

Combining Ability Analysis and Selection Effectiveness for Tolerance to Cold-Induced Sterility in Rice

Huhn Pal Moon* and J. Neil Rutger**

벼 障害型 耐冷性の 組合能力檢定과 選拔效果

文憲八* · 존 닐 랫거**

ABSTRACT

Cold-induced sterility is a problem of rice (*Oryza sativa* L.) production in temperate regions and high elevation tropics. The present study was conducted to measure combining ability, determine character associations, and to evaluate effectiveness of F_2 selection for tolerance to this type of cold injury.

The F_1 , F_2 , F_3 and reciprocal backcross F_1 populations of a nine-parent diallel were grown at Davis, California, a relatively cool location for rice. Additive genetic variance was predominant but some non-additive genetic variance existed for cold tolerance. Good general combining ability (GCA) was generally associated with the cold tolerant parents, 'M-101' and 'L-201', and poor GCA with the most susceptible parent, 7703008.

Sterility was positively correlated with late heading, negatively with mature plant height, and negatively with spikelet number. Of the three agronomic characters, heading date had the greatest influence on sterility.

Selection of F_2 's in seven crosses involving M-101, the most cold-tolerant parent, was effective for increasing cold tolerance. Realized heritability estimates for cold tolerance averaged 0.53, and observed selection response for cold-induced sterility averaged -9.4 percentage points.

Additional index words : *Oryza sativa* L., realized heritability, cold tolerant donors.

INTRODUCTION

In temperate environments and the high elevation tropics low temperatures during the early reproductive stage often induce spikelet sterility in rice. This cold-induced sterility results from abortive pollen formation during microsporogenesis, which occurs 10 to 14 days before heading (Satake and Hayase, 1970; Peterson et

al., 1974)^{7,9)}.

In northern Japan poor rice crops due to cold damage in the summer occurred in 26 of the 100 years since rice farming began in that region (Shibata, 1979)¹⁰⁾. In Taiwan, cool temperature during the second crop season induced cold damage which caused yield losses of 42 to 70 percent (Lin, 1971)⁹⁾. In Korea, Chung (1979)³⁾ reported that cold injuries occur both at early and late season stages.

* 作物試驗場(Crop Experiment Station, RDA, Suwon 440-100, Korea)

** 캘리포니아 大學校(美農務省)(USDA-ARS, Department of Agronomy and Range Science, University of California, Davis, CA 95616 U.S.A.) '88.11.22 接受

Cold-induced spikelet sterility is a problem in California when night temperatures fall below 15C over a prolonged period prior to heading (Rutger and Peterson, 1979)⁸⁾. Field surveys showed that the spikelet sterility ranged from 3.8 to 25.5 percent among 40 fields in 1971, and from 2.7 to 34.8 percent among 59 fields in 1972 (Peterson et al., 1974)⁷⁾. Breeding efforts to minimize cold-induced sterility have been underway in California since the early 1970's (Carnahan et al., 1972).²⁾

In Japan Toriyama and Futsuhara (1960)¹²⁾ reported that the heritability for cold tolerance in F_2 populations was comparatively high, 64 percent, even though cold tolerance was complex with a polygenic system of more than seven effective factors involving dominance and additive effects. Futsuhara and Toriyama (1969)⁴⁾ found that actual F_3 selection responses agreed well with predicted responses. Genes governing cold tolerance in Japanese cultivars were reported to be associated with 20 gene markers which are distributed over nine of 12 linkage groups (Takahashi, 1974)¹¹⁾. Cold induced-sterility has been reported to be positively correlated with increased plant height (Toriyama and Futsuhara, 1962)¹³⁾ and with late maturity in California (Board et al., 1980)¹⁾. However, short statured cultivars were more tolerant in California because their young panicles were protected by being below the water level, where temperature was 5-6 C warmer than that of the air on cool nights (Board et al., 1980)¹⁾.

The present study was carried out 1) to measure the combining ability of several rice cultivars for tolerance to cold-induced sterility, 2) to determine character associations with cold tolerance, and 3) to evaluate the effectiveness of F_2 selection for tolerance to cold-induced sterility.

MATERIALS AND METHODS

A nine-parent diallel cross was made, using three parents known to show high cold-induced sterility, 'Labelle', 7703008, and 7701074, four

with intermediate sterility, 7402003, 7802003, 7801067, and 'Skybonnet', and two with low sterility, 'M -101' and 'L -201', based on previous performance at Davis, California. At this location the average minimum air temperature during the reproductive stage of rice often is below 15C, occurring at night between 2200 to 0800 hours. The first seven parents are from southern US breeding programs, and the latter two are from California. Crosses and reciprocal backcrosses were made in the greenhouse in 1978 and 1979, respectively.

In 1979 sterility percentages of the nine parents were compared in a direct-seeded test. Two seeds were sown per hill and thinned to one seedling per hill at the 5-6 leaf stage. The experimental design was a randomized complete block with four replications. Each plot consisted of two 2.4 m long rows, 0.3 m apart. Hills were spaced 0.15 m apart, allowing a final population of 17 plants per row.

Heading date was recorded as the number of days from seeding to full exertion of the first panicle on the plant. Mature plant height was measured from ground level to the tip of the panicle of the longest tiller of the plant. The two earliest heading panicles were collected on each of 15 individual plants in the center of the rows and sterile and fertile spikelets were counted to obtain sterility percentages.

Statistical analysis was performed on the plot means. In 1980 the direct-seeded test was repeated, and a transplanted test was also conducted. Pre-germinated seeds of a set of nine parental genotypes were planted in the greenhouse, and subsequently transplanted in the field at 5-6 leaf stage at one plant per hill. Final spacings and data collection in the two 1980 tests were the same as in the 1979 test.

In 1980 the parents, F_1 , F_2 , F_3 , B_1F_1 and B_2F_1 generations were evaluated in a combining ability experiment. Two seeds per hill of the F_2 , F_3 and the 9 parents were direct-seeded. One week later pre-germinated seeds of F_1 , B_1F_1 , and B_2F_1 generations were planted in jiffy pots in the

greenhouse, and three-week old seedlings (5-6 leaf stage) subsequently were transplanted in the field. At the time of transplanting the direct-seeded hills were thinned to a single plant per hill. The experimental design was a two replicate split-plot, with cross combinations as main plots, and the different generations in a cross as subplots. Each subplot consisted of one row each of F_1 and both parents, two rows each of reciprocal backcrosses (B_1F_1 and B_2F_1), eight rows of F_2 , and five rows of the F_3 generation. The F_3 populations were constituted by composition equal amounts of seed from 30 random F_2 plants grown the previous year. Each row was 2.4 m long which allowed for 17 plants at 0.15 m apart. Row width was 0.3 m. Every third row was skipped to reduce plant competition as well as for experimental convenience. Data were collected on 15 center plants of each row.

An F_2 selection experiment within M-101 crosses was initiated in 1979. Two seeds were directly planted in hills spaced 0.15 m apart, in rows 5.1 m long and 0.3 m apart, allowing 35 hills per row, and thinned to a single plant per hill at three weeks after emergence. The experimental design was a single replicate with crosses, parents, and generations completely randomized. The F_2 plots consisted of 10 rows, or 350 plants. One cross, M-101/7701074, was not available for this test. Parental plots were represented by eight single rows. Heading date, percentage sterility, and the total number of spikelets were recorded for each plant. In 1980 two different F_3 populations derived from each of seven M-101 crosses, plus parents, were planted in a split plot design with two replications to evaluate selection effects for cold-induced sterility. Each selected F_3 population was derived by selecting the 5% of the corresponding F_2 generation with the lowest sterility, and each random F_3 population was derived by compositing an equal amount of seed from 30 random F_2 plants. All other treatments were similar to the combining ability experiment described above.

Combining ability analysis was conducted based

upon the experimental method 2, model I of Griffing (1956)⁹.

RESULTS AND DISCUSSION

Genotype Response to Different Environments

Both year and planting effects were highly significant for cold-induced spikelet sterility in the nine parents, with sterility in direct seedings averaging 43.1% in 1979 and 52.0% in 1980, reflecting slightly lower temperatures in 1980 at the early stages of rice growth, which caused delayed growth and heading (Table 1). In the 1980 comparison of direct-seeded and transplant methods, sterility under transplanting (36.7%) was lower than under direct seeding (52.0%), suggesting possible escape of cold stress, related to field planting time.

Parents M-101 and L-201 showed less sterility and were more stable for cold tolerance over the three different environmental conditions than the other parents (Table 1). Correlations of spikelet sterility of genotypes between pairs of planting environments were $r=0.84^{**}$ for 1979 direct-seeded versus 1980 direct-seeded, $r=0.82^{**}$ for 1979 direct-seeded versus 1980 transplanted, and $r=0.97^{**}$ for 1980 direct-seeded versus 1980 transplanted. The last correlation indicates that comparisons made within the large combining ability experiment in 1980 were valid even though some generations within this experiment were direct-seeded and others were transplanted.

Combining Ability Analysis

Genotype effects for cold-induced sterility were highly significant in each generation in this experiment. The combining ability analysis showed that both GCA and SCA mean squares were highly significant in each of the five generations (Table 2). High GCA/SCA ratios in Table 2 suggested that additive genetic variation was more important than non-additive for cold induced-sterility. The large differences of GCA/SCA ratios between reciprocal backcross generations indicate the existence of maternal effects for

Table 1. The percent spikelet sterility and days to heading of 9 parent genotypes grown under spaced direct-seeded (D) and transplanted (T) conditions in 1979 and 1980.

| | Spikelet sterility † | | | | Drys to Heading † | | | |
|-----------|----------------------|-------|-------|--------|-------------------|-------|-------|------|
| | 1979D | 1980D | 1980T | Mean | 1979D | 1980D | 1980T | Mean |
| M-101 | 18.4 | 14.8 | 15.3 | 16.2a | 97 | 112 | 112 | 107 |
| 7703008 | 64.6 | 89.9 | 65.3 | 73.2c | 125 | 132 | 137 | 131 |
| 7801067 | 53.6 | 63.9 | 43.7 | 53.7b | 119 | 128 | 134 | 127 |
| Skybonnet | 63.3 | 56.5 | 42.9 | 54.3b | 117 | 125 | 130 | 124 |
| L-201 | 16.0 | 19.1 | 16.3 | 17.1a | 116 | 123 | 126 | 122 |
| 7402003 | 32.1 | 50.4 | 42.4 | 41.7b | 113 | 124 | 126 | 121 |
| Labelle | 63.5 | 62.4 | 36.3 | 50.4b | 120 | 126 | 131 | 126 |
| 7802003 | 19.7 | 36.9 | 23.8 | 26.8ab | 113 | 125 | 135 | 124 |
| 7701074 | 56.7 | 74.0 | 44.2 | 58.3bc | 117 | 121 | 141 | 123 |
| Average | 43.1 | 52.0 | 36.7 | | 115 | 124 | 129 | |
| S.E. | 3.9 | 8.1 | 11.9 | 5.5 | | | | |

† Values are means of four replications, and underlines and the same letters indicate non-significant differences at 5% level within genotypes and between genotypes, respectively.

Table 2. Mean squares for combining ability analysis of spikelet sterility in the F_1 , F_2 , F_3 , B_1F_1 , and B_2F_1 , in the nine-parent diallel cross. Analysis based on plot means.

| Source | df | Mean squares | | | | |
|---------|----|--------------|-----------|-----------|----------|----------|
| | | F_1 | F_2 | F_3 | B_1F_1 | B_2F_1 |
| GCA | 8 | 619.10** | 1181.62** | 1200.55** | 977.23** | 272.90** |
| SCA | 36 | 233.96** | 115.19** | 116.53** | 205.33** | 270.57** |
| Error | 44 | 60.80 | 58.95 | 73.01 | 53.47 | 58.75 |
| GCA/SCA | | 2.7 | 10.3 | 10.3 | 4.8 | 1.0 |

*, ** Significant at 5 and 1% levels, respectively.

tolerance of cold induced-sterility in rice, depending upon the genetic constitutions of recurrent genotypes.

For cold tolerance as measured by spikelet sterility, negative values for combining ability effects for parental entries indicate a desirable average performance for the character in the cross combination. Thus good GCA effects for cold tolerance were invariably associated with the cold tolerant parents, M-101 and L-201, and the poorest GCA with the most susceptible parents, 7703008 and 7701074, over generations (Table 3). L-201 showed consistently good GCA effects over all generations, and M-101 showed strong GCA effects in F_2 , F_3 and B_1F_1 generations. These results generally indicate that the tolerant parents possessed more favorable genes for cold tolerance than the less tolerant ones. Four crosses, M-101/7703008, M-101/Labelle, L-201/7703008, and L-201/Labelle generally exhibited desirable (nega-

tive) SCA effects over generations for cold tolerance (Table 4), suggesting the existence of considerable non-allelic interaction effects. The magnitudes of SCA variances associated with each parent were variable (Table 4). Although M-101 had GCA, it had generally high SCA variances and had consistently good SCA effects for cold tolerance with the susceptible genotypes 7703008 and Labelle, over generations. L-201 showed the best GCA for cold tolerance with almost uniform high GCA variances over generations. The high GCA and relatively smaller SCA variances of L-201 suggested stable transmission of cold tolerance to its progenies over generations. Although the later maturity of L-201 relative to M-101 may be less desirable, L-201 is also a good donor of cold tolerance.

Character Associations with cold Tolerance

Highly significant, positive phenotypic (r_p) and

Table 3. The observed parental mean values and general combining ability (GCA) effects for the percent sterility in the F_1 , F_2 , F_3 , B_1F_1 , and B_2F_1 of the 9-parent diallel in 1980.

| Parents | Mean percent sterility | GCA effects | | | | |
|-------------|------------------------|-------------|----------|----------|----------|----------|
| | | F_1 | F_2 | F_3 | B_1F_1 | B_2F_1 |
| M-101 | 14.57 | -3.25 | -18.74** | -18.18** | -12.99** | -3.35 |
| 7703008 | 91.12 | 10.05** | 13.37** | 14.31** | 18.39** | 4.59* |
| 7801067 | 62.96 | 2.29 | 5.21* | 2.08 | 0.94 | 1.73 |
| Skybonnet | 55.82 | -0.46 | 5.66* | 5.58* | 4.89* | -0.29 |
| L-201 | 21.06 | -14.11** | -14.24** | -14.49** | -13.10** | -10.88** |
| 7402003 | 52.87 | -4.58* | -0.64 | -0.46 | 1.14 | -0.99 |
| Labelle | 70.64 | -2.36 | 5.03* | 4.76 | 0.16 | 1.27 |
| 7802003 | 36.83 | 2.30 | -1.85 | -1.74 | 2.02 | 1.65 |
| 7701074 | 71.95 | 10.12** | 6.20* | 8.14** | 1.45 | 6.28** |
| S.E (gi) | | 2.22 | 2.28 | 2.43 | 2.08 | 2.18 |
| S.E (gi-gj) | | 3.32 | 3.27 | 3.64 | 3.12 | 3.27 |

*, ** Significant at 5 and 1% levels, respectively.

Table 4. Specific combining ability (SCA) effects, and estimates of specific (σ_{si}^2) and general (σ_{gi}^2) combining ability variances for cold induced-sterility in the five generations of 15 crosses involving M-201 derived from the 9-parent diallel cross.

| | | SCA Effects | | | | | | | σ_{si}^2 | σ_{gi}^2 | |
|-------|----------|-------------|---------|-----------|-------|---------|---------|---------|-----------------|-----------------|----------|
| | | 7703008 | 7801067 | Skybonnet | L-201 | 7402003 | Labelle | 7802003 | | | 77010074 |
| M-101 | F_1 | -10.3 | 21.4 | 2.6 | -11.3 | 19.9 | -7.5 | 5.3 | 27.4 | 223.6 | 5.7 |
| | F_2 | -21.3 | -3.5 | 10.7 | 7.2 | 13.3 | 5.0 | 14.3 | -16.1 | 126.6 | 346.3 |
| | F_3 | -24.1 | -9.3 | 4.5 | 22.6 | -0.1 | -13.0 | 5.6 | 11.4 | 155.2 | 324.7 |
| | B_1F_1 | -19.6 | 5.3 | 1.4 | 6.3 | 15.2 | 5.0 | 1.7 | -5.4 | 59.9 | 164.4 |
| | B_2F_1 | -8.6 | -8.9 | 3.3 | -2.9 | 9.4 | -13.5 | 24.5 | 34.9 | 272.2 | 6.5 |
| L-201 | F_1 | -6.3 | -14.2 | 17.5 | - | 11.4 | -4.7 | 8.1 | -10.1 | 96.0 | 194.2 |
| | F_2 | -3.9 | 1.7 | 0.2 | - | 06.7 | -12.1 | 13.2 | 4.9 | 6.8 | 198.0 |
| | F_3 | -6.4 | -7.1 | 4.9 | - | -11.0 | -1.4 | -1.0 | -1.0 | 44.7 | 204.2 |
| | B_1F_1 | 6.2 | -12.1 | 11.6 | - | -4.7 | -9.6 | -2.1 | -9.1 | 33.9 | 167.2 |
| | B_2F_1 | 2.9 | -10.8 | -2.3 | - | 2.7 | 3.9 | 8.5 | -1.0 | -10.3 | 113.7 |

genotypic (r_G) correlations between sterility and heading date were observed in all generations, meaning that cold tolerance was positively associated with early maturity (Table 5). Values of r_G similar to r_p values suggest that genetic relationships dominated environmental relationships. The partitioning of additive (r_a) and non-additive (r_n) genetic correlations from genotypic correlations indicated that the additive genetic correlations were larger and more stable over generations.

Significant negative correlations were observed between sterility and plant height in segregating generations, with the additive genetic correlation component larger than the non-additive component in three of the four cases. This indicates that cold tolerance is associated with tall plant height,

which agrees with the result from a cold water study in Japan (Toriyama and Futsuhara, 1962)¹³⁾ This seems to be in contradiction to the results of Board *et al.* (1980)¹¹⁾, who found that the semidwarf cultivar 'Calrose 76' exhibited significantly less sterility than its tall parent, 'Calrose'. In that study, increased water depth and decreased plant height reduced sterility by placing the young panicles under the water, which is usually 5 to 6 C warmer than the air temperature at the coldest part of the night in California rice growing regions. Also, there was no difference in heading date between the semidwarf 'Calrose 76' and the tall 'Calrose', whereas in the present study segregation occurred for heading date as well as height.

Negative correlations were generally found

Table 5. Phenotypic (r_p), genotypic (r_G), general combining ability (r_g ; additive), and specific combining ability (r_s ; nonadditive) correlation coefficients of cold induced-sterility with days to heading, plant height, and spikelet number per panicle in the five generations derived from the 9-parent diallel.

| Coefficient | Generation | | | | |
|-------------|--------------------------------------|----------------|----------------|-------------------------------|-------------------------------|
| | F ₁ | F ₂ | F ₃ | B ₁ F ₁ | B ₂ F ₁ |
| | <u>Sterility vs. Days to heading</u> | | | | |
| r_p | 0.34* | 0.79** | 0.75** | 0.68** | 0.61** |
| r_G | 0.44** | 0.82** | 0.75** | 0.68** | 0.58** |
| r_g | 0.61 | 0.82 | 0.83 | 0.81 | |
| r_s | 0.41 | 0.93 | 0.35 | 0.57 | 0.81 |
| | <u>Sterility vs. Plant height</u> | | | | |
| r_p | -0.23 | -0.56** | -0.51** | -0.60** | -0.32* |
| r_G | -0.28 | -0.55** | -0.44** | -0.71** | -0.40* |
| r_g | -0.78 | -0.69 | -0.53 | -0.97 | -0.06 |
| r_s | -0.06 | -0.21 | -0.03 | -0.37 | -0.56 |
| | <u>Sterility vs. spikelet number</u> | | | | |
| r_p | -0.22 | -0.40** | -0.41** | -0.62** | -0.24 |
| r_G | -0.24 | -0.12 | -0.23 | -0.71** | -0.06 |
| r_g | -0.82 | -0.24 | -0.25 | -0.86 | -0.57 |
| r_s | 0.05 | -0.20 | -0.21 | -0.58 | 0.03 |

*, ** Significant at 5 and 1% levels, respectively.

between sterility and spikelet number per panicle (Table 5, which may aid progress in selection for desired combinations of these two characters. Of the three agronomic characters, heading date had the greatest influence on sterility, reflecting the declining temperatures late in the growing season.

Effectiveness of F₂ Plant Selection

The mean sterility of the selected F₂ plants of the seven crosses having M-101 as a common parent averaged 6.7 percent while unselected F₂ populations averaged 24.3 percent sterility (Table 6). The mean sterility of the selected F₃ populations was 21.6 percent, compared to the mean sterility of 31.0 percent for the random F₃

Table 6. Population size (N), means (\bar{X}), selection responses (R and \hat{R}) and realized heritability (h^2_R) for spikelet sterility in F₂ and F₃ populations of seven rice crosses.

| Cross | 1979 F ₂ Populations | | | | 1980 F ₃ Populations | | | | Selection response | | |
|---------------|---------------------------------|-----------|-----------------------|-----------|---------------------------------|-----------|----------------|-----------|--------------------|-----------|---------|
| | Unselected | | Selected [†] | | Random | | Selected | | R | \hat{R} | h^2_R |
| | N | \bar{X} | N | \bar{X} | N | \bar{X} | N [‡] | \bar{X} | | | |
| M-101/7703008 | 319 | 20.7 | 16 | 5.5 | 120 | 21.9 | 480 | 11.7 | -10.2 | -15.2 | 0.67 |
| /7801067 | 199 | 29.1 | 10 | 8.5 | 135 | 24.3 | 300 | 19.9 | -4.4 | -20.6 | 0.21 |
| /Skybonnet | 168 | 23.0 | 9 | 5.9 | 150 | 41.7 | 270 | 29.1 | -12.6 | -17.1 | 0.74 |
| /L-201 | 367 | 23.6 | 20 | 7.0 | 150 | 39.4 | 600 | 24.8 | -14.6 | -16.6 | 0.88 |
| /7402003 | 229 | 19.5 | 12 | 4.8 | 150 | 31.1 | 360 | 19.5 | -11.6 | -14.7 | 0.79 |
| /Labelle | 217 | 20.1 | 11 | 6.9 | 148 | 23.4 | 330 | 17.0 | -6.4 | -13.2 | 0.48 |
| /7802003 | 286 | 34.6 | 14 | 8.2 | 119 | 35.5 | 420 | 29.4 | -6.1 | -26.4 | 0.23 |
| Average | | 24.3 | | 6.7 | | 31.0 | | 21.6 | -9.4 | -17.6 | 0.53 |

[†]Best 5 percent for low sterility

[‡]Total number of plants, 30 plants per lines which are equal to N of selected F₂.

R = F₃ selected - F₃ random, \hat{R} = F₂ selected - F₂ unselected.

h^2_R = Realized heritability calculated by R/ \hat{R} .

Table 7. Means (\bar{X}) and standard deviations (S) for days to heading, plant height, and the number of florets per panicle for random and selected F_3 populations, selected for low sterility in 7 rice crosses.

| | Days to heading | | | | Plant height, cm | | | | No. florets/panicle | | | |
|--|-----------------|-----|------------|-----|------------------|------|------------|-----|---------------------|------|------------|------|
| | Random † | | Selected ‡ | | Random † | | Selected ‡ | | Random † | | Selected ‡ | |
| | \bar{X} | S | \bar{X} | S | \bar{X} | S | \bar{X} | S | \bar{X} | S | \bar{X} | S |
| M-101/7703008 | 122 | 4.6 | 118 | 3.2 | 84.2 | 6.9 | 87.9 | 5.1 | 149.6 | 33.0 | 157.4 | 24.3 |
| /7801067 | 118 | 6.8 | 120 | 3.4 | 95.3 | 8.8 | 96.5 | 7.9 | 168.5 | 32.6 | 172.5 | 28.4 |
| /Skybonnet | 125 | 4.3 | 125 | 3.2 | 96.6 | 10.9 | 99.9 | 7.9 | 137.9 | 36.1 | 136.8 | 24.0 |
| /L-201 | 123 | 5.6 | 122 | 3.4 | 95.5 | 12.2 | 99.1 | 7.8 | 154.5 | 41.9 | 133.6 | 23.7 |
| /7402003 | 117 | 3.2 | 117 | 2.5 | 96.4 | 10.6 | 98.4 | 7.0 | 170.6 | 30.3 | 172.0 | 21.9 |
| /Labelle | 117 | 3.6 | 116 | 3.0 | 97.9 | 11.9 | 104.5 | 8.3 | 182.6 | 33.8 | 182.1 | 29.8 |
| /7802003 | 125 | 7.2 | 122 | 5.1 | 85.4 | 8.1 | 91.5 | 7.1 | 150.1 | 33.3 | 147.8 | 25.7 |
| Standard Error (LSD _{0.05, 13 df}) | | | | | | | | | | | | |
| Between populations | | | 1.66(3.6)§ | | 1.34(2.9) | | | | 4.84(10.5) | | | |
| Between crosses | | | 3.10(6.7) | | 2.50(5.4) | | | | 9.06(19.6) | | | |

† Random F_3 populations derived from compositing 30 F_2 plants.

‡ Selected F_3 populations derived from compositing the 5 percent with lowest sterility in F_2 .

§ LSD values in parentheses.

populations (Table 6). The realized heritability (h_R^2) ranged from 0.21 for the cross of M-101/7801067 to 0.88 for M-101/L-201, and averaged 0.53 over the seven crosses (Table 6). The observed directional responses for cold induced sterility varied from the high of -14.6 percentage points for M-101/L-201 and the low of -4.4 percentage points for M-101/7801067. The results indicate that effectiveness of individual F_2 plant selection for cold tolerance depended on the cross combination.

Means of other characters were compared in the two F_3 populations, randomly composited and directionally selected for cold tolerance (Table 7). Standard deviations of all characters were smaller in the selected populations than in the random overall population crosses. The mean plant heights were slightly taller in the selected than in the random populations. In general, the directional selection based only on sterility did not significantly alter days to heading and number of florets per panicle, with some exceptions. The associated effect of days to heading on cold tolerance was favorable in the cross of M-101/7703008, but was unfavorable for number of florets per panicle on cold tolerance in the cross of M-101/L-201.

摘 要

水稻의 冷害는 그 栽培期間에 低溫이 發生되는 水稻栽培地域에서 重要한 生産阻害要因으로 作用한다. 그러나 稻作期間동안의 氣象은 地域에 따라 다르기 때문에 發生되는 冷害樣相 또한 다르게 나타난다. 一般적으로 冷害는 低水溫에 依한 生育의 遲延 및 低氣溫에 依한 不稔發生 등으로 크게 나눌 수 있다.

本 研究는 耐冷性 品種育成效率를 높이기 위한 遺傳情報를 얻고져 耐冷性程度가 서로 다른 9個 品種의 二面交雜된 36組合의 F_1 , F_2 , F_3 , 相互戻交 配集團 및 母本集團을 供試하여 障害型耐冷性에 對한 組合能力, 作物學的 形質과의 關聯性을 檢討하고 F_2 集團의 選拔效率를 評價하였다. 不稔發生程度로서 評價된 障害型耐冷性은 相加的 遺傳分散이 主宗이었으나 非相加的 遺傳分散 역시 有意하게 나타났다. 一般적으로 耐冷性이 강한 母本인 M 101 과 L 201 이 一般組合能力(GCA)이 높았는 反面, 弱한 品種인 7703008에서 가장 낮았다. 障害型耐冷性은 出穗期, 稈長 및 穗當粒數와 關係가 있었는데, 出穗가 빠를수록, 稈長이 클수록 그리고 穗當粒數가 많을수록 耐冷性이 강한 傾向이었으며, 特히 出穗期의 影響이 가장 높았다. 比較的 耐冷性이 강한 M 101 과 交配된 7組合에서 F_2 個體 選拔이 耐冷性向上에 效果가 있었으며 이때 耐冷性에 對한 平均遺傳力(Realized heritability)은 0.53이었고 低溫不稔에 對한 選拔效率는 -9.4%였다.

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