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# TWELVE YEARS OF DISTRICT YIELD TRIALS OF NEW JAPONICA RICE VARIETIES IN TAIWAN

## I. Analysis, Evaluation, and Recommendations[1,2]

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### Abstract

Analysis of yield data from six district yield trials of new Japonica rice varieties in Taiwan from 1965—1977 showed the following.

1. Avereged over all trials location and crop differences in yield were generally similar to those shown by regional rice yield data.
2. However within trials over locations, or within locations over years yields at the experimental stations correlated poorly with yields in the surrounding area. The stations may therefore not adequately represent the regions where they are located.
3. Variety effects were small but mostly significant in the overall analysis. Variety × environment interactions effects exceeded always in total and often individually, the main varietal effects. Environmental effects were large and highly significant: unpredictable (year) effects constituted about two thirds of predictable (location, crop) effects. The large crop × location interactions suggest much of the causes of the lower yield of the second crop are location specific. Breeding for island wide varieties fails to exploit location specific responses.
4. Gains expected from breeding for location specific rather than location general varieties were small in absolute terms (3-4%), but about the same as gains that would be obtained by using the best rather than an average variety in a location.
5. Gains expected from growing crop specific rather than crop general varieties were less (2%), and about 30% of gains that would be obtained by using the best rather than an average veriety.
6. Varieties grown in the location where they were bred yielded 4-5% more than varieties grown away from their location of origin. The effect was more marked in the second then first crop.
7. Island wide best yielding varieties showed least local adaptation: high

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island wide yield was achieved by stability over locations.

8. There was evidence of some gains due to improved cultivation over the past twelve years, but the averae gains were small (about 1% per year).
9. There was no evidence of any increases in yield relative to controls due to improved varieties over the past twelve years, based on mean yields, yields of best varieties, and on progressive improvement with time. Gains from the best yielding varieties were in fact less than gains expected by chance due to inherent experimental error.

It is recommended that in future district yield trials an island wide check variety be used, that yield trial data should be analysed on an overall two year basis (an analysis of variance model is given in Table 9) and that the number of within location replications be reduced. Experiments should be carried out to analyse the discrepancies between stations and local area yields, and to establish the relationship between year, season, and location stability. It is futher recommended that the genetic base for breeding Japonica varieties should be broadened, that long term programs of breeding for location and crop specific varieties be introduced, and that basic research into new plant breeding methods be vigorously pursued.

## Introduction

"Breeding is an enterprise of long-term investment"
C. S. Huang (1977)

In Taiwan, new varieties of Japonica (Ponlai) rice (*Oryza sativa* var. *Japonica*) developed by various District Agricultural Improvement Stations (DAIS), by the Taiwan Agricultural Research Institute (TARI), and by the Chiayi Agricultural Experimental Station are tested every two years in district yield trials. These trials are carried out at eight District Agricultural Improvement Stations (hereafter termed simply "Stations") (Fig. 1) which are regarded as being representative of the main rice growing regions of Taiwan characterised by quite different climates. A different group of varieties are tested every two years, together with two control or check varieties using a randomised complete block design with six replicates. The control varieties are high yielding varieties commonly grown in the respective areas: they therefore differ from locality to locality and have been changed at various intervals in the past (Table 1). The actual number of new varieties tested in each group has varied between nine and twelve. Different groups of varieties are started with the second crop, on odd years: the sequence is therefore Yr 1: Crop II/Yr 2: Crop I, Crop II/Yr 3: Crop I. The present study reports on six sets of varietal trials carried out during the period 1965 to 1977. Data on individual trials for the period 1970 to 1976 with details of specific varieties used is published in the Annual Report of Rice Improvement (Department of Agriculture and Forestry, Taiwan Provincial Government). Additional data for the periods preceding this and for 1977 were obtained from TARI. The results of these district yield trials had previously only been analysed on a

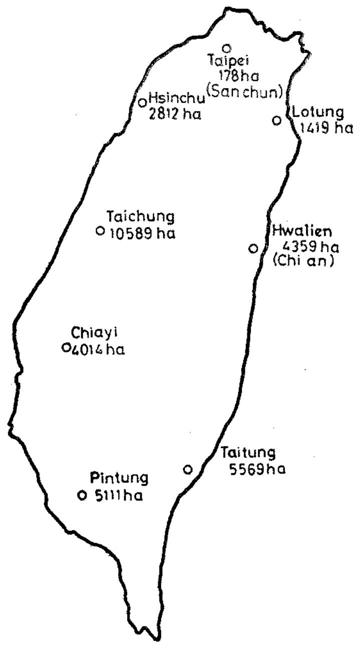


Fig. 1. District Agricultural Improvement Stations in Taiwan where district yield trials were carried out. The data shows 1975 acreage of rice in the local areas of each station on which the data in Fig. 2b were based.

year to year, crop to crop basis, and then usually only location by location. The present study of the whole data set was undertaken to answer the following questions.

a) What are the yields of the first and second crop in different regions of the island, when the same varieties are grown in all regions, i. e. regional differences are not confounded as a result of different varieties being grown in different regions.

b) How representative are yields at the specific stations of yields in the immediate surrounding area (hereafter termes simply "local area")? And are the year to year fluctuations of yield at the specific stations correlated with the fluctuations in yield in the respective local areas?

c) What are the relative effects of variety, location, year, crop season, and interaction effects in causing variations in yield? What is the relative magnitude of variance due to varietal (genotypic) differences and the magnitude of genotype-environmental interaction effects?

d) What gains would be likely as a result of breeding for locality specific or crop season specific varieties?

e) What have been the increases in yield due to improved cultivation at

**Table 1.** *Control (or check) varieties used in regional trials at different locations in Taiwan*

Control varieties are the same in first and second crops. In the first trial, at both Taipei and Pintung one check variety was changed half way through the trial.

| Trial | Taipei | | Hsinchu | | Taichung | | Chiayi | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 |
| 1 | TC 65 | TN 3 | TC 65 | HC 56 | TC 65 | TN 3 | CN 8 | TN 1 |
| | | TP 309 | TC 65 | HC 56 | | | | |
| 2 | TC 65 | TP 309 | TC 65 | HC 56 | TC 184 | TN 1 | CN 8 | TN 5 |
| 3 | TC 65 | TP 309 | TC 65 | HC 56 | TC 184 | TN 5 | CN 8 | TN 5 |
| 4 | TC 65 | TP 309 | TC 65 | HC 56 | TC 184 | TN 5 | CN 8 | TN 5 |
| 5 | TC 65 | TP 309 | TC 65 | HC 56 | TC 184 | TN 5 | CN 8 | TN 5 |
| 6 | TC 65 | TP 309 | TN 5 | HC 56 | TC 184 | TN 5 | TN 6 | TN 5 |

| Trial | Pintung | | Taitung | | Hualien | | Lotung | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 |
| 1 | KS 64 | CN 242 | CN 8 | TT 25 | CN 8 | HL 18 | TC 65 | TN 3 |
| | KS 122 | | | | | | | |
| 2 | KS 136 | CN 242 | CN 8 | TT 25 | CN 8 | HL 18 | TP 309 | TN 3 |
| 3 | KS 137 | CN 242 | CN 8 | TT 25 | CN 8 | HL 18 | TP 309 | TN 3 |
| 4 | KS 138 | TN 5 | CN 8 | TT 25 | CN 8 | HL 18 | TP 309 | TN 5 |
| 5 | KS 137 | TN 5 | CN 8 | TT 27 | TN 5 | HL 18 | TP 309 | TN 5 |
| 6 | KS 137 | TN 5 | CN 8 | TT 27 | TN 5 | — | TN 3 | — |

these localities over the past twelve years (as judged by directional change in the year to year yields of the check varieties)?

f) What have been the increases in yield due to improved varieties?

A later paper will consider stability analysis of the different trials: an initial stability analysis of the 1973–1975 trial has been carried out by Wu (1975).

## Analysis and Results

In order to clarify the nature of the values used in the calculations the following notation will be used. The raw values are termes $X_{tvlcy}$, where $t=$ trial, $v=$variety, $l=$location, $c=$crop, and $y=$year. If means of any of these values are taken, then a bar is marked over the variable that the value is averaged over: for example, average over years is $X_{tvlc\bar{y}}$. If the value is then an average of originally derived values, then the original derived value is placed in parentheses and the variable over which the mean is taken is indicated by the variable subscript plus bar placed outside the parenthesis; thus the values of yields relative to location and crop yields averaged over two years are $(X_{tvlc\bar{y}}/X_{t\bar{v}lc\bar{y}})$ and the mean of these values over locations are indicated by $(X_{tvlc\bar{y}}/X_{t\bar{v}lc\bar{y}})\bar{l}$. Relative values are always expressed as percentages. Averages taken over trials are, unless otherwise indicated, unweighted averages (i. e. not weighted by the number of varieties in each trial). There were certain irregularities in the data such as odd missing values, and in such cases means were based on one or two fewer values, or in computer analysis, missing valves were estimated by hand and inserted to generate a complete design. In the case of 1969, crop II the data for the Lotung location were unavailable and in that trial the design for the analysis of variance was reduced to seven locations. Such minor variations in sample size are not indicated since they would have had negligible effect on the final values.

Figure 2a shows the yield of the first and second crops $(X_{\overline{tv}lc\bar{y}})$ and their relative yield $(X_{\overline{tv}lc_1\bar{y}}/X_{\overline{tv}lc_2\bar{y}})$ averaged over the twelve years of the study period and all new varieties (i. e. excluding check varieties). It can be seen that the yields vary considerable from station to station with the highest first crop yields being in the south eastern (Chiayi and Pintung) regions, and the highest second crop yields being in the central eastern region (Taichung). The second crop yields about 80% of the first crop, except in Chiayi and Pintung, where the relative yields are much lower, Fig. 2b shows the corresponding yields of rice in the immediate local areas surrounding these stations (see Fig. 1 for details) as taken from the Taiwan Food Statistics Book (published by the Taiwan Provincial Food Bureau), for the ten year period 1965 to 1974. For the first crop, the yields at the stations were greater in Taipei, Taichung, and Chiayi but elsewhere the yields obtained in the local areas by farmers using common varieties was greater than in the experimental stations. For the second crop, only the yield at Taipei clearly exceeded that of the Taipei local area: in all other areas yields were about the same or somewhat lower in the experimental stations. In terms of relative first and second crop yields, the reduction in yield of the second crop seemed somewhat greater in the experimental stations than in their corresponding surrounding area except in the northern region (Taipei and Lotung) where reduction in second crop yields was much less at the stations.

In order to assess the degree to which the specific stations are representative of their respective areas, two further analyses were carried out. Firstly, for each year and crop season, the correlation between mean yield at different stations $(X_{t\bar{v}lcy})$ and yield in the corresponding local areas was calculated (Table 2a). In the first crop, the correlations were generally positive but low, whereas in the second crop, apart from a significant negative correlation

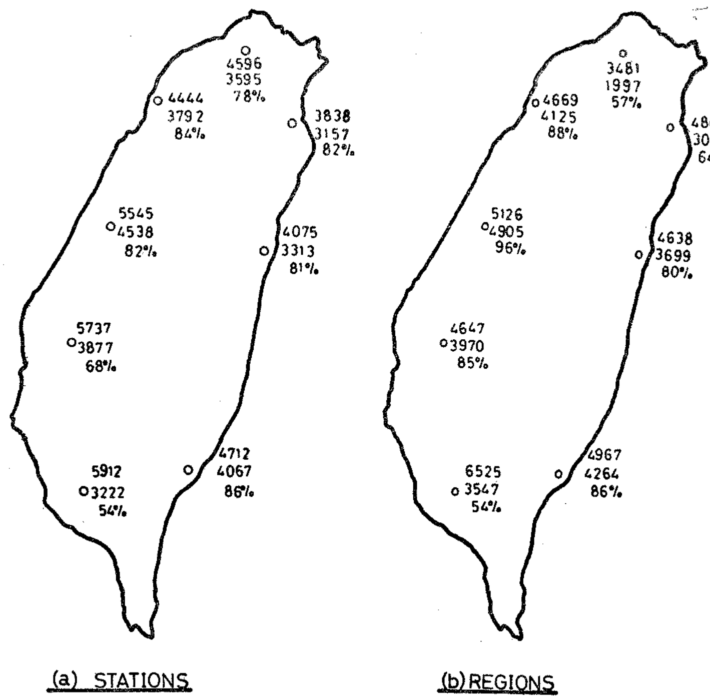


Fig. 2(a) Yields of the first and second crop and their relative yields averaged over all district yield trials but excluding control varieties.

(b) Corresponding yields of rice in the immediate local areas surrounding the experimental stations averaged from 1966 to 1976.

(Note: Regional data coverded to brown rice values, using overall means for I and II separately)

in 1969, the correlations were stronger, often positive and significant or approaching significance. Correlations based on overall means ($X_{\bar{t}\bar{v}lc\bar{y}}$) were positive but not significant. Secondly, correlations were calculated between the mean yield of all varieties in a station for a given year ($X_{t\bar{v}lcy}$) and the yield obtained by the farmer that year in the surrounding locality. The correlations were frequently weak and a number of times negative (Table 2b). Only two correlations were statistically significant, and only at two localities (Taichung and Lotung) could the correlations be said to be substantial in both the first and second crop. However, when the correlations were performed using means over all locations ($X_{t\bar{v}\bar{l}c\bar{y}}$), significant correlations were obtained in both crops. These results suggest that overall year to year fluctuations in yield are not reflected well in the fluctuations at the individual stations, but when stations are averaged a fairly good representation of the island wide year to year fluctuation is obtained.

In order to assess the relative roles of genotype, environment and their interaction in causing variance in yield, the data for each two-year period was

**Table 2a.** *Correlation over locations between mean yield of all varieties at a station and yield in the local area for each year and each crop*

| Year | Crop I | Crop II |
|---|---|---|
| 65 | | .81*(1) |
| 66 | .52 | .45 |
| 67 | −.13 | .25 |
| 68 | .36 | −.14 |
| 69 | .42 | −.78* |
| 70 | .58 | .34 |
| 71 | .47 | .73* |
| 72 | .31 | .67 |
| 73 | .80* | .73* |
| 74 | .25 | .70 |
| 75 | .31 | .69 |
| Correlation using overall means | .52 | .65 |

(1) *: Statistical significance at 5% level.

**Table 2b.** *Correlation over years between mean yield of all varieties at a station and the yield in the local area for each location and each crop*

| Location | Crop I | Crop II |
|---|---|---|
| 1. Taipei | .56 | −.19 |
| 2. Hsinchu | −.27 | .68 |
| 3. Taichung | .57 | .60 |
| 4. Chiayi | .21 | −.05 |
| 5. Pintung | .45 | .16 |
| 6. Taitung | −.28 | .36 |
| 7. Hualien | .34 | .32 |
| 8. Lotung | .84**(1) | .93*** |
| Correlation using overall means | .84** | .71* |

(1) *, **, ***: Statistical significance at 5%, 1%, and 0.1% level, respectively.

analysed as a complete randomised block design with varieties (the number depending on the two-year period), 8 locations, 2 crop seasons, and 2 Years. For each variety, locality, crop season, and year, the values used were the means of the original six replicates. Varieties (V), locations (L), and crop seasons (C) were considered as fixed effects (Model I: see Sokal and Rohlf, 1969) and years (Y) was considered as a rondom effect (Model II). The crop season effect is hereafter abbreviated simply as the crop effect. The resulting mean square components and tests are listed for each of the six trials in Table 3a and variance components in Table 3b. Since the analysis was performed on the means of replicate values, there was no way to obtain a true error estimate. Therefore two error estimates were used for the calculation of variance components. Firstly, the four way interaction effect was used as an error component. This may overestimate the error, since it assumes that the interaction effect itself is negligible and most of this component is error. Indeed, the fact that the three way interaction terms (especially Y×L×C) were large and highly significant makes it unlikely that the value of the four-way term was negligible, and therefore variance components estimated in this way should be considered to represent minimum estimates. This error component was used for the significance tests. Secondly, information was available on the within crop, within location error component for the first three series of yield trials. Since this excludes the replicate with crop, year, and location

**Table 3a.** *Analysis of variance model used in testing significance and in estimating variance components for each of the district yield trials*

Varieties (V), Locations (L), and Crops (C) are treated as fixed effects; Years (Y) are treated as a random effect.

| Effect number | Effect | Mean square components | Significance tested against effect |
|---|---|---|---|
| 1. | L | $\sigma_e^2 + vc\sigma_{ly}^2 + vcy\sigma_l^2$ | 7 |
| 2. | V | $\sigma_e^2 + lc\sigma_{vy}^2 + lcy\sigma_v^2$ | 9 |
| 3. | C | $\sigma_e^2 + lv\sigma_{cy}^2 + lvy\sigma_c^2$ | 10 |
| 4. | Y | $\sigma_e^2 + lcv\sigma_y^2$ | (15)[1] |
| 5. | L×V | $\sigma_e^2 + c\sigma_{lvy}^2 + cy\sigma_{lv}^2$ | 12 |
| 6. | L×C | $\sigma_e^2 + v\sigma_{lcy}^2 + vy\sigma_{lc}^2$ | 13 |
| 7. | L×Y | $\sigma_e^2 + vc\sigma_{ly}^2$ | (15) |
| 8. | V×C | $\sigma_e^2 + l\sigma_{vcy}^2 + ly\sigma_{vc}^2$ | 14 |
| 9. | V×Y | $\sigma_e^2 + lc\sigma_{vy}^2$ | (15) |
| 10. | C×Y | $\sigma_e^2 + lv\sigma_{cy}^2$ | (15) |
| 11. | L×V×C | $\sigma_e^2 + \sigma_{lcvy}^2 + y\sigma_{lvc}^2$ | 15 |
| 12. | L×V×Y | $\sigma_e^2 + c\sigma_{lvy}^2$ | (15) |
| 13. | L×C×Y | $\sigma_e^2 + v\sigma_{lcy}^2$ | (15) |
| 14. | V×C×Y | $\sigma_e^2 + l\sigma_{vcy}^2$ | (15) |
| 15. | L×V×C×Y | $\sigma_e^2 + \sigma_{lcvy}^2$ | |

[1]: Parentheses indicate test is approximate.

**Table 3b.** *Variance components and significance of effects in each of varietal trials*(1)

| Effect | Trial years | | | | | |
|---|---|---|---|---|---|---|
| Number of varieties | 65–67<br>12 | 67–69<br>9 | 69–71<br>11 | 71–73<br>10 | 73–75<br>9 | 75–77<br>11 |
| Varieties and predictable effects | | | | | | |
| V | 58 | 86*(2) | 375*** | 119*** | 253*** | 260*** |
| V × L | 70 | 238** | 140* | 180** | 151** | 325** |
| V × C | 26 | 213* | 13 | 132 | 86* | 230** |
| V × C × L | 139* | −28 | 162 | −36 | 149 | 416* |
| Varieties and unpredictable effects | | | | | | |
| V × Y | 68 | 26 | 58 | 3 | 23 | 35 |
| V × Y × L | 217 | 239 | 203 | 253 | 201 | 451 |
| V × Y × C | 57 | 51 | 97 | 129 | −1 | 55 |
| V × Y × L × C | 51 | 119 | 86 | 83 | 142 | 179 |
| Predictable effects | | | | | | |
| L | 3763* | 2475*** | 2829*** | 5262*** | 3931*** | 2788 |
| C | 904 | 7956 | 17631* | 365 | 11046 | 6772 |
| L × C | 1686 | 2186 | 7100* | 3409 | 1020 | 1849 |
| Unpredictable effects | | | | | | |
| Y | 4017*** | 10 | 750*** | 169*** | 710*** | 1001*** |
| Y × L | 2510*** | 407*** | 1291*** | 586*** | 3147*** | 1667*** |
| Y × C | 303*** | 477*** | 32 | 7295*** | 145** | 1229*** |
| Y × L × C | 1432*** | 4261*** | 1986*** | 4712*** | 5266*** | 4916*** |
| Error (minimum) | 261 | 381 | 324 | (322) | (322) | (322) |
| Error (maximum) | 537 | 1098 | 839 | 823 | 1174 | 1395 |

(1) Since most of the varieties and unpredictable effects were negative when the maximum error (two way interaction) term was used, the components for these are presented using the minimum error: they are therefore to be considered as maximum estimates and no significance levels are indicated. Number of years, crops, and locations are 2, 2, and 8 respectively, except in 1969–71, when there are 7 locations.

(2) *, **, ***: Statistical significance at 5%, 1%, and 0.1% level, respectively.

interactions, it is probably an underestimate of the true error term: therefore variance components calculated from this are overestimated, and can be considered to represent maximum estimates. These minimum and maximum estimates are shown in Table 3c. With regard to main effects the most important in causing variation in yield are crop, location and year, with varieties being but a small fraction of these other effects. Interaction effects often appear to be more important than main effects. This is true with regard

**Table 3c.** *Variance components averaged over six varietal trials*
Minimum and maximum estimates are calculated using maximum and minimum error estimates respectivity (See test for explanation).

| Effect | Average variance component | | Standard error | |
|---|---|---|---|---|
| Varieties and predictable effects | | | | |
| V | 19,174 | | 5,039 | |
| V × L | 18,390 | | 3,596 | |
| V × C | 11,664 | | 3,749 | |
| V × C × L | 13,367 | | 6,721 | |
| Varieties and unpredictable effects | | | | |
| | MIN | MAX | MIN | MAX |
| V × Y | −647 | 3,554 | 1,373 | 976 |
| V × Y × L | −6,922 | 26,066 | 4,079 | 3,893 |
| V × Y × C | −1,930 | 6,471 | 2,728 | 1,811 |
| V × Y × L × C | 0 | 10,966 | — | 1,877 |
| Predictable environmental effects | | | | |
| L | 350,812 | | 42,299 | |
| C | 744,562 | | 264,793 | |
| L × C | 287,492 | | 90,404 | |
| Unpredictable environmental effects | | | | |
| | MIN | MAX | MIN | MAX |
| Y | 110,955 | 112,766 | 60,125 | 61,431 |
| Y × L | 165,123 | 168,404 | 44,306 | 44 403 |
| Y × C | 158,014 | 157,848 | 115,601 | 115,569 |
| Y × L × C | 376,211 | 382,773 | 66,655 | 67,654 |

to the variance components due to varietal (genotype) effects. It can be seen (Table 3c) that the genotype × environment interaction effects are large, and in total far exceed the main genotype effect in magnitude. Looking at trials individually (Table 3b) it can be seen that in four out of the six trials at least one interaction effect exceeds the main effect, and in two cases the three-way interaction is larger than the main effect. These results suggest that variety specific responses to crop and location are important sources of variation in yield among the varieties. One can further consider the components in terms of those including year effects and those not including year effects. The former represent "unpredictable variations," since year to year climatic effects cannot be predetermined, whereas the latter are "predictable" in that one can choose a particular combination of variety, crop, or location. The results for variety and year combinations are difficult to interpret since the maximum and minimum estimates sometimes (especially for V×Y×L) vary widely; however, it appears that the variety×year interaction effects are generally less than the predictable variety interaction effects. The variety independent environmental effects are large, both as regards main effects and interactions. Indeed the largest average effect after the crop effect (and this is highly variable from year to year) is the three way interaction of year, location and crop, and unpredictable effect. In total the unpredictable effects constitute about two thirds of the predictable effects. These values show considerable variation among different trials as a result of very different climates from year to year and each trial only being carried out for two years.

In order to assess what gains might be expected by breeding for locality or crop specific varieties, the data for each trial were standardised by expressing yield as a percentage of the overall mean yield (excluding check varieties) for each location, year, and crop. Since years were considered as replicates, the average of the percentages for each of two years were calculated $(X_{tvlcy}/X_{t\bar{v}lcy})\bar{y}$. The data were than examined as follows. To assess the gains to be expected by breeding for location specific versus location general varieties, the yield of the best two varieties in each location was compared with yield of the best two varieties over all locations $(X_{tvlcy}/X_{t\bar{v}lcy})\overline{yl}$. The gains obtained in this way (Table 4a) appear small (around 3–4%) unless one compares them with the yield of the best general varieties relative to the overall average yield ($X_{t\bar{v}\bar{l}cy}$=100%). Expressed in this way, the average gain by using location specific rather than general varieties is almost as large (86%) as the gain by using the best rather than a variety with average yield over all locations. Gains in the second crop are somewhat greater than in the first crop. To assess the gains expected from growing crop specific varieties, rather than general varieties adapted to both crops, the yield of the best two varieties over both crops was compared to the yield of the best variety within each crop. The results (Table 4b) showed very small gains from growing crop specific varieties; even when expressed as a percentage of the gains from growing the best general variety rather than a variety with average yield, the value was only around 30%. Finally, the gains to be expected from growing locality and crop specific varieties rather than completely generally varieties were calculated (Table 4c). The results show gains of nearly the same amount as the gains from growing the best general variety as opposed to a variety with average yield.

In order to assess whether there was any evidence of local adaptation of new crop varieties to the locality in which they were bred, the yield of a variety in its location of origin was compared with its yield at various distances from the locality where it originated. This was done by treating the stations in Taiwan as forming a "circle," so that given any particular station, stations on either side were considered to be one unit of distance away, stations one removed again were considered two units away, etc. Yield was again expressed as a percentage of the mean yield of all varieties in any location, crop, and year ($X_{tvlcy}/X_{t\bar{v}lcy}$). The average yields of all varieties in the stations where they were bred, the means one, two, etc. units of distance away were calculated for all varieties whose place of origin in Taiwan could be identified. The numbers of varieties on which the means are based

**Table 4a.** *Yields of best and second best variety in each location (specific) compared with yields of best and second best variety over all locations (general) for each of the six yield trials*

Values expressed as percentage of mean yield of all varieties within trial, year, crop and location.

Crop I

| | Trial | | | | | | Average |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | |
| Best variety | | | | | | | |
| Specific | 107.5 | 108.8 | 107.5 | 111.1 | 111.7 | 110.8 | 109.57 |
| General | 105.1 | 105.1 | 105.1 | 107.2 | 107.6 | 107.4 | 106.25 |
| Gain | 2.4 | 3.7 | 2.4 | 3.9 | 4.1 | 3.4 | 3.32 |
| 2nd best variety | | | | | | | |
| Specific | 106.0 | 105.4 | 106.0 | 107.6 | 107.5 | 107.4 | 106.65 |
| General | 103.0 | 102.7 | 103.0 | 102.9 | 103.8 | 105.2 | 103.43 |
| Gain | 3.0 | 2.7 | 3.0 | 2.9 | 3.8 | 2.2 | 3.22 |

Crop II

| | Trial | | | | | | Average |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | |
| Best variety | | | | | | | |
| Specific | 108.9 | 110.1 | 108.9 | 112.4 | 107.3 | 111.9 | 109.92 |
| General | 104.9 | 104.5 | 104.9 | 109.5 | 102.9 | 106.0 | 105.45 |
| Gain | 4.0 | 5.6 | 4.0 | 2.9 | 4.4 | 5.9 | 4.47 |
| 2nd best variety | | | | | | | |
| Specific | 106.5 | 106.6 | 106.5 | 107.5 | 105.5 | 108.7 | 106.88 |
| General | 101.1 | 104.0 | 101.0 | 104.7 | 102.6 | 104.9 | 103.05 |
| Gain | 5.4 | 2.6 | 5.5 | 2.8 | 2.9 | 3.8 | 3.53 |

**Table 4b.** *Yields of the best and second best variety in each crop (specific) compared to yields of best and second best variety over both crops, (general) averaged over eight locations for each of the six yield trials*

Values expressed as percentage of mean yield of all varieties within trial, year, crop and location.

| | Trial | | | | | | Average |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | |
| Best variety | | | | | | | |
| Specific | 108.23 | 109.51 | 110.96 | 111.80 | 109.48 | 111.36 | 110.22 |
| General | 105.87 | 107.16 | 109.16 | 109.34 | 107.93 | 107.42 | 107.81 |
| Gain | 2.36 | 2.35 | 1.80 | 2.46 | 1.55 | 3.94 | 2.41 |
| S. E. of gain | ±.73 | ±.70 | ±.55 | ±1.94 | ±.83 | ±1.00 | ±.83 |
| 2nd best variety | | | | | | | |
| Specific | 106.29 | 106.00 | 107.80 | 107.58 | 106.53 | 108.05 | 107.04 |
| General | 104.70 | 104.89 | 106.77 | 105.28 | 104.90 | 105.75 | 105.38 |
| Gain | 1.59 | 1.11 | 1.03 | 2.30 | 1.63 | 2.30 | 1.66 |
| S. E. of gain | ±.52 | ±.61 | ±.73 | ±1.70 | ±.52 | ±.47 | ±.55 |

**Table 4c.** *Yields of the best and second best variety in each crop and each location (specific) compared to yield of best and second best variety over both crops and all locations (general) for each of the six yield trials*

Values expressed as percentage of mean yield of all varieties within trial, year, crop and location.

| | Trial | | | | | | Average |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | |
| Best variety | | | | | | | |
| Specific | 108.2 | 109.5 | 110.9 | 111.8 | 109.5 | 111.4 | 110.22 |
| General | 104.0 | 103.6 | 108.1 | 108.4 | 104.7 | 103.7 | 105.42 |
| Gain | 4.2 | 5.9 | 2.8 | 3.4 | 4.8 | 7.7 | 4.80 |
| 2nd best variety | | | | | | | |
| Specific | 106.3 | 105.9 | 107.8 | 107.6 | 106.5 | 108.1 | 107.67 |
| General | 102.6 | 103.1 | 104.6 | 103.8 | 100.9 | 103.4 | 103.07 |
| Gain | 3.7 | 2.8 | 3.2 | 3.8 | 5.6 | 4.7 | 3.97 |

is indicated in Fig. 3. Since there were two locations either side of the station of origin, points at 2, 3, 4 units away are based on twice as many points as varieties used for each analysis. The results (Fig. 3) show clearly that the yield of a variety in the location where it was bred is greater than in other locations. In the first crop, this adaptation appears highly localised, in that there is a decrease in yield in the immediately adjacent stations, but thereafter no decrease in yield is obvious; the trend is in fact the reverse. A variety in its own location yield about 4% greater than when grown in an adjacent location. In the second crop, the adaptation is more clear cut. The reduction in yield away from the location of origin is seen more pronounced than in the first crop, and if the unusual case of the 5th trial is excluded from the data then the gains are in the region of 5%.

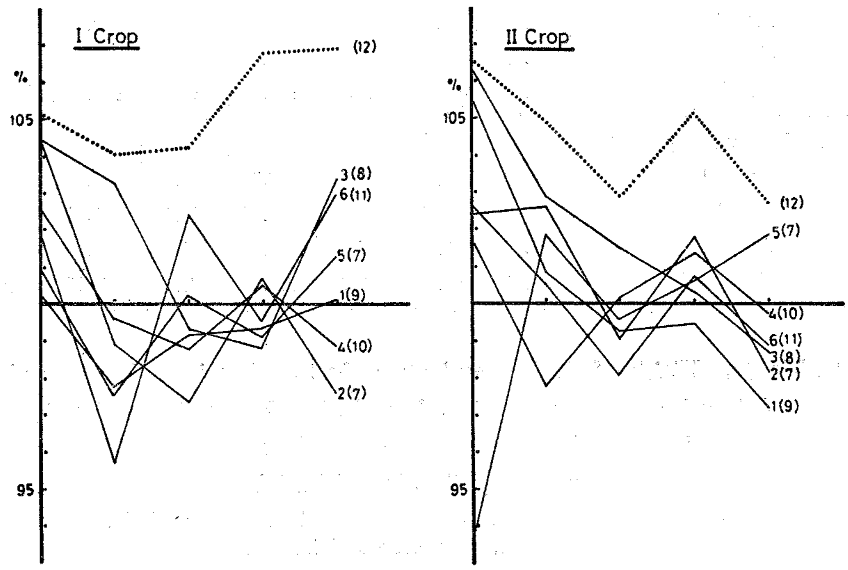


Fig. 3. Yields of varieties grown at locality where they were bred compared with yields at stations 1, 2, 3 and 4, removed from that station for yield trials 1-6, and (dotted line) for best two varieties in each of the six trials. Figures in parenthese indicate number of varieties on which results are based.

The data were also collected separately for the two varieties that yielded best over all locations in each trial, to see whether the best yielding varieties showed a pattern of adaptation similar to that of all varieties. The results (dotted line in Fig. 3) show that in the best yielding varieties there was less evidence of local adaptation and therefore more regional stability: this is particularly true in the first crop where the best varieties in their own location yield only about 1% better than in the immediately adjacent stations. In the second crop, there in still clear evidence of adaptation but it does not decline as smoothly as in the overall data. These results therefore suggest that the best yielding varieties are more stable over locations than the average varieties. Or expressed in another way, high overall yield is not achieved bv extrme specialisation in one environment.

The assessment of gains over the past twelve years due to both breeding and cultivation were difficult since control varieties differed among locations and were changed at intervals within locations, so were not the same throughout the twelve year period (Table 1). To assess the gains due to cultivation for each crop, the yield of each control variety was regressed against time, and the weighted average of these regressions calculated for each location and overall (Table 5). Varieties that were grown for less than two trials were excluded from the analysis. The results show an island wide average annual improvement of 34.2 kg/ha in the first crop and 25.9 kg/ha in the second crop. For both crops this represents a yearly improvement of about 1%. However the results vary considerably from location to location (Table 5), but the

**Table 5.** *Regression coefficients of yield of check varieties against time*

| Location | Variety | Trials | Crop I (II) (Numbers) | Regression | |
|---|---|---|---|---|---|
| | | | | Crop I | Crop II |
| 1 | TC 65 | 1-6 | 12 | −69 | −80 |
| | TP 309 | 1,5-6 | 11 | −198 | −265 |
| 2 | TC 65 | 1-5 | 10 | −95 | −161 |
| | HC 56 | 1-6 | 12 | 0 | −45 |
| 3 | TC 184 | 2-6 | 10 | 62 | 154 |
| | TN 5 | 3-6 | 8 | −65 | 197 |
| 4 | CN 8 | 1-5 | 10 | 110 | 81 |
| | TN 5 | 2-6 | 10 | 197 | 174 |
| 5 | KS 137 | 3,5,6 | 6 | 74 | 105 |
| | CN 242 | 1-3 | 6 | 236 | −142 |
| | TN 5 | 4-6 | 6 | 262 | 340 |
| 6 | CN 8 | 1-6 | 12(11) | 108 | −37 |
| | TT 25 | 1-4 | 8 | −123 | −46 |
| | TT 27 | 5-6 | 4 | 429 | 530 |
| 7 | CN 8 | 1-4 | 8 | 110 | 200 |
| | TN 5 | 5-6 | 4 | 150 | 207 |
| | HL 18 | 1-5 | 10 | −61 | 160 |
| 8 | TP 309 | 2-5 | 8(7) | −26 | 2 |
| | TN 3 | 1-3 | 6(5) | 160 | −308 |
| | TN 5 | 3-5 | 4 | 299 | 5 |
| Weighted mean regression | | | | 34.2 | 25.9 |

interpretation of these local variations is complicated by the fact that different locations are confounded with different varieties. Thus the northern stations (Taipei, Hsinchu, and Lotung) generally show declining yields, but the controls used in these stations have generally been older varieties such as Taichung 65 (TC 65), Hsinchu 56 (HC 56), and Taipei 309 (TP 309), which may not be adapted to modern management such as increased fertilizer levels. If we look at just the central and southern regions, yield increases average around 100 kg/ha/year.

By comparing the yield of the new varieties with controls we can similarly assess the increase in yield due to plant breeding efforts. This can be done in terms of the average values of new varieties and secondly in terms of the best varieties. The data can then be looked at on a time basis to see if over the years there has been any evidence of consistent improvement. If we look at the yields of controls as a percentage of the mean of all new varieties at a particular location, and average over all locations $(X_{t\bar{v}_c lc\bar{y}}/X_{t\bar{v}lc\bar{y}})\bar{l}$, there is very little difference between the mean of the controls and the mean of the new varieties (Table 6). In the first crop the values are about the

**Table 6.** *Yield of controls as percentage of mean yield of all new varieties at a particular location averaged area control varieties and locations*

| Trial | Crop | |
|---|---|---|
| | I | II |
| 1 | 100.2 | 102.7 |
| 2 | 98.0 | 100.9 |
| 3 | 98.7 | 101.1 |
| 4 | 103.5 | 101.4 |
| 5 | 96.6 | 100.2 |
| 6 | 102.3 | 101.3 |
| Average | 99.9 | 101.3 |

same, whereas in the second crop in every trial the mean of the controls is marginally greater than the mean of the new varieties. To assess the gains due to breeding as a function of time, the mean yield of all varieties relative to the controls were regressed against time (for those periods when controls were grown for two or more trials); the weighted mean regression was then calculated. For both the first and second crop there was a negligible relationship with time, and indeed the trends were negative rather than positive (−0.35% and −0.17% per trial).

Since plant breeding is more concerned with maximum gains rather than mean gains, the yield of the best varieties were investigated in relationship to the yields of the controls. This was done at the level of the individual crop and location, over all locations within crops, and over all locations and both crops. The difference between the yield of the best variety within each crop and location averaged over locations $((X_{tvlc\bar{y}}/X_{t\bar{v}lc\bar{y}})-(X_{tv_c lc\bar{y}}/X_{t\bar{v}lc\bar{y}})\bar{l})$ and the same values considering both crops jointly $((X_{tvlc\bar{y}}/X_{t\bar{v}lc\bar{y}})\bar{c}-(X_{tv_c lc\bar{y}}/X_{t\bar{v}lc\bar{y}})\bar{c})\bar{l}$ are presented in Table 7. The results show that the best new variety exceeds the best control by 2–10% (average 7%) in the first crop and by 3–9% (average 5%) in the second crop. When both crops are considered together the gain averages over 4%. It is difficult to carry out this analysis over all locations since different control varieties are grown in different locations and there is therefore no "best" control variety over all locations. However it is possible to look at the difference between the best variety and the mean of the controls, considered over all locations, and considered over all locations and both crops (Table 8). The results show that the gains in the first crop are somewhat more than in the second crop, but that overall the gains from the best variety versus the average of the controls is under 5%. We can further examine if the yields of the best variety have improved with time, by comparing then to the yield of the control and regressing the difference against time. This was done for periods when controls were grown for more than two trials, and the weighted mean overall regression was calculated. The results showed little change: in the first crop, the difference between the best variety and the control actually decresed slightly with time (−0.19% per

**Table 7.** *Difference between the yield of the best new variety and the yield of the best control in averaged over years in a crop and location averaged over locations, as well as averaged over years and crops within a location*

| Trial | Crop | | |
|---|---|---|---|
| | I | II | I + II |
| 1 | 4.88 | 3.78 | 2.54 |
| 2 | 6.95 | 3.26 | 3.86 |
| 3 | 9.69 | 5.61 | 5.88 |
| 4 | 1.83 | 8.88 | 4.11 |
| 5 | 10.33 | 4.17 | 7.18 |
| 6 | 6.25 | 6.69 | 2.96 |
| Average | 6.66 | 5.40 | 4.42 |

trial), while in the second crop, the difference did increase but again only slightly (0.51% per trial).

**Table 8.** *Difference between yield of the best new variety over years and locations and the best control over years and locations for each crop, and over both crops*

| Trial | Crop | | |
|---|---|---|---|
| | I | II | I + II |
| 1 | 4.9 | 2.2 | 2.3 |
| 2 | 7.1 | 3.6 | 4.1 |
| 3 | 11.1 | 5.2 | 8.0 |
| 4 | 3.7 | 8.1 | 5.9 |
| 5 | 11.0 | 2.7 | 6.3 |
| 6 | 5.1 | 4.7 | 1.9 |
| Average | 7.15 | 4.42 | 4.75 |

## Evaluation

It is generally acknowledged that increases in the yield of Japonica rice varieties in Taiwan have reached a plateau in the past ten or so years. (Huang, 1977; Taiwan Agricultural Statistics 1965–1976). This analysis of district yield trials over the past twelve years strongly supports this view. Although the results here indicate some progress from improvements in cultivation, average effects are small and regional variations rather difficult to interprete because varieties are confounded with location and time effects. In terms of progressive improvement of varieties due to breeding there is no evidence either from mean yields or from yields of the best varieties that any real progress has been made. Nevertheless, it may seem that some gains have been made in that the best variety usually outyields the best control by an amount in the region of 5–7%. However, there is a danger in interpreting these results over-optimistically, because in every trial there are only two control varieties and about 10 new varieties. If we take the most extreme value out of a sample of ten, we would in fact expect a larger value than if we took the most extreme value from a sample of two, even if they were drawn from the same distribution. To be specific (Gumbel, 1958) the expected value of the largest value from a sample of two will be 0.57 standard deviations from the mean, whereas the expected value from a sample of ten will be 1.55 standard deviation greater than the mean, a difference of about 1 standard deviation. Applying these figures to the present data, and considering, as in the analysis of variance, that the year×variety interaction term is the error term for differences between varieties, we can calculate that the standard deviation of the error averaged over six trials, is 6.6% of the mean. In other words, given the inherent error in the experiment, by chance alone we would expect the best new variety to differ from the best control by over 6%. In fact the nearest equivalent observed figure is 4.4% from the pooled data for crop and location in Table 7. We see that this is *less* than the gain expected by chance alone. The data therefore strongly supports the contention that very little, if anything has been gained by breeding over the past twelve years.

Although overall yields have not been increased by breeding, there is overwhelming evidence that the varieties presented for evaluation in the trials are indeed different: this is seen in analyses done on a within crop and within location basis (given in the Annual Reports of Rice Improvement) and based on the present overall analyses: in only one trial were differences between varieties not significant, and in four trials they were highly significant. It is particularly interesting that by expressing the yields of the different vareities in the different locations relative to mean yields in that locations, it was possible to show that these differences among varieties were "adaptive," in that varieties bred in a particular location performed relatively better in that location. This effect was stronger, and had a greater geographical component in the second crop compared with the first crop. Moreover, although the gains to be expected by growing location specific best varieties rather than island wide best varieties were small in absolute terms, they were of the same order of magnitude as the gains from selection for island wide best varieties.

There has been considerable controversy in Taiwan (Huang, 1977) regarding the relative merits of breeding for island wide performance versus breeding for location or crop specific performance. The present analysis pinpoints many of the reasons for this controversy. In the overall analyses of variance, whereas differences do exist between varieties on an island wide basis, the variety × location plus the variety × crop × location terms are large and in excess of the main variety effect in all trials. This would suggest that selection for location specific varieties is indeed possible (and as mentioned above has taken place as a by product of breeding at local station), especially since the location effects are also frequently significant. Nevertheless if we look at the unpredictable environmental effects (year and location interactions) the variance components are large and in excess of main effects, sometimes by overwhelming amounts. This clearly shows that the problem with breeding for location specific varieties is that the year to year fluctuations are large so making it difficult to predict the precise conditions in a location in a given year. Therefore, whereas breeding for island wide varieties fails to exploit environment specific responses, breeding for location specific varieties would require a longer period of breeding in any given location to define the mean environment in that region given the large year to year fluctuations. In past breeding programs it seems that a by-product of breeding for island wide performance has been stability over space and if such stability over space is related to stability over time then there will be also good performance within locations given year to year variations. That the varieties showing best island wide performance are stable over locations is shown in our data: the best island wide varieties show less local adaptation than other varieties. This is not surprising, since the environments within Taiwan differ sufficiently such that it is difficult to have such excellent performance in one location, that it compensates for reduced performance in seven other locations.

The present data may seem to suggest that the gains to be obtained from breeding for crop specific, rather than year round varieties, may be small and much less than the gains from breeding for location specific varieties. This result is surprising in view of the very different environments experienced by the first and second crop (the crop effect is on average the largest variance component): intuitively it would seem that the gains might be substantial. However, it must be remembered that the results of the present yield trials have been based on varieties that have *already* been selected for performance in both seasons, since selections are carried out twice a year. Therefore, the gains from crop specific varieties cannot truly be tested since the breeding has been carried out with the opposite goal. Nevertheless, it is interesting that in three out of six of the trials, the variety×crop interaction is still significant.

Again, as with locations, there are conflicts between the predictable and unpredictable differences between the two crop seasons. Year×crop interactions are generally highly significant and large, so that again breeding for crop specific varieties would require a longer period to define the mean environment within a crop; moreover, selections could only take place once a year rather than twice a year. It is also extremely important to note that the location×crop interactions and the higher order interactions involving there, are also very large. This suggests that the difference between the first and the second crop is highly dependent on the location. This result is well known and is evident in the overall means obtained for the first and second crop at the different stations. There has been a tendency to overgeneralise the problem of the second crop in Taiwan, and to speak about the causes of the difference in yield between the two as if the reasons were uniform throughout the island. The existence of such significant interactions provides concrete evidence that warns strongly against oversimplification.

One of the most important and at first sight discouraging findings is that, averaged over all trials, the second largest variance component is the three way year×location×crop interaction effect. This suggests, in simple terms, that the effect of location and crop is highly dependent on the year. And since the year effect is essentially unpredictable (such reliable long range weather forecasts are unknown) we are dealing with an effect for which it may seem impossible to breed suitably adapted varieties. Nevertheless, it may be possible to breed for varieties that are stable over years either directly by extending trials of particular varieties for more than two years, or by finding if crop to crop or location to location stability correlates with year to year stability. If the latter is the case then it may be possible to assess overall year to year stability from relatively short term trials and so come up with predictions about yields of varieties given year to year fluctuations. Unfortunately, there have been almost no experiments where the same varieties have been grown for more than two years in more than one or two locations, so that accurate assessment of the relationship between year to year stability and other kinds of stability is difficult to carry out. Nevertheless, such an analysis is currently underway using these district trials as the data base, and will be published in a subsequent paper.

The data presented here poses one further problem in relation to breeding for crop and location specific varieties, namely that the environment in a District Agricultural Improvement Station may not be equivalent to that in the local areas which it is supposed to represent. The present study can simply point to this as a problem in view of the low correlations between local area yields and yields at the stations. That there is a difference has not been conclusively proven since different varieties are confounded with the difference between station and local area. However, given the large environmental effects compared with varietal effects, it is likely that the problem is a real one. It is certainly deserving of a more thorough study to both document the differences, and to pinpoint possible causes. Such causes could range from simple errors resulting from extending small plot data to a large acreage basis (as is done in the trials), to local variations in soil, or to differences in management. However, if a program of breeding for location and crop specific varieties is to be established it is imperative that such differences be investigated and resolved since it is clearly pointless breeding for region or crop season specific varieties if the environments in which such vareities are bred are not representative of the regions or seasons.

The present analysis cannot pinpoint the causes, but can only document the failure of breeding for improved Japonica varieties. However, some comments regarding the possible reasons for this failure are appropriate. It seems that breeding for Japonica varieties in Taiwan has been limited both by goals and by genetic variability. The emphasis has always been on island wide general performance rather than region specific performance: this approach has been very successful as evidenced by the very high adaptability of Taiwanese rice selections in other parts of the world and their incorporation in other breeding programs (Huang *et al*, 1972). However, selection in Taiwan has been carried out using a very limited genetic base: Huang and Chen (1961) reported that all varieties released after Taichung 65 were related to it to some degress. Therefore there is clearly a call to both expand the genetic base and attempt more region and crop specific selection. Indeed region specific and crop specific selection may be unsuccessful if the present genetic base is used exclusively, since in the past emphasis in breeding has been precisely in the opposite direction. Huang (1977) recently argued that "a provision of practicing nondisruptive (i. e. crop specific) seasonal selection on rice in Taiwan seems to be redundant." However, this opinion was mostly on the basis of selection that were carried out for one or two years. The present analysis shows that positive results in environment specific selection are extremely unlikely if selections are carried out over a short period of time since the year, crop, and location interactions are large. Indeed stable vareities will then be an advantage. However, on a longer term basis crop and region specific selections should produce real dividends; benefit from region specific varieties are evidenced in the present study. Indeed later in the same paper, Huang (1977) recommends just such selection in the form of selection for tolerances to low solar radiations and temperatures, drought tolerance for upland varieties, salt tolerance for coastal areas, tolerance against reduced siols, and "tolerance against the problem soil of Pintung in the second season." All such tolerances are crop and location specific, and it would certainly be redundant to make such selections on an island wide basis. Above all, in view of the degree to which breeding of Japonica varieties appears to be stalled in Taiwan, some change in breeding goals and methods is strongly indicated

## Recommendations

Recommendations are divided into those of a more technical nature pertaining to execution of the regional trials and analysis of data from these trials, and those of a more general nature pertaining to breeding programs for Japonica varieties in Taiwan.

*Technical*

1) It would be very helpful for the future evaluation of breeding programs if the same control varieties were used throughout the island. Many of the

interpretations of yield gains were difficult in view of the fact that different control varieties were grown in different locations. We recommend that the presently highly successful variety Tainan 5 be used island wide in the trials, and that a second variety considered to be the currently (or second best after Tainan 5) for a given region be also included in the trials for that region.

2) Data should be analysed on a two year, rather than on a year to year basis, using the design outlined in Table 9. In particular the year × variety effect should be used as error for testing varietal differences, and in multiple range tests.

**Table 9.** *Analysis of variance model to be used in testing significance and in estimating variance components for district yield trials*

Vaieties, Locations, and Crops are treated as fixed effects;
Years and Blocks are treated as a random effect

| Effect number | SOV | *df* | E(MS) | Significance tested against effect |
|---|---|---|---|---|
| 1 | Year (Y) | $(y-1)$ | $\sigma^2_e + v\sigma^2_\delta + nclv\sigma^2_y$ | 8 |
| 2 | Crop (C) | $(c-1)$ | $\sigma^2_e + v\sigma^2_\delta + nlv\sigma^2_{yc} + nylv\sigma^2_c$ | 3 |
| 3 | Y × C | $(y-1)(c-1)$ | $\sigma^2_e + v\sigma^2_\delta + nlv\sigma^2_{yc}$ | 8 |
| 4 | Location (L) | $(l-1)$ | $\sigma^2_e + v\sigma^2_\delta + ncv\sigma^2_{yl} + nycv\sigma^2_l$ | 5 |
| 5 | Y × L | $(y-1)(l-1)$ | $\sigma^2_e + v\sigma^2_\delta + ncv\sigma^2_{yl}$ | 8 |
| 6 | C × L | $(c-1)(l-1)$ | $\sigma^2_e + v\sigma^2_\delta + nv\sigma^2_{ycl} + nyv\sigma^2_{cl}$ | 7 |
| 7 | Y × C × L | $(y-1)(c-1)(l-1)$ | $\sigma^2_e + v\sigma^2_\delta + nv\sigma^2_{ycl}$ | 8 |
| 8 | Block within year, crop and location (Error a) | $ycl(n-1)$ | $\sigma^2_e + v\sigma^2_\delta$ | 17 |
| 9 | Variety (V) | $(v-1)$ | $\sigma^2_e + ncl\sigma^2_{yv} + nycl\sigma^2_v$ | 10 |
| 10 | Y × V | $(y-1)(v-1)$ | $\sigma^2_e + ncl\sigma^2_{yv}$ | 17 |
| 11 | C × V | $(c-1)(v-1)$ | $\sigma^2_e + nl\sigma^2_{ycv} + nyl\sigma^2_{cv}$ | 12 |
| 12 | Y × C × V | $(y-1)(c-1)(v-1)$ | $\sigma^2_e + nl\sigma^2_{ycv}$ | 17 |
| 13 | L × V | $(l-1)(v-1)$ | $\sigma^2_e + nc\sigma^2_{yev} + ncy\sigma^2_{lv}$ | 14 |
| 14 | Y × L × V | $(y-1)(l-1)(v-1)$ | $\sigma^2_e + nc\sigma^2_{ylv}$ | 17 |
| 15 | C × L × V | $(c-1)(l-1)(v-1)$ | $\sigma^2_e + n\sigma^2_{yclv} + ny\sigma^2_{clv}$ | 16 |
| 16 | Y × C × L × V | $(y-1)(c-1)(l-1)(v-1)$ | $\sigma^2_e + n\sigma^2_{yclv}$ | 17 |
| 17 | Error b | $ycl\ (n-1)(v-1)$ | $\sigma^2_e$ | |

3) In view of the year × interaction effect being the most important source of error, the number of replicates within each year, crop and location could be reduced from six to five (perhaps even four) without any appreciable loss in sensitivity for detecting varietal differences.

4) Since different numbers of control and check varieties are grown analysis for improved performance of the best new variety over the best control should take into account statistics of extremes and be cognisant of the chance differences resulting from extreme selections from different sample sizes.

*General*

1) Experiments should be carried out to establish the magnitude and cause of the differences between yields at the stations and the local areas. Steps should be taken to make stations representative of those areas or trials should be carried out under more realistic conditions outside the stations at an earlier stage in the breeding and testing process.

2) Experiments of a factorial nature should be carried out establish the relationship between year to year, season to season, and location to location stability, and calculate gains to be derived from various combinations of yield and stability increases, given expected year to year yield fluctuations.

3) The genetic base from which selections for improved Japonica varieties are made should be broadened considerably. Given the lack of progress in the past twelve years, relatively drastic broadening could be contemplated, with a view to obtaining future improved gains at the risk of some short term decrease in yields.

4) Establish crop and region specific selection programs (preferably both together) simultaneously with current programs. It would seem erroneous to abandon altogether current breeding practices for generalised varieties, especially since they have been successful before, and because they may continue to be so with more genetic variability. Breeding is a process of selection for chance extremes so that a highly successful variety may still be procuced by present methods.

5) Region and crop specific programs should be long term programs to take into account yearly fluctuations, and because the current gene pool is oriented to general rather than specific adaptation. Moreover the degree to which the Improvement Stations are representative of the environments in question should be rigorously investigated.

6) New techniques of exploiting hybrid vigour, clonal selection, cell and tissue culture, as well as new techniques for introducing particular traits, should be vigorously pursued.

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# 臺灣第二期水稻產量的遺傳因子型與環境交感作用之研究

## —稉稻部份—

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本研究收集本省12年來(民國54～66年)稉稻新品種六個區域試驗之產量資料加以分析，其結果如後。

1. 各地方試驗的平均產量和期作間產量的差異，大體上與一般農田所得的結果相一致。

2. 各改良場之試驗結果，每年的產量和其轄區內一般稻田的結果相差甚遠，因此改良場的產量資料並不具代表性。

3. 在所有分析項目中，品種的效應較小，但顯著存在。環境效應較大且極為顯著，其中不可預測之效應（年度）約為可預測效應（地區、期作）的⅔。品種與環境的交感效應往往大於品種的主效應（個別與綜合分析皆同）。期作與地區間的交感效應較大，此示二期作低產因地區而異。由於有地區性存在，擬育成全省性適應品種較為困難。

4. 地方性品種的增產很小（3～4%）。同樣的增產效果可從當地最優的品種中獲得。

5. 期作間採用適當的期作品種時其增產效果很小（約2%），反不如栽培最優品種，其增產有時可高達30%。

6. 品種常具有地方適應性，尤其是二期作較一期作更為顯著。一品種在其育成地的產量較其他地區為高（4～5%）。

7. 過去12年來，栽培技術的改進有助於產量之提高，但其效率不大（每年約增加1%）。

8. 具全省性高產的品種對地方的適應性較低，但安定性較大。

9. 由平均產量，最優品種產量與逐年之品種改良資料的分析結果知，12年來的育成品種並無增產之效。許多高產品種，其增產值反而比試驗估值小。

綜合本研究的結果，我們認為將來進行區域性產量比較試驗時應設立全省統一的對照品種，而產量的分析則宜採用兩年的資料綜合分析之（分析模式如表9），同一地方的重複可以減少。試驗設計需顧及改良場及其轄區內一般稻田所得結果之差異，並探討年度、期作與品種的安定性問題。更深入而言，應引入更多的種源以拓展稉稻品種的育種工作，進行較長期的育種計劃，俾能育成優良的地方性品種或期作性品種，同時急需加強基礎研究以開創育種新技術。