | | 8 | | | | 8 | | | |
| 1961 | P-123×P-130 | 39 | 59 | 12 | 12 | 49 | 1 | 110 | 62 | 172 | 9 : 7 | 4.148 | 0.02-0.05 |
| | | 98 | | 24 | | 50 | | | | | 9 : 3 : 4 | 3.266 | 0.1-0.2 |
| | P-130 | 22 | 37 | 5 | 4 | 30 | 2 | | | 100 | | | |
| | P-123×7114 | 34 | 77 | 10 | 16 | 61 | 2 | 121 | 79 | 200 | 9 : 7 | 1.468 | 0.2-0.3 |
| | | 111 | | 26 | | 63 | | | | | 9 : 3 : 4 | 6.927 | 0.02-0.05 |
| | 7114 | 55 | 39 | 1 | 4 | 1 | | 95 | 5 | 100 | | | |
| | P-124 | 45 | 20 | 3 | 8 | 24 | | | | 100 | | | |
| | P-124×T-215 | 34 | 22 | | 5 | 31 | 2 | 56 | 38 | 94 | 9 : 7 | 0.421 | 0.5-0.7 |
| | T-215 | 14 | 35 | 15 | 2 | | | | | 66 | | | |
| | P-138×7247 (I) | 11 | 17 | 7 | 12 | 3 | | 35 | 14 | 49 | 3 : 1 | 0.333 | 0.5-0.7 |
| | (II) | 56 | 14 | 28 | 13 | 17 | 4 | 98 | 34 | 132 | 3 : 1 | 0.040 | 0.9-0.95 |
| | 7247 (I) | 11 | 5 | 2 | 4 | | | | | 22 | | | |
| | (II) | 69 | 5 | 6 | 4 | 2 | | | | 86 | | | |
| | P-123 (II) | | | 1 | 3 | 64 | 9 | | | 77 | | | |
| | P-123×T-215 (I) | 11 | 4 | 10 | 7 | 54 | 1 | 25 | 62 | 87 | 1 : 3 | 0.648 | 0.3-0.5 |
| | (II) | 20 | 3 | | 3 | 58 | 6 | 23 | 67 | 90 | 1 : 3 | 0.015 | 0.8-0.9 |
| | T-215 (I) | 14 | 35 | 15 | 2 | | | | | 66 | | | |
| | (II) | 70 | 26 | 2 | 2 | | | | | | | | |

(I) Data of 1960. (II) Data of 1961.

## 2. Inheritance of resistance to leaf blast disease in field experiment

During the second crop season of 1958, 14 $F_2$ crosses together with their parents were planted in an experimental field located at Tunshu, Taichung Prefecture, where the blast disease prevails in both the first and second crop seasons.

The leaf infection in adult plants was recorded by an index number indicating the percentage of lesion area, as shown in Table 2.

Table 2. Index-numbers showing the percentage of diseased leaf area

| % of diseased leaf area | 0 | 0.2 | 0.5 | 1 | 3 | 5 | 11 | 25 | 55 | 80 | 100 | 120 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Index number | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 8.5 | 8.8 | 9 |

Since this classification was too complicated, the writer tried to group the index numbers into five classes by a statistical method so as to maximize the difference between line means relative to that within lines. However, the result showed that the grouping differed according to the season. Therefore, the resistant and susceptible classes in $F_2$ were determined by comparing with the variation range with those of parental lines. The frequency distributions as shown by the index-numbers given in Table 2 are shown in Table 3.

As Table 3 shows, the $F_2$ plants of most crosses between resistant strains were all resistant, but a cross, J-320×T-248, both parents being highly resistant, gave 36 highly resistant and 21 intermediate plants. This ratio is in a good fittness with a 9:7 ratio. This suggests that there may be resistant genes with complmentary effects. In crosses T-248×M-511 and T-220×T-248, most $F_2$ plants were resistant but a few were moderatly resistant. If this is due environmental modification or not is being tested.

As shown in the same table, the $F_1$ and $F_2$ plants of crosses between susceptible strains, such as P-123×D-1, P-123×C-1, P-123×7156 and P-321×P-123, were all susceptible. However, a few resistant plants were found in the cross P-123×H-25. In the $F_2$ of P-123×7156, both parents were susceptible, 57 highly resistant and 38 susceptible plants were found. They fitted quite well to a 9:7 ratio. It then seems that at least two dominant genes with complementary effect are responsible for the resistance to leaf blast disease.

In crosses between susceptible and resistant strains such as P-123×T248, P-123×7237 and P-123×U-401, the $F_1$s were resistant, and the $F_2$s showed a 3 resistant to 1 susceptible ratio. The $F_2$ of P-123 and 7126 gave a countinous range of variation in resistances. These differences in segregation ratio indicate that different genes are responsible for the resistance of parental strains. We may assume that a resistant gene $R_1$ (Okada's symbol 1956) gives higher resistance than $R_2$ and the presence of both of them brings about a high resistance to leaf blsease. Based on this assumption, the genotypes of the parental strains used may be putatively assumed.

During the first crop season of 1959, $F_2$ crosses wear again planted at the Tunshu Experimental field together with their parental lines in order to get more

Table 3. Variations of $F_2$ and parental plants in leaf blast resistance in field experiment

| Parents and crosses | Disease index number | | | | | | | | | | | | Total | Segr. ratio | $X^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 8.5 | 8.8 | 9 | | | |
| P-169 | | 13 | 3 | 1 | | | | | | | | | 17 | | |
| P-169×T-220 | 77 | 26 | | 1 | 1 | | | | | | | | 105 | 1 : 0 | |
| T-220 | 67 | 95 | 14 | 13 | 6 | | | | | | | | 195 | | |
| J-320 | | 20 | | | | | | | | | | | 20 | | |
| J-320×T-248 | 4 | 32 | 9 | 5 | 4 | 2 | 1 | | | | | | 57 | | |
| | (36) | | (21) | | | | | | | | | | | 9 : 7 | 1.067 |
| T-248 | 34 | 4 | | | | | | | | | | | 38 | | |
| T-248×M-511 | 370 | 90 | 42 | 11 | 2 | 10 | 2 | | | | | | 527 | 1 : 0 | |
| M-511 | 142 | 48 | 2 | 1 | | | | | | | | | 193 | | |
| T-220×T-248 | 71 | 24 | 10 | 3 | | 3 | 2 | 1 | | | | | 114 | 1 : 0 | |
| P-123 | | | | | | 5 | 3 | 15 | 19 | | | | 42 | | |
| P-123×H-25 | | 2 | 1 | 1 | 2 | 3 | 20 | 108 | 154 | 16 | 6 | 5 | 318 | | |
| H-25 | | | | | | | | 11 | 21 | 11 | 10 | 19 | 72 | | |
| P-123×D-1 | | | | | | | 3 | 103 | 204 | 58 | 2 | 6 | 376 | 0 : 1 | |
| D-1 | | | | | | | | 6 | 16 | 14 | 2 | | 38 | | |
| P-123×C-1 | | | | | | | 1 | 36 | 188 | 67 | 23 | 32 | 347 | 0 : 1 | |
| C-1 | | | | | | 19 | 20 | 25 | 30 | 21 | 5 | | 120 | | |
| P-123×7164 | | | | | | 1 | | 19 | 37 | 45 | 55 | 95 | 252 | 0 : 1 | |
| 7164 | | | | | | | | | 7 | 19 | 17 | 3 | 46 | | |
| J-321 | | | | | | | | | 4 | 10 | 17 | 79 | 110 | | |
| J-321×P-123 | | | | | | | 6 | 10 | 17 | 52 | 25 | | 110 | 0 : 1 | |
| P-123×7165 | 1 | 13 | 19 | 24 | 17 | 8 | 5 | 7 | 1 | | | | 95 | | |
| | (57) | | | | (38) | | | | | | | | | 9 : 7 | 0.542 |
| 7165 | | | | | 15 | 22 | 14 | 22 | 25 | 3 | | | 101 | | |
| P-123×T-248 | | 25 | 12 | 12 | 4 | 9 | 9 | 4 | 2 | 1 | | | 78 | | |
| | | (53) | | | | (25) | | | | | | | | 3 : 1 | 2.068 |
| T-248 | 116 | 67 | 20 | 3 | | | | | | | | | 206 | | |
| P-123×7126 | 26 | 80 | 33 | 19 | 18 | 5 | 5 | 5 | 4 | | | | 195 | (?) | |
| 7126 | 8 | | | | | | | | | | | | 8 | | |
| P-123×7237 | 6 | 50 | 24 | 23 | 16 | 19 | 9 | 4 | 6 | | | | 157 | | |
| | (119) | | | | | (38) | | | | | | | | 3 : 1 | 0.411 |
| 7237 | 21 | 54 | 5 | 3 | 1 | | | | | | | | 94 | | |
| J-321 | | | | | | | | | 4 | 10 | 17 | 79 | 110 | | |
| J-321×U-401 | | 57 | 42 | 67 | 43 | 35 | 34 | 24 | 15 | 6 | 4 | 3 | 330 | | |
| | | (244) | | | | | (89) | | | | | | | 3 : 1 | 0.198 |
| U-401 | 1 | 89 | 32 | 18 | 9 | 2 | | | | | | | 151 | | |

Table 4. Segregation for neck blast resistance

| Crosses | % of diseased ear | | | | | | | | | | Total | Segregation ratio | $X^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | | | |
| P-140 | 6 | 3 | 3 | 7 | 4 | | | | | | 23 | | |
| P-140×T-233 | 35 | 12 | 10 | 9 | 8 | 4 | 4 | 4 | 2 | 6 | 94 | | |
| | (74) | | | | | (20) | | | | | | 3 : 1 | 0.695 |
| T-233 | 5 | 1 | 8 | 6 | 3 | | | | | | 26 | | |
| P-167 | | | | | | 8 | 18 | 15 | 21 | 18 | 80 | | |
| P-167×La-8-4 | 14 | 11 | 14 | 15 | 9 | 4 | 5 | 7 | 8 | 9 | 96 | | |
| | (67) | | | | | (29) | | | | | | 3 : 1 | 1.389 |
| La-8-4 | 12 | 7 | 2 | 3 | 3 | | | | | | 27 | | |
| P-167×P-168 | 35 | 10 | 4 | 7 | 2 | 2 | 2 | 5 | | 8 | 75 | | |
| | (58) | | | | | (17) | | | | | | 3 : 1 | 0.218 |
| J-302 | | | | | | 1 | 3 | | 3 | 15 | 22 | | |
| J-302×T-234 | 18 | 4 | 10 | 13 | 20 | 4 | 9 | 7 | 2 | 3 | 90 | | |
| | (55) | | | | | (25) | | | | | | 3 : 1 | 0.370 |
| P-123 | | | | | | | 4 | 3 | 3 | 3 | 13 | | |
| P-123×J-303 | 10 | 11 | 21 | 14 | 9 | 9 | 13 | 3 | 2 | 3 | 95 | | |
| | (56) | | | | | (39) | | | | | | 9 : 7 | 0.280 |
| J-303 | | | | | 2 | 2 | 2 | 2 | 2 | 4 | 14 | | |
| P-124 | | | | | 7 | 2 | 0 | 7 | 7 | 8 | 40 | | |
| P-124×T-208 | 62 | 27 | 18 | 18 | 21 | 7 | 7 | 10 | 5 | 4 | 179 | | |
| | (107) | | | | | (72) | | | | | | 9 : 7 | 0.904 |
| T-208 | 36 | 37 | | | | | | | | | 73 | | |
| P-123×P-130 | 4 | 11 | 14 | 15 | 10 | 7 | 2 | 11 | 2 | 27 | 102 | | |
| | (61) | | | | | | (13) | | (28) | | | 9 : 3 : 4 | 2.432 |
| P-130 | | 1 | 6 | 4 | 6 | 4 | 7 | 2 | | | 30 | | |
| P-124×T-208 | 62 | 27 | 13 | 18 | 21 | 7 | 7 | 10 | 50 | 4 | 179 | | |
| | (89) | | (36) | | (35) | | | (19) | | | | 9 : 3 : 3 : 1 | 7.047 |
| T-208 | 36 | 2 | | | | | | | | | 38 | | |
| P-124×T-215 | 12 | 2 | 2 | 4 | 7 | 8 | 11 | 7 | 8 | 15 | 69 | | |
| | (27) | | | | | (42) | | | | | | 27 : 37 | 0.265 |
| T-215 | 7 | 6 | 7 | 4 | 6 | | | | | | 30 | | |
| P-138 | | | | | | | 1 | | 5 | 24 | 30 | | |
| P-138×T-215 | 18 | 2 | 4 | 3 | 7 | 8 | 4 | 6 | 2 | 38 | 92 | | |
| | (42) | | | | | | (50) | | | | | 27 : 37 | 0.454 |
| T-215 | 7 | 6 | 7 | 4 | 6 | | | | | | 30 | | |

results on the inheritance of leaf blast resistance. However, the prevalence of the disease was not serious due to unfavorable environmental conditions in that year. Only the neck blast was quite serious at maturity and the inheritance of neck blast resistance could be observed.

The degree of damage by neck blast disease was expressed by the percentage

of diseased panicles. The range of variation in parental lines was compared with those in $F_2$ to determine the border of resistant and susceptible classes. The data thus obtained are given in Table 4. As the table shows, 3:1, 9:7, 3:4 and 27:37 ratios were assumed. There might be at least three genes controlling the resistance to neck blast disease.

As will be shown later the resistance to neck blast is in some crosses correlated with the resistance to leaf blast but in other crosses not correlated siginficantly. This suggests that genes which modify neck resistance are present. The writer has already assumed two pairs of genes $R_1$ and $R_2$ for leaf resistance. They may be effective also for neck resistance. Assuming that three genes are involved in neck resistance, we may assume that the third gene is responsible for neck resistance. Then the observed segregation ratios of neck resistance can be explained well in most crosses.

## DISCUSSION

Hsu: How many genes are involve in the resistance to leaf blast in your study?

Hsieh: This experiment was conducted under a controlled condition in this Institute, and under natural conditions at Tunshn, Taichung Prefecture. It was found that the $F_1$ and most $F_2$ plants of crosses between resistant varieties were resistant. Those between two susceptible varieties were mostly susceptible. Crosses between resistant and susceptible varieties showed a 3:1 and 9:7 ratios, showing that at least 1-2 genes are responsible for resistance.

Oka: According to your data, some parental varieties show a wide range of variation in resistance. This seems to be due to the impurity of materials. Such materials are not suitable for genetic study.

Lin: I think the index number is too complicated and must be simplified.

Hsieh: I noticed this problem before, and I am going to group the 9 classes into 4-5 classes by a statistical method so as to maximize the difference between line means relative to that within lines.

Oka: Linkage relations between genes for resistance to blast disease and other characters have not been studied so intensively by previous workers, you had better put more emphasis on this problem.

Hsieh: Yes, one of the difficulties in this experiment is that we can't record various characters at the same time in the same field due to the death of infected plants. In order to overcome this difficulty, 2-3 tillers of plant grown in Toughu were taken back to Taipei, and were planted with completly the same arrangement as that in the original field, and kept them in a good growing condition; then various characters could be recorded and related to the degree of blast resistance. From the preliminary study it seems that one of the resistant genes is linked with liguleless gene and phenol reaction genes. More will be done in order to confirm this assumption.

Oka: In your coming experiment it is desired to increase crosses between resistant

×resistant and susceptible×susceptible to see whether or not there is complementary action of genes.

Hsieh: Yes, we will do this in the next year.

Ku: In your experiment under the field condition, you can't control the purity of pathogenes. Therefore, the segregation ratio may be disturbed by different races of the pathegene. Have you ever considered this problem?

Hsieh: This is a quite important problem. As Mr. Hung's report shows we have different races in Taiwan, but we don't know yet whether they appear at the same time at the same locality or not. We can only carry out experiments on the assumption that the different races will not occur in the same locality at the same time. Hashioka (1950) formerly assumed that we do not need to be afraid so much about the disturbing effect of races on segregation ratios. Stricty speaking we must use a single race in genetic studies but we can't do this in a large scale, because it is difficult to get a large amount of inoculum suply. Anyway, I think we must overcome this difficulty.

# b. ANALYSIS OF GENES FOR COLORATIONS AND OTHER MORPHOLOGICAL CHARACTERS IN RICE

Sung-ching Hsieh

(Cytogenetics laboratory, TARI)

With the view to re-examining the system of genes established by Drs. Nagao and Takahashi, the writer is being engaged in genetic experiments. The gene marker strains obtained from Dr. Jodon and four from Dr. Nagao, and three local strains belonging to the Ponlai or the Japonica type were used as cross-parents. The gene symbols given by Dr. Nagao were directly used, while those by Dr. Jodon were rewritten in accordance with the Nagao's system.

Colorations at apiculus and stigma were observed at the heading time, using the symbol "+" and "−" to represent colored (purple to red) and colorless states, respectively. Colorations in lemma, palea, pericarp and other parts of plants were observed at different stages. The glutinous vs. non-glutinous character of endosperm was determined by the iodine test of grains.

## 1. Inheritance of coloration at the apiculus

Coloration at the apiculus in parental strains, $F_1$s and its segregation in $F_2$ are given in Table 1. In all the crosses given in Table 1. Taichung No. 65 (P–123), is used as the female parent. The apiculus of this strain is colorless or green at the heading time, but show a light brownish color at maturity. Among the male parents, seven have a purple color, two have a red color and the remaining five are colorless. In all crosses between P–123 and colored (purple or red) strains, the $F_1$s were colored at the heading time, and the $F_2$ segregated into 3 colored: 1 colorless without exception.

According to Nagao and Takahashi (1951, 1957), apiculus coloration is determined by the chromogen gene *C* and its activator *Sp*. The gene loci *C* and *Sp* each comprises a multiple allelic series, five genes at the *C*-locus and three at the *Sp*-locus, and their dominance relations are $C^R > C^{Rp} > C^{Rt} > C^{Rr} > c$ and $Sp > Sp^a > sp$ respectively. The phenotype of P–123, apiculus being colorless at the heading time and lightly colored at maturity, is expressed by the combination *Csp*, where *C* may be $C^R$, $C^{Rp}$, $C^{Rt}$ or $C^{Rr}$ The genotypes of the two strains, A–58 and H–59, which are the materials used by Drs. Nagao and Takahashi, are already known to be $C^R$ *Sp* and $C^R$ $Sp^a$ respectively.

When P–123 was crossed with A–58, the $F_1$ showed the same purple coloration as A–58 and the $F_2$ at the heading time segregated into 3 colored (purple to red): 1 colorless. When crossed with H–59, the $F_1$ showed a light red color as seen in H–

59 and the $F_2$ segregated into 9 dark red ($C^R$ $Sp$), 3 light red ($C^{Rr}$ $Sp_d$) and 4 colorles ($C^R$ $sp$, $C^{Rr}$ $sp$). When P-123 was crossed with colorless strains such as 7156, 7184 and 7126, the $F_1$s had a red color, and $F_2$ segregated into 9 red: 7 colorless at the heading time. Then, the genotype of P-123 may be assumed to be $C^{Rr}$ $sp$.

Regarding the genotypes of strains 7101, 7107, C-12, 7111, 7237 and C-1, their $F_1$s with P-123, and colored segregants of the $F_2$, all showed the purple color as that of A-58. Their genotypes may therefore be $C^R$ $Sp$. According to Jodon's (1955) personal correspondence, 7237 has the gene $Ap$ (Apiculus purple). It seems that the $Ap$ corresponds to the $C$ of Nagao.

The genotypes of colorless strains which gave a 3:1 ratio in the $F_2$ may have $csp$, since all their $F_1$s and $F_2$s were at the heading time colorless, and after maturity, the $F_1$ and three quarters of the $F_2$ plants showed a light coloration as seen in P-123.

Further, it was pointed out by Chao (1928), Jodon (1948), Morinaga (1943) and Nagao and Takahashi (1956) that there should be the third gene ($A$ by Nagao or $Ap$ by Morinaga) which is responsible for the spreading of anthocyanin pigment and works in a complementary manner with $C$ and $Sp$ for apiculus coloration. According to Nagao and Takahashi (1951, 1957), both A-58 and H-59 have the dominant gene $A$; it then seems that all the strains used in the present study have $A$.

## 2. Segregation for stigma coloration in $F_2$

It is generally found that plants with colored stigmas always have colored apiculus, but apiculus coloration is not always correlated with colored stigma. In other words, genes for apiculus coloration are epistatic to those for stigma coloration. The data in Table 1 also show that this relation holds good in the data of the present study, though exceptional cases for this rule is reported.

The following four manners of inheritance were found with regard to the coloration of stigmas, as shown in Table 1.

| Cases | Stigma color | | $F_1$ stigma color | $F_2$ stigma color segregation in apiculus colored plants | Male parents |
|---|---|---|---|---|---|
| | Female (P-123) | Male | | | |
| (1) | − | + | + | 1 : 0 | A-58, C-12, 7101, 7107 |
| (2) | − | + | − | 3 : 13(?) | 7111, 7237, C-1 |
| (3) | − | − | − | 0 : 1 | H-59 |
| (4) | − | − | − | 9 : 55(?) | 7108 |

In so far as the coloration of stigma is hypostatic to apiculus color, there should be a stigma coloration gene which will be hypostatic to $C$, $Sp$ and $A$, provisionally symboled $Ps$. The gene $Ps$ may then be considered to be a modifier which spreads the antocyanin pigment into the stigma.

Then, for explaining "Case 1" in the above table, we must assume that both

Table 1. Segregation for apiculus and stigma colorations in $F_2$

| Crosses | Female parent | | Male parent | | $F_1$ | | Fertility (%) | $F_2$ Apiculus being | | | | Total | Apiculus | | | Stigma | | | Genptype of male parents | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Colored Stigma | | Colorless Stigma | | | | | | | | | | |
| | *ap* | *st* | *ap* | *st* | *ap* | *st* | | + | − | + | − | | Segregation ratio | $X^2$ | P | Segregation ratio | $X^2$ | P | Apiculus | Stigma |
| P-123×A-58 | | | P | P | P | P | 88 | 354 | | | 135 | 489 | 3 : 1 | 1.632 | 0.2-0.3 | 1 : 0 | | | $C^R\ Sp\ A$ | $i(?)\ Ps\ i(?)$ |
| P-123×C-12 | | | P | P | P | P | 80 | 216 | | | 77 | 293 | 3 : 1 | 0.888 | 0.3-0.5 | 1 : 0 | | | $C^R\ Sp\ A$ | $i(?)\ Ps\ i(?)$ |
| P-123×7101 | | | P | P | P | P | 70 | 406 | | | 143 | 549 | 3 : 1 | 0.321 | 0.5-0.7 | 1 : 0 | | | $C^R\ Sp\ A$ | $i(?)\ Ps\ i(?)$ |
| P-123×7107 | | | P | P | P | P | 65 | 197 | | | 76 | 273 | 3 : 1 | 1.173 | 0.1-0.2 | 1 : 0 | | | $C^R\ Sp\ A$ | $i(?)\ Ps\ i(?)$ |
| P-123×7156 | | | | | R | | 80 | | 143 | | 125 | 269 | 9 : 7 | 0.912 | 0.3-0.5 | 0 : 1 | | | $c\ Sp\ A$ | |
| P-123×7184 | | | | | R | | | | 167 | | 110 | 277 | 9 : 7 | 1.837 | 0.1-0.2 | 0 : 1 | | | $c\ Sp\ A$ | |
| P-123×7126 | | | | | R | | 82 | 58 | 118 | | 135 | 311 | 9 : 7 | 0.015 | 0.8-0.9 | 9 : 55 | 51.978 | 0.01>P | $c\ Sp\ A$ | $I_2^{ps}\ Ps\ i_1$* |
| P-123×7245 | | | | | R | | 75 | | 429* | | 140 | 569 | 3 : 1 | 0.047 | 0.8-0.9 | 0 : 1 | | | $c\ sp\ A$ | |
| P-123×7156 | | | | | B | | 85 | | 288 | | 102 | 390 | 3 : 1 | 0.277 | 0.5-0.7 | 0 : 1 | | | $c\ sp\ A$ | |
| P-123×7111 | | | P | P | P | | | 115 | 227 | | 134 | 476 | 3 : 1 | 0.260 | 0.1-0.2 | 3 : 13 | 49.688 | 0.01>P | $C^R\ Sp\ A$ | $I_2^{ps}\ Ps\ i_1$ |
| P-123×H-59 | | | R | | R | | 80 | | 166 | | 51 | 217 | 3 : 1 | 0.260 | 0.1-0.2 | 0 : 1 | | | $C^R\ Sp^d\ A$ | $I_2^{ps}\ Ps\ I_1^{ps}$ |
| P-123×7237 | | | P | P | P | | 40 | 117 | 263 | | 124 | 504 | 3 : 1 | 0.042 | 0.8-0.9 | 3 : 13 | 36.155 | 0.01>P | $C^R\ Sp\ A$ | $I_2^{ps}\ Ps\ i_1$ |
| P-123×C1 | | | P | P | P | | 80 | 73 | 113 | | 52 | 238 | 3 : 1 | 1.260 | 0.2-0.5 | 3 : 13 | 51.290 | 0.01>P | $C^R\ Sp\ A$ | $I_2^{ps}\ Ps\ i_1$* |
| P-123×7108 | | | R | | R | | 78 | 224 | 260 | | 116 | 400 | 3 : 1 | 3.413 | 0.05-0.1 | 9 : 55 | 7.400 | 0.01>P | $C^{Rt}\ Sp\ A$ | $I_2^{ps}\ Ps\ i_1$ |

Note: 1. P……Purple
P……Red
+……Colored
−……Colorless
2. *……Light brown color after maturation
3. The Taichung No. 65 or P-123 has $C^{Rr}\ sp\ Ai_2\ Ps\ I_1^{ps}$.

parents have the same dominant *Ps*. For "Case 2" there should be at least two inhibitors, $I_1^{ps}$ and $I_2^{ps}$ which act as complementary genes to inhibit the expression of stigma color, because, P-123 should have *Ps*. For "Case 3", it is necessary that one of the two inhibitors is linked with *Sp*. In this case, the male parent H-59 has $Sp^d$. It is then possible to assumed that the effect of $Sp^d$ is equal to $Sp+I_2^{ps}$, though it should be confirmed by further tests.

The above considerations lead to the assumption of genotypes that the female parent P-123 has $C^{Rr}$ *sp* $i_2^{ps}$ *A Ps* $I_1^{ps}$, A-58, C-12, 7101 and 7107 have $C^R$ *Sp i* (?) *A Ps i* (?), 7111, 7237 and C-1 have $C^R$ *Sp* $I_2^{ps}$ *A Ps* $i_1^{ps}$, H-59 has $C^R$ $Sp^d$ $I_2^{ps}$ *A Ps* $I_1^{ps}$ and 7126 has *cSp* $I_2^{ps}$ *A Ps* $i_1^{ps}$. However, further experiments are necessary to test whether these assumptions are quite right, or not. In regard to "Case 4", if we assume the genotype of 7108 to be $C^{Rt}$ *Sp* $I_2^{ps}$ *A Ps* $i_1^{ps}$, the behavior of stigma color can be explained though not conclusive.

## 3. Coloration of outer and inner glumes or hulls

According to Nagao and Takahashi (1951), the coloration of lemma and palea is due to the distributing gene *Rp* which spreads the pigment produced by *C* and *Sp* over the surface of glumes. The genotype of A-58 which had purple coloration on the surface of the hull, was assumed to be $C^R$ *Sp Rp* by Nagao (1951). The strain 7101 might have the same genotype as A-58. For the coloration of glumes in this strain, the gene "*Hp*" was assumed by Jodon (1948), which however seems to correspond to $C^R$ *Sp Rp*. When these strains were crossed with P-123, the $F_1$ showed a full coloration of the hull, and the $F_2$ segreated into 27 purple and 37 green at the time of heading, as shown in Table 2. However, during maturation, the color tone changed according to genotypes, and at least five classes were distinquished at maturity. The genotypes for the color classes were assumed as shown in table 3.

A-13 showed a brownish coloration of glumes at maturity, though was green at the heading time. Its genotype is $C^R$ *sp Rp* according to Nagao (1951). When crossed with P-123 which has $C^{Rr}$ *sp rp*, a 3:1 ratio was found regarding the brown color of glumes at maturity (Table 4). This can be explained in the same manner as for the apiculus color of P-123 which appears at maturity.

Table 2. Segregation ratio for lemma and palea colorations at heading time, in the $F_2$ of P-123 ($C^{Rr}$ *sp rp*)×7101 ($C^R$ *sp Rp*)

| Classes | Apiculus, lemma and palea purple | Apiculus, lemma and palea colorless | Total |
|---|---|---|---|
| | $C^R$ *Sp Rp* | Other gene combinations | |
| Observed | 120 | 147 | 267 |
| Expected (27:37) | 112.64 | 154.36 | 267 |
| $X^2=0.831$ | | 0.3>P>0.5 | |

Table 3. Segregation ratio for lemma and palea coloration at maturity in the $F_2$ of P-123 ($C^{Br}$ *sp rp*)×A-58 ($C^{B}$ *Sp Rp*)

| Classes | Apiculus, lemma and palea purple | Apiculus purple, lemma and palea green | Apiculus, lemma and palea tawny | Apiculus tawny, lemma and palea white | Apiculus, lemma and palea are red or green at the heading, became straw white at maturation | Total |
|---|---|---|---|---|---|---|
| | $C^{B}$ *Sp Rp* | $C^{B}$ *Sp rp* | $C^{B}$ *sp Rp* | $C^{B}$ *sp rp* | $C^{Br}$ *sp Rp*, $C^{Br}$ *sp Rp* $C^{Br}$ *sp rp*, $C^{Br}$ *sp rp* | |
| Observed | 200 | 69 | 70 | 19 | 80 | 438 |
| Expected (27:9:9:3:16) | 184.78 | 61.59 | 61.59 | 20.54 | 109.5 | 438 |
| $X^2$=11.241 | | | | | 0.02>P>0.05 | |

Table 4. Segregation ratio for lemma and palea colorlation at maturity in the $F_2$ of P-123 ($C^{Br}$ *sp rp*)×A-13 ($C^{B}$ *sp Rp*)

| Classes | Lemma and palea ripening tawny | Lemma and palea ripening white | Total |
|---|---|---|---|
| | $C^{B}$ *sp Rp*, $C^{Br}$ *sp Rp* | $C^{B}$ *sp rp*, $C^{Br}$ *sp rp* | |
| Observed | 431 | 139 | 570 |
| Expected (3:1) | 427.5 | 142.5 | 570 |
| $X^2$=0.115 | | 0.7>P>0.8 | |

## 4. Linkage between colorlation genes and other characters

The characters dealt with in this study were mostly independent of coloration genes. However, the color gene *Sp* was found to be linked with twisted stem gene $ts_1$ or ($ts_2$) in the cross with 7237, Further, the twisted grain gene *ltg* was found to be linked with *df* and $ts_1$ or $ts_2$, as shown in Table 5.

As shown in Table 5, *Sp* and *d* (7237) are linked with a recombination value 37.35%. Since the gene *d* carried by 7237 has not been described in the *Sp* linkage group by Nagao, nor by Jodon in his group IV, it may be considered as new locus to be added to this group. The apiculus color gene *Sp* was also found to be linked with the twisted stem gene provisionally symboled $ts_1$ (or $ts_2$), with a recombination value 22.9%. The $ts_1$ (or $ts_2$) gene was further linked with the twisted grain gene *ltg* with a recombination value 29.57% and with *d* with a recombination value 27.72%.

As shown in Table 6, the linkage between purple hull gene *Rp* and liguleless genes *lg* was found in three crosses. Since *Rp* gene is hypostatic to apiculus coloration, purple hulls in apiculus colored plants were counted in combination with liguleless characters in calculating recombination value. The average recombination value between *Rp* and *lg* genes is 31% in coupling phase. This value is comparable with 28.2% calculated by Nagao and Takahashi (1959).

Strain 8001 is a dwarf plant (about 30 cm in plant height) with purple leaf blade. The dwarfness is a monogenic character. In its cross with 521 (the normal plant

Table 5. The $F_1$ genotypes and recombination values in P-123×7237

| Gene pair | $F_1$ genotype | Phase | AB | Ab | aB | ab | Total | Recombination value % | $X^2$ | P |
|---|---|---|---|---|---|---|---|---|---|---|
| *Sp—d* (3:1)(3:1) | $\frac{C^{Br}\ sp\ +}{C^{B}\ Sp\ d}$ | R | 170 (170.63) | 80 (68.62) | 58 (63.62) | 11 (11.13) | 319 | 37.35±39 | 3.535 | 0.3-0.5 |
| *Sp—ts*$_1$ (*ts*$_2$) (3:1)(9:7) | $\frac{C^{Br}\ sp\ Ts_1\ Ts_2}{C^{B}\ Sp\ ts_1\ ts_2}$ | R | 115 (122.75) | 113 (116.50) | 64 (56.69) | 27 (23.06) | 319 | 22.92±24 | 2.210 | 0.5-0.7 |
| *d—ts*$_1$ (*ts*$_2$) (3:1)(9:7) | $\frac{Lgt\ +}{lgt\ d}$ | C | 218 (215.27) | 17 (23.93) | 32 (23.93) | 52 (55.77) | 319 | 16.37±16 | 5.018 | 0.0-0.2 |
| *ltg—ts*$_1$ (*ts*$_2$) (3:1)(9:7) | $\frac{Lgt\ Ts_1\ Ts_2}{lgt\ ts_1\ ts_2}$ | C | 147 (149.20) | 88 (90.05) | 32 (30.24) | 52 (49.51) | 319 | 29.67±29 | 0.306 | 0.95-0.98 |
| *d—ts*$_1$ (*ts*$_2$) (3:1)(9:7) | $\frac{+\ Ts_1\ Ts_2}{d\ ts_1\ ts_2}$ | C | 155 (150.89) | 95 (88.38) | 24 (28.55) | 45 (51.18) | 319 | 27.72±0.3 | 2.079 | 0.5-0.7 |

height with green leaf blade), linkage was found between *d* and *Pl* genes. Since *Pl* gene is also hypostatic to apiculus coloration the plants having apiculus color were counted in combination of *d* and *Pl* characters in calculating recombination value. The recombination value between *Pl* and *d* was calculated to be 27.4%. According to Nagao and Takahashi (1959), the recombination value between $d_3$ and *Pl* is 35.2%, between $d_2$ and *Pl* is 38.1%. The value of 27.4% obtained in the present study may be comparable with that of 35.2%. Then strain 8001 might be situated at the same locus of $d_3$, otherwise it may be the third dwarf gene belong to group II. However, further study is needed for confirmation.

Linkage between purple leaf blade gene *Pl* and glutinous endosperm gene *gl* was found in the cross between P-138×7102 as shown in Table 6. According to Nagao and Takahashi (1950) *gl* gene is linked with *Pla*, one of allelic genes belongs to *Pl* series, with 44.7% of recombination value. *Pl* gene is independent to *gl* group (or group I). However, 39.6% of recombination value between *Pl* and *gl* was found in the present study. The writer included all purple plants regardless of *Pl*, *Pla* and *Plm* plants in *Pl* class in calculating recombination value, might be the main cause of the difference between two studies. 39.6% recombination value obtained in the present study approches 44.7% that between *Pla* and *gl* genes calculated by Nagao and Takahashi (1959), therefore the *Pl* gene assumed in this study may be the same order as that *Pla*. However, further studies are necessary for this assumption.

One of stigma color genes $Ps_1$ is linked with the phenol reaction gene *Ph* with 17.8% of recombination value in cross of 108×7108 as seen in Table 6.

In the cross of J-308×A-5, linkage between $Ps_1$ and *Rp* was found as seen in Table 6. The recombination value between these two genes was calculated to be 26%. Since $Ps_1$ genes was not included in Nagao's *Pl* group, it may be a new locus to be added to this group.

Table 6. $F_1$ genotypes and recombination values between characters

| Genes in Inkage | Crosses | $F_1$ Genotype | Phase | AB | Ab | aB | ab | Total | Recombination value % | $X^2$ | P | Linkage group |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Rp—lg* (3:1) (3:1) | J-308×7041 | $\frac{C^{Br}\ Sp\ Rp\text{-}lg}{C^{B}\ Sp\ Rp\text{-}Lg}$ | C | 180 (187.44) | 40 (36.06) | 30 (36,06) | 39 (38.44) | 298 | 28.1±2.90 | 1.7532 | 0.9-0.95 | I I |
| *Rp—lg* (3:1) (3:1) | P-167×7101 | $\frac{C^{Br}\ sp\ rp\text{-}lg}{C^{B}\ Sp\ Rp\text{-}Lg}$ | C | 133 (134.27) | 29 (27.72) | 27 (27.72) | 27 (26.27) | 216 | 30.3±3.37 | 0.0990 | 0.99 | II |
| *Rp—lg* (3:1) (3:1) | J-398×A-5 | $\frac{C^{Br}\ Sp\ rp\text{-}lg}{C^{B}\ Sp\ Rp\text{-}Lg}$ | C | 138 (140.79) | 33 (31.70) | 32 (31.70) | 27 (25.78) | 230 | 33.0±3.51 | 0.1460 | 0.7-0.3 | II |
| *Pl—d* (3:1) (3:1) | 521×8001 | $\frac{C\ sp\ pl\text{-}D}{C^{Bp}\ Sp\ Pl\text{-}d}$ | N | 39 (43.57) | 17 (19.42) | 26 (19.42) | 2 (1.57) | 84 | 27.4±0.47 | 3.0100 | 0.3-0.5 | II |
| (?) *Pla—gl* (3:1) (3:1) | P-138×7102 | $\frac{C^{Br}\ sp\ Pl\text{-}gl}{C^{Br}\ Sp\ Pl\text{-}Gl}$ | C | 86 (94.99) | 24 (25.76) | 32 (25.76) | 19 (14.49) | 161 | 39.6+14.51 | 3.8860 | 0.2-0.3 | I |
| *Ph—*$Ps_1$ (3:1) (9:7) | 108×7108 | $\frac{Ph\text{-}Ps_1\ Ps_2}{ph\text{-}Ps_1\ Ps_2}$ | C | 95 (82.69) | 40 (32.91) | 5 (4.42) | 14 (19.25) | 154 | 17.8±7.04 | 4.9120 | 0.1-0.2 | II |
| *Rp—*$Ps_1$ (3:1) (9:7) | J-308×A-5 | $\frac{C^{Br}\ Sp\ rp\text{-}Ps_1\ ps_2}{C^{Br}\ Sp\ Rp\text{-}ps_1\ Ps_2}$ | C | 107 (109.44) | 68 (61.56) | 16 (18.81) | 37 (38.19) | 228 | 26.0±0.49 | 1.1850 | 0.7-0.8 | I I |
| *Lro—C(Sp)* (3:1) (9:7) | P-163×9783 | $\frac{Lro\text{-}C^{Br}\ sp}{lro\text{-}c\ sp}$ | C | 160 (138.37) | 81 (86.37) | 27 (30.37) | 32 (44.62) | 300 | 32.2±4.85 | 7.6890 | 0.05-0.1 | I or IV |

Strain 9783 is a roll-leaved dwarf. A gene *lro* was assigned by Kadam (1943) to this character, *lro* is linked with one of apiculus color genes either *C* or *Sp* with 32.2% of recombination value. It may belong to Nagao's group I or group IV though needed further studies.

## DISCUSSION

Hsieh: Experiments done by other sections can be related with the low yield problem in tropical and subtropical regions. But it seems difficult to link this work to the title of the joint project. Any comment on this point will be much appreciated.

Oka: Genic analysis is a basic research not easily correlated with yield of rice. However, the joint work is based on varietal differences, when different varieties are used there exists genetic problems.

Hsu: Various characters dealt with in your experiment, such as colorations at various organs of the plant, or spreading habit etc, can be related with the yield problem, can't they?

Hsieh: Usually quantitative characters are more closedy related with yield than characters controlled by major genes. It seems however, that genetics on major gene should be done first.

Oka: Segregation ratios, such as 3:1 or 9:7, will be meaningless without studying linkage relations with other characters.

Hsieh: Linkage studies have been our main purpose, before calculating linkages, it is necessary to find the genetic behavior of each characters.

Wu: Genetic study occupies one of the important parts in this joint work. You should deal more with quantitative characters which can be related with yield than major genes such as coloration at various plant organs. Another thing I want to suggest is that the name, Pai-kan-tao, a liguleless variety, must be standarized.

Hsieh: Yes, we will improve this situation.

# c. GENIC ANALYSIS BY RECIPROCAL TRANSLOCATION METHOD

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## 1. Isolation for Reciprocal translocation homozygotes

In order to obtain information on artificially induced translocation in rice, dormant seeds, germinating seeds and panicles just before blossoming of two varieties were X-rayed. More than two hundreds strains thus obtained were observed from the second to the fifth generations after the treatment with regard to fertility and other characters.

In a greater part of strains, fertile and semi-sterile plants were found in approximately 1:1 ratio, while in some other strains, either fertile or semi-sterile plants were predominant; in a few strains, the fertility variation seemed to be continuous. In strains segregating into fertile and semi-sterile plants the former produced no sterile plant in their offspring, while the latter continued segregation. In strains showing continuous variation, the progeny of semi-sterile plants generally showed a similar continuous variation.

In a greater part of strains showing segregation of fertile and semi-sterile plants the latter plants were found to form a quadrivalent chromosome in pollen-mother cells, with different frequencies in different strains. The frequency ranged from 2% to 83%. A majority of those quadrivalent chromosomes were ring-shaped, but some of them showed chain or other shapes. Thus, the majority of the strains observed seemed to posses a segmental interchange.

In the majoriy of strains showing segregation of fertile and semi-sterile plants, semi-sterile plants×original stock (non-treated) showed segregation of fertile and semi-sterile plants like the offspring of semi-sterile plants. In contrast to this, fertile plants×original stock produced either semi-sterile or fertile plants, without segregation within the same cross. Such a behavior of sterility was to be expected in a translocation heterozygote.

Fertile plants which produce semi-sterile plants when crossed with the original variety may be homozygous for a translocation. According to the results of these back-cross experiments, 28 translocation homozygotes were selected from different strains. They were quite similar to the original variety in growth habit.

## 2. Analysis of reciprocal translocations

In order to determine the interrelationship between translocated segments, 28 RT lines isolated by the above mentioned method were intercrossed, and cytological

analysis of the RT lines was made regarding the following respects. In $F_1$s between two RT lines.

1) If all the chromosome paired normally, the parental lines would have the same translocations.
2) If a quardrivalent chromosome was formed, the chromosomes involved in translocations of both lines would be the same, though it is possible that the translocations are situated in different, for instance 1-3 2-4 and 1-4 2-3.
3) If a ring of six chromosome was formed, the parental lines would have one

Table 1. Segregation of fertile and semi-sterile plants after self-fertilization, behavior of sterility in back-cross experiments, and the presence or absence of a quadrivalent chromosome in different strains

| Strain | Self* | | | Back** cross | | Quadri-valent | Strain | Self* | | | Back** cross | | Quadri-valent |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $X_2$ | $X_3$ | $X_4$ | I | II | | | $X_2$ | $X_3$ | $X_4$ | I | II | |
| Xg 108 (ear) | | | | | | | Xs 108 (seed) | | | | | | |
| 1-1-12-11-6 | + | + | + | + | + | | 4-8-5-12-2 | + | + | + | + | + | + |
| 2-6-16-1-6 | + | + | + | + | + | + | Xg 521 (ear) | | | | | | |
| 3-1-17 | + | + | | + | +? | ± | 1-7-1-5 | + | − | + | | + | ± |
| 3-6-1 | + | − | − | − | − | − | 1-8-7-3 | + | + | + | | ? | + |
| 3-11-11-1-1 | + | + | +? | +? | + | + | 1-9-1-3 | + | + | + | | + | |
| 3-18-15 | + | + | − | − | − | − | Xs 521 (seed) | | | | | | |
| 3-19-1 | + | + | − | − | ? | ± | 1-4-2-6-7 | + | + | + | + | + | − |
| 3-21-15-11-1 | + | + | + | + | ? | + | 2-5-6-6-7 | + | + | + | ? | + | + |
| 3-24-13-1-6 | + | + | − | −? | + | + | 3-4-1-8 | + | + | + | | ? | |
| 3-26-19-2-1 | + | + | +? | + | + | + | 3-11-3-3 | + | + | + | | + | − |
| 4-1-2-2 | + | + | + | | + | + | 3-20-15-20 | + | + | − | | ? | + |
| 4-4-2-12 | + | + | + | | + | + | 3-22-1 | + | + | +? | | +? | |
| 4-5-1-11 | + | + | + | | +? | − | 3-29-2 | + | + | + | | + | + |
| 4-6-3-1 | + | + | + | | + | + | 3-32-6 | + | +? | + | | ? | + |
| 4-8-3-11 | + | − | + | | + | + | 3-36-11-12 | + | + | + | | + | + |
| 4-13-2-3 | + | − | − | | ? | + | 3-43-1-2 | +? | + | + | | ? | + |
| 4-20-3-2 | − | + | − | | +? | + | 3-45-3 | + | + | + | | + | |
| 4-21-11-6 | + | + | + | | ? | | 4-5-4-1 | + | + | + | | + | + |
| 4-23-2-2 | + | + | + | | ? | + | 4-15-2-1 | + | + | + | | +? | |
| 5-1-3-1 | −? | + | + | | +? | | 4-28-6-3 | + | + | + | | ? | + |
| Xs 108 (seed) | | | | | | | 4-37-3-13 | + | + | + | | + | − |
| 1-4-5-16-5 | + | + | + | + | + | + | 4-40-1-2 | + | + | + | | ? | |
| 1-10-15-2-6 | +? | + | +? | −? | + | + | 4-45-7-1 | + | + | + | | ? | |
| 2-1-13-7-6 | + | + | + | −? | ? | + | 4-47-1-3 | + | + | + | | +? | |
| 4-1-4-13-11 | + | + | + | ? | ? | | | | | | | | |

*……Self-fertilization, + shows a distinct segregation of fertile and semi-sterile plants.

**……Back-cross experiments, colums I and II show the results of (semi-sterile plant × original variety) and (fertile plants × original variety) respectively; + shows that the results of back-crosses agree with the expectation.

Table 2. Percentage of quardrivalents in PMCs in $F_1$s of intercrosses of 13 reciprocal translocation homozygotes (108)

| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 12II | 30.53 | | | | | | | | | | | | |
| | 1(4) | 69.47 | | | | | | | | | | | | |
| 2 | 12II | 55.56 | 70.16 | | | | | | | | | | | |
| | 1(6) | 37.37 | 29.84 | | | | | | | | | | | |
| | 2(4) | 7.07 | | | | | | | | | | | | |
| 3 | 12II | 84.00 | 11.38 | 45.65 | | | | | | | | | | |
| | 1(4) | 16.00 | 38.83 | 54.35 | | | | | | | | | | |
| | 2(4) | | 49.80 | | | | | | | | | | | |
| 4 | 12II | 60.36 | 26.32 | 29.33 | 77.07 | | | | | | | | | |
| | 1(4) | 22.50 | 26.97 | 25.96 | 22.74 | | | | | | | | | |
| | 1(6) | 17.14 | 46.71 | 44.71 | | | | | | | | | | |
| 5 | 12II | 23.25 | 18.85 | 22.50 | 16.67 | 71.85 | | | | | | | | |
| | 1(4) | 44.30 | 39.34 | 61.88 | 64.59 | 28.15 | | | | | | | | |
| | 2(4) | 32.45 | 41.81 | 15.62 | 15.76 | | | | | | | | | |
| 6 | 12II | 4.14 | 8.07 | 20.69 | 6.51 | 57.07 | 66.67 | | | | | | | |
| | 1(4) | 21.89 | 38.04 | 41.38 | 26.05 | 8.70 | 33.33 | | | | | | | |
| | 2(4) | | 53.89 | 37.93 | 67.44 | | | | | | | | | |
| | 1(6) | 73.97 | | | | 34.23 | | | | | | | | |
| 7 | 12II | 30.20 | 3.85 | 19.11 | 3.33 | 38.48 | 12.76 | 66.00 | | | | | | |
| | 1(4) | 52.97 | 33.08 | 40.13 | 21.67 | 43.03 | 41.27 | 34.00 | | | | | | |
| | 2(4) | 16.83 | | | | 8.49 | 15.95 | | | | | | | |
| | 1(6) | | 63.08 | 10.76 | 75.00 | | | | | | | | | |
| 8 | 12II | | 44.90 | 26.17 | 2.97 | 39.38 | 12.96 | 12.99 | 62.83 | | | | | |
| | 1(4) | | 37.24 | 50.47 | 50.54 | 45.00 | 53.70 | 48.05 | 37.17 | | | | | |
| | 2(4) | | 17.86 | 23.36 | 46.53 | 15.63 | 33.33 | 39.96 | | | | | | |
| 9 | 12II | 82.00 | 20.32 | 11.31 | | 1.01 | 80.53 | 1.20 | | 4.41 | | | | |
| | 1(4) | 17.00 | 52.94 | 49.40 | | 38.38 | 19.47 | 9.64 | | 95.59 | | | | |
| | 2(4) | | 20.74 | 39.29 | | | | 89.16 | | | | | | |
| | 1(6) | 1.00 | | | | 60.61 | | | | | | | | |
| 10 | 12II | 9.71 | | 32.84 | 16.93 | 35.48 | 13.43 | | 75.00 | 4.93 | 22.12 | | | |
| | 1(4) | 47.57 | | 43.53 | 50.79 | 35.48 | 43.28 | | 26.62 | 52.11 | 61.00 | | | |
| | 2(4) | 42.72 | | 18.63 | | 29.03 | 43.28 | | 2.38 | 42.96 | 16.81 | | | |
| | 1(6) | | | | 32.28 | | | | | | | | | |
| 11 | 12II | 1.88 | 7.65 | 1.97 | 13.74 | 5.56 | 81.16 | | | | 5.82 | 11.97 | | |
| | 1(4) | 28.64 | 46.94 | 42.36 | 86.26 | 83.33 | 52.04 | | | | 54.50 | 60.68 | | |
| | 2(4) | 69.48 | 45.41 | | | 11.11 | | | | | 39.68 | 27.35 | | |
| | 1(6) | | | | | | 39.80 | | | | | | | |
| 12 | 12II | 41.14 | 7.73 | 6.67 | | 14.65 | 5.50 | 5.67 | 18.79 | 1.88 | 9.57 | 0.96 | 52.45 | |
| | 1(4) | 22.08 | 63.40 | 56.66 | | 56.69 | 15.00 | 42.55 | 52.35 | 48.87 | 49.87 | 1.90 | 47.55 | |
| | 2(4) | | | 36.67 | | 28.66 | | | 28.86 | | 42.55 | | | |
| | 1(6) | 36.80 | 28.87 | | | | 79.50 | 51.77 | | 49.25 | | 97.14 | | |
| 13 | 12II | 4.40 | 28.57 | 1.89 | | 39.81 | 1.76 | | | 12.00 | 9.23 | 12.26 | 7.18 | 22.32 |
| | 1(4) | 19.78 | 41.35 | 50.94 | | 44.49 | 27.06 | | | 48.00 | 34.62 | 31.60 | 42.54 | 77.68 |
| | 2(4) | | | | | 15.74 | 71.18 | | | 40.00 | 56.15 | 56.13 | 50.28 | |
| | 1(6) | 75.82 | 30.08 | 47.17 | | | | | | | | | | |

Note: 1(4)…one ring of four 2(4)…two rings of four 1(6)…one ring of six

chromosome in common in their translocations.

4) If two rings of four were found, the parental lines would have quite different translocation.

By the above method the RT lines were grouped on the basis of their behavior in respective crosses. The results are shown in Table 2.

## 3. Agronomic characters in RT Homozygotes

The X-ray induced RT homozygotes did not show any marked difference in morphological characters from normal plants. Therefore, it seems that no major genic changes are involved in the translocation lines. However, in agronomic characters which are controlled by polygenes, some changes may or may not occur together with translocations. In view of this respect a number of translocation homozygotes were compared regarding agronomic characters. The RT homozygotes, 10 lines of 108 and 7 lines of 521, 10 lines of 504 were used for field experiment. The results of analysis with regard to various agronomic characters are shown in Table 3.

Table 3. Analysis of variance for various agronomic characters of RT Homozygotes

| Strains | Source of variation | D. F. | Heading time | | Plant height | | Number of tiller | | Number of panicles | | Grain yield | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Mean square | F value | Mean square | F value | Mean square | F value | Mean square | F value | Mean square | F value |
| 108TH | Between lines | 10 | 140.260 | 0.026 | 36.166 | 13.405** | 1.445 | 1.02 | 0.764 | 1.07 | 0.02140 | 2.780* |
| | Replication | 2 | 8.450 | | 0.555 | | 8.351 | | 2.970 | | 0.01950 | |
| | Error | 20 | 5,452.260 | | 2.698 | | 1.415 | | 0.739 | | 0.00770 | |
| 521TH | Between lines | 7 | 1.749 | 2.580 | 10.930 | 2.726 | 1.435 | 1.14 | 1.760 | 1.45 | 0.00307 | 1.480 |
| | Replication | 2 | 0.263 | | 6.210 | | 1.540 | | 1.440 | | 0.05560 | |
| | Error | 14 | 0.679 | | 4.010 | | 1.240 | | 1.210 | | 0.02070 | |
| 504TH | Between lines | 10 | 0.625 | 0.197 | 23.150 | 2.514 | 1.124 | 1.75 | 0.907 | 1.87 | 0.00640 | 1.391 |
| | Replication | 2 | 0.930 | | 39.870 | | 1.315 | | 0.820 | | 0.04400 | |
| | Error | 20 | 0.318 | | 9.210 | | 0.644 | | 0.484 | | 0.00460 | |

*……Significant at 5% level.
**……Significant at 1% level.

As the table shows, no marked differences among lines were seen with regard to various agronomic characters except for a few lines of variety 108. It may be said that translocation lines are generally homogenious in agronomic characters and may be regarded as having the same genotype except for translocations. Accordingly, the translocation method may be used to some extent for locating quantitative characters on chromosomes.

## 4. Genic analysis by reciprocal translocation method

(a) Linkage between the point of breakage and the glutinous gene or the apiculus color gene.

Some of the above mentioned RT homozygores were crossed with glutinous varieties with different combinations of the genes for apiculus coloration (*C* and *Sp*), to investigate the linkage relation of translocations with those genes. The relation between fertility and segregation for the glutinous gene is shown in Table 4.

When a genic difference is involved in a chromosome with translocated segment, the heterozygous plant for that gene should be heterozygous for the translocation, and semi-sterility will result. As Table 4 shows, in the crosses 160×108 TH-6, 563×521 TH-3b and 563×521 TH-6, semi-sterile plants were found mostly among those

Table 4. Relation between fertility and apiculus coloration, and between fertility and glutinous vs. non-glutinous endosperm, in $F_2$s of crosses between a glutinous strain and strains homozygotes for translocations

| Crosses | Seed fertility in $F_1$ | Class | Apiculus | | $X^2$ | Endosperm | | | $X^2$ |
|---|---|---|---|---|---|---|---|---|---|
| | | | Colored | Colorless | | ++ | +*gl* | *gl gl* | |
| 160×108 | | | | | | | | | |
| TH-1 | 29% | F | 26 | 5 | 0·130 | 5 | 17 | 8 | 2.23 |
| | | S | 53 | 15 | | 5 | 46 | 16 | |
| TH-4 | 26 | F | 26 | 12 | 0.135 | 7 | 18 | 13 | 2.16 |
| | | S | 41 | 16 | | 11 | 33 | 13 | |
| TH-6 | 31 | F | 22 | 10 | 0.528 | 8 | 9 | 15 | 5.29** |
| | | S | 35 | 11 | | 7 | 25 | 14 | |
| TH-8 | 24 | F | 34 | 9 | 0.038 | 6 | 21 | 13 | 3.82 |
| | | S | 54 | 13 | | 21 | 31 | 15 | |
| TH-9 | 23 | F | 37 | 6 | 1.720 | 9 | 17 | 16 | 0.01 |
| | | S | 43 | 14 | | 12 | 23 | 21 | |
| TH-11 | 30 | F | 18 | 6 | 0.435 | 3 | 13 | 7 | 1.45 |
| | | S | 31 | 15 | | 7 | 19 | 29 | |
| TH-12 | 33 | F | 40 | 13 | 0.413 | 8 | 20 | 25 | 1.12 |
| | | S | 40 | 17 | | 10 | 24 | 20 | |
| TH-13b | 16 | F | 30 | 4 | 3.014 | 5 | 20 | 9 | 1.32 |
| | | S | 46 | 17 | | 5 | 37 | 21 | |
| TH-15 | 29 | F | 24 | 11 | 1.090 | 8 | 18 | 8 | 0.69 |
| | | S | 50 | 14 | | 11 | 40 | 13 | |
| 108 | 87 | F | 66 | 14 | — | 8 | 51 | 21 | — |
| 563×521 | | | | | | | | | |
| TH-1 | 30 | F | 26 | 16 | 0.114 | 10 | 24 | 8 | 0.64 |
| | | S | 31 | 22 | | 9 | 33 | 10 | |
| TH-3b | 20 | F | 22 | 17 | 0.142 | 12 | 20 | 7 | 8.58** |
| | | S | 29 | 19 | | 4 | 29 | 17 | |
| TH-4b | 16 | F | 30 | 20 | 3.416 | 8 | 25 | 17 | 2.89 |
| | | S | 18 | 26 | | 2 | 24 | 15 | |
| TH-4c | 23 | F | 22 | 18 | 0.191 | 13 | 23 | 4 | 3.83 |
| | | S | 22 | 22 | | 9 | 24 | 11 | |
| TH-6 | 24 | F | 14 | 7 | 0.539 | 6 | 10 | 5 | 2.60 |
| | | S | 20 | 15 | | 5 | 24 | 6 | |
| TH-8 | 24 | F | 23 | 28 | 1.450 | 14 | 23 | 14 | 0.66 |
| | | S | 28 | 21 | | 12 | 26 | 11 | |

F: Fertile plants.
S: Semi-sterile plants.

*……Significant at 5% level.
**……Significant at 1% level.

heterozygous for glutinous vs. non-glutinous endosperm. It seems that the glutinous endosperm gene +:*gl* is involved in the translocated chromosomes. The apiculus coloration gene *C* is linked with *gl*. However, no correlation between semi-sterility and apiculus coloration was found. It may be due to the distance between *C* gene and the point of interchange.

The recombination value between *gl* and interchange point was calculated according to the following formula.

| | AA | Aa | aa |
|---|---|---|---|
| Fertile group | $\frac{1}{4}(1-2p+2p^2)$ | $p\ (1-p)$ | $\frac{1}{4}(1-2p+2p^2)$ |
| Semi-sterile group | $\frac{1}{2}p\ (1-p)$ | $\frac{1}{2}(1-2p+2p^2)$ | $\frac{1}{2}p\ (1-p)$ |

Solving the equations obtained by maximum linkelihood method, the recombination value between *gl* and interchange point in 108×H-6, 521 TH-3b and 521 TH-6 were estimated to be 26%, 39% and 25% respectively.

(b) Relation between translocations and quantitative characters.

Variations in heading date and plant height were compared between fertile and semi-sterile classes of $F_2$ plants to see if genes for these quantitative characters are involved in the translocations under observation. The results obtained is shown in Table 5.

Table 5. Variations in heading date and plant height among fertile and semi-sterile $F_2$ plants

(a) Heading date

| Cross | Class | Sep. | | | | | | Oct. | | | No. of plants | $X^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 20 | 22 | 24 | 26 | 28 | 30 | 2 | 4 | 6 | | |
| 160×108-TH-1 | F | | 1 | | 17 | 16 | 15 | 4 | | | 53 | 15.58** |
| | S | 1 | | | 5 | 10 | 26 | 13 | 1 | 1 | 57 | |

(b) Plant height

| Cross | Class | cm 70 | 75 | 80 | 85 | 90 | 95 | 100 | 105 | 110 | 115 | 120 | 125 | 130 | No. of plants | $X^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 180×108-TH-1 | F | | | | | 7 | 2 | 5 | 11 | 2 | 2 | 8 | | 1 | 31 | 10.78* |
| | S | 2 | | 2 | | 7 | 15 | 22 | 8 | 5 | 5 | | 1 | 1 | 68 | |
| 563×521-TH-4c | F | | 1 | 6 | 2 | 13 | 14 | 4 | | | | | | | 40 | 22.88** |
| | S | | 3 | 11 | 15 | 12 | 2 | 1 | | | | | | | 44 | |

*.....Significant at 5% level.
**.....Significant at 1% level.

As the data in the table shows, in 160×108 TH-2, heading dates in the semi-sterile group were later than those of the fertile group, and the difference was statistically significant. Heading date showed a continuous variation. It then seems that there may be a number of genes are concerned in heading date, and some of them are located in the chromosomes involved in the translocation.

Similar phenomona were also recognized with regard to plant height. As Table 5 (b) shows, in the crosses 180×108 TH-1 and 563×521 TH-4c, the semi-sterile group was lower in plant height than the fertile group being statistically significant. This may indicate that some genes controlling plant height were involved in the chromosome with a translocated segment.

## DISCUSSION

Chang: I would like to suggest Mr. Chiu to add one glutinous variety of Taichung No. 65 which was selected in the genetic loboratory of Provincial Taichung College of Agriculutre in order to test the effect of high temperature to nutrient absobtion in relation to the glutinous gene. How about the idea?

Hsu: I think it is a good idea, you had better cousult this matter with Mr. Chiu, so that you can make chemical analysis.

Tan: I think major genes should be studied in relation with polygenes.

Oka: Yes, we can study them at the same time but it seems necessary to make clear the genetic behavior of major genes first.

Hsieh: I think you had better make reciprecal translocation analysis in more details to get 12 different RT homozygotes which involves all the chromosomes.

Chang: Yes, I am just doing this work and expect to complete this RT analysis in near future. Since it takes quite a lot of cytological labor, I think this work still need some time.

Hsu: What is the difference of your work from Mr. Hsieh's.

Chang: Essentially the same, but the method is different. The linkage relation between genes is usually determined by the common method as practiced by Mr. Hsieh. By the RT method, the genes can be related directly to the chromosomes. Therefore, the linkage groups can be acurately corresponded to the chromosomes. But this method is more laborous than the former.

# RECORD OF DISCUSSIONS AND CONCLUSION

## 1. Hypothesis for the cause of low yield of rice in tropical and sub-tropical regions

The following five points were recorded from our discussions based on the data of our experiments which are still under way:

1. Temperature-sensitivity and photo-sensitivity of varieties

It is known that there are "vegetative" and "reproductive" growing stages in rice. These two stages are usually divided by "flower bud formation stage" which is largely controlled by temperature and day length. The grain yield is always intimately correlated with "basic vegetative growing days". The "basic vegetative growing days" in Temperate zone is relatively longer, therefore carbon assimilation can be made efficiently and the transmission of assimilation products to grains is more efficient. However, in sub-tropical region, the "basic growing days" are always shortened due to high temperature and critical day length. This may be one of the reasons for low yield in that region.

In Taiwan, most Ponlai varieties and native varieties of first crop nature are insensitive to photoperiodic response, and can be grown in both lst and 2nd crops. In contrast, the native varieties of 2nd crop nature are thermo-insensitive and photo-sensitive, and can not be grown in lst crop. These photo-sensitive varieties can not be grown vigorously under the short-day condition and needed to prolong "the days of vegetative growth" so that the grain yield can be promoted.

From practical point of view, it is suggested that, in Frigid and Temperate zones, it is better to plant eary-maturity varieties which are generally highly sensitive to temperature and insensitive to photoperiodic response. In sub-tropical zone, the medium-maturity variety, whose response to temperature is low but sensitive to daylength. Wherease, the late-maturity varieties which are less sensitive to temperature and highly sensitive to photoperiod are suggested to be grown in Tropical zone.

2. Effect of temperature and fertilizer on flower-bud-formation

As discussed previously, "basic vegetative growing days" is usually determind by flower-bud-formation stage. This stage is largely controlled by high temperature and soil fertility condition. Under sub-tropical climate, "Premature heading" resulted from early formation of flower bud due to high temperature (Otani and Siraki 1942) and soil fertility (Terao and Katayama 1929) is reported. The similar phenomenon is also frequently observed in 2nd crop of Taiwan. Such "premature heading" causes multiform of plant growth and bring about to affect the grain yield. This may be another reason for low yield under high temperature condition.

3. Relation between temperature and fertilizer response

In Taiwan, it is known that the fertilzer application efficiency of native varieties (Indica type) is smaller than that of Ponlai (Japonica type) varieties. The increment of panicle number by fertilizer application is larger, but that of plant height, and number of grains per panicle is smaller. Such difference in fertilizer response in 2nd crop (high temperature) is larger than that of lst crop (low temperature), Oka (1954). The increment of panicle number with fertilizer application is higher in Japonica varieties, especially those in Temperate zone, but the reverse is true in Indica varieties.

Under sub-tropical climate, efficiency of fertilizer application is relatively small (Camus 1921, Iso 1944). It is considered that Indica varieties (especially photosensitive varieties) may be more adaptable to high temperature condition. However, in Taiwan, the yield of native varieties in second crop which is under relatively higher temperature is generally lower than that of Ponlai varieties. This may be due to a decrease of fertilizer response. It is then inferred that under high temperature the low increment of yielding capacity by fertilizer application may be due to a reduction of fertilizer response. Further, varieties which show low fertilizer response is more numberously cultivated in Tropical regions than those showing high fertilizer response.

4. Crop nutrition and yield of rice in relation to climate

In the previous study we pointed out that high temperatures increased plant weight and nutrient absorption, but it didn't always result in an increase of grain yield. So the plants always might respond to high temperature by making a very large increase in straw growth which is accompanied by a disappointing yield of grain. In the first and second crops in Taiwan, the straw/grain weight ratio of the yield of rice is noted as 110/100 and 120/100 respectively. Due to the rapid growth of rice under high temperature the absorbed nutrients may tend to be consumed for the formation of leaves and stems and for respiration, leaving little for the production of grains. It is also commonly known in Japan that the straw/grain weight ratio in warm climatic area is larger than that in cold climatic area. The status of nutrient absorption is apparently different in the both areas.

Our results also showed that the loss of nitrogen in flooded soils was mostly caused by denitrification and it was accelerated under high temperatures. The loss of nitrogen took place remarkably in the first and second month after flooding and increased in neutral and limed acidic soils. Paddy soils with easily decomposable organic matter bring about strong reducing power of soil under high temperature which cause physiological disease or low yield of rice as frequently found in Taiwan and tropical regions. It was reported that the affected plants always come under high temperature with low Eh of soils. Climate and soil condition play an important role in nutrient absorption which is one of the factors affecting the crop yield. The nutritional study of rice would also taken important part in solving the low yield of rice in tropical countries.

5. Prevalence of blast disease under sub-tropical climate

Blast disease caused by *Piricularia Oryzae* seriously damages rice in the most rice growing areas. According to Ito (1932), blast disease can be easily controlled in low temperature zone. However, in Taiwan (sub-tropical zone) the blast disease can not be effectively controlled, because of suitable temperature and humidity condition for the growth of blast fungus.

Temperature is the main factor for the prevalence of blast disease in Temperate zone. Usually at 20°–30°C and 90% of humidity, the disease preveils seriously. In sub-tropical region, the disease prevalence is controlled by age difference of plant in addition to temperature effect. Other factors relative to yield of rice remain to be studied.

Based on the above mentioned considerations, the interrelation of factors affecting low yield of rice in tropical and sub-tropical regions are further assumed as shown in the following diagram:

| | High temp. condition | | Low temp. condition | |
|---|---|---|---|---|
| | Intensive cultivation | Extensive cultivation | Intensive cultivation | Extensive cultivation |
| Photo-sensitive varieties | × | 1. Tropical Indica type<br>2. Taiwan native rice (2nd crop nature) | Japonica varieties | 1. Japanese Native rice<br>2. Montaninous native rice of Taiwan |
| Photo-insensive varieties | Ponlai varieties | 1. Tropical Insular type<br>2. Taiwan native rice (1st crop nature)<br>3. Indian "Aus" varieties | 1. Ponlai varieties<br>2. Taiwan native rice (1st crop nature) | × |

1. Under high temperature conditions, most photo-sensitive varieties cultivated extensively belong to the Indica type, e. g. Taiwan native varieties of the second crop nature. These photo-sensitive varieties may not be adapted to intensive cultivation.
2. Under high temperature conditions, photo-insensitive varieties such as the Tropical Insular type, Taiwan native (1st crop nature) and "Aus" of India are cultivated. Ponlai varieties of Taiwan are also cultivated with a intensive cultivation technique.
3. Under low temperature conditions, photo-sensitive varieties intensively cultiveted are Japonica varieties.
4. Under low temperature conditions, photo-insensitive varieties adaptable to intensive cultivation are mostly Ponlai varieties and Taiwan native varieties of the first crop nature.

## 2. Problems related to researches

1. Method of experiment:

   One should carry on his experiment keeping his "hypothesis" in mind.
2. The ranges of materials and experimental conditions:

The object of our research program is to study the cause of low yield in sub-tropical and tropical Asia. Therefore, the materials must be taken widely from various regions. The probability of an idea being obtained from experiments may be related to the range of materials used in a certain manner.

3. Relation between genotype and environmental factors:
   The interaction between these two must be looked for.
4. Terms used in experiment should each have a certain definition. For instance, the term "thermo-sensitivity" included temperature responses in different phases of growth.
5. The obtained date must be analyzed statistically.

## 3. Problems for future studies

1. The majority of native varieties cultivated in sub-tropical region are photo-sensitive. What is the reason for this trend?
2. The native varieties of second crop habit in Taiwan are photo-sensitive while those of first crop habit are photo-insensitive. Therefore, the varieties of first crop habit can be grown in the second crop, though those of second crop habit can not in the first crop. When the varieties of first crop habit were planted in second crop season, however the yield is always relatively low. The reason of this low yield must be studied with regard to photoperiodism.
3. Together with varietal differences in photosensitivity, transmission of nutrient in rice plant at the stage of flower-initiation must be taken into consideration.
4. How do time of flower-initiation, and number of days of vegetative growth, differ under different temperatures? How does the fertilizer application a few weeks before flower-initiation benefit the plants?
5. How is the relation between duration of vegetative growth and yield? Whether or not yield increases with the increase of carbon assimilation due to the exposure of plants to sun-light for a longer time?
6. Varietal difference in fertilizer response in accordance with changing temperatures and day lengths.
7. Fertilizer response in the second crop is generally lower than that to the first crop. What is the reason for this, and there varietal difference in this trend?
8. Linkages of genes for blast disease resisitant with other genes.
9. For growing photo-sensitive variety in the second crop, there may be two trans-planting dates (first at May, second at June), between which the difference in nutrient absortion may be investigeted and the effect of photo-sensitivity on nutrient absorption may be evaluated, comparing varieties of both Japonica and Indica types.
10. Relation between nutrient absorption and growing period.
11. Besides the development of root system, more emphasis should be laid on the transmission of nutrient in plant.

12. In agronomy section, varieties to be used should be increased. We had better increase up to 12 varieties including native varieties of both the first and second crop nature and those from Tropical Asian countries.
13. In addition to photo-insensitive native varieties of the first crop nature (Pai-mi-fen, etc), those of the second crop nature (Min-tan, Chin-kao-tsan, Swan-chian etc) must also be investigated.
14. Differences in soils, especially in the content of orgaic matter under different temperature zones is a problem to be studied.

The above problems can be summarized as follows:

| | Same variety | Different varieties |
|---|---|---|
| High temp. vs. Low temp. | 1. Nutrient absorption<br>2. Nutrient transmission | 1. Difference in fertilizer response<br>2. Difference in fertilizer and temp. responses |
| Photo-sensitive vs. Photo-insensitive | (long day-short day)<br>1. Nutrient absorption<br>2. Response in yield | (long day-short day)<br>1. Difference in fertilizer response<br>2. Difference in temp. response |

The above problems will be studied under a condition of intensive cultivation.