INFLUENCE OF SPACING ON HERITABILITY AND INTERRELATIONSHIPS AMONG AGRONOMIC TRAITS IN THE F_2 POPULATION OF A RICE CROSS[1]

By

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Grain yields of rice generally increase with increased planting density. One of the major difficulties confronted with dense planting is lack of commercial varieties adapted to this growing conditions. This can be explained partly that the present varieties now commercially available are developed without paying special attention to their spacing responses during the course of selection, suggesting that some basic changes in the architecture of rice plant for these varieties may be needed (Chang, 1965). Hence, considerable emphasis has been placed on breeding rice varieties for dense planting in recent years. An understanding of the impact of spacing on yield and several other characters commonly obtained in the evaluation of individual plants or lines will permit the use of more efficient breeding techniques.

Estimates of heritablity and the interrelationships among important agronomic traits are useful in designing an effective breeding program. Heritabilities and correlations for most agronomic characters in rice have been reported by a number of investigators (Bollich, 1957; Toriyama and Futsuhara, 1953; Nei, 1960; Futsuhara et al., 1965). However, these values change with spacing (Kariya and Yamamoto, 1963; Sakamoto *et al.*, 1963; Chang, 1564), and time of planting (Akemine and Kumagai, 1958). Thus, in breeding rice varieties for dense planting, such estimates are of most value when based upon materials grown under different spacings.

The objectives of this study were to estimate heritability and interrelationships among important agronomic traits of the F_2 population of a rice corss grown under three spacings.

MATERIALS AND METHODS

Japonica varieties, Tainan 3 and Pi No. 4 were used as parents to make a cross which was studied in the F_2 generation in the second crop of 1965 at the Rice Experimental Farm of Chiayi Agricultural Experiment Station. Tainan 3, developed by Tainan Agricultural Improvement Station, is a commercial variety noted for its high yielding ability and wide adaptablity, while Pi. No. 4, an introduction from Japan, has been widely used as the breeding material because of its high level of resistance to rice blast disease (*Piricularia oryzae*). Both

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parents and F_2 population were grown under three spacings given in Table 1. For each spacing, more than 200 plants for each parent and 500 plants for F_2 generation were represented. One seedling was transplanted to each hill. Standard cultural practices were strictly followed for the management of the experimental plot. Climatic conditions were favorable for good rice growth and yield during the test period.

Table 1. Spacing for experimental materials

Spacing	Distance between row (cm)	Distance between hills (cm)	Number of hills per m^2
Wide	25	40	10
Standard	25	20	20
Close	25	10	40

About 50 and 100 plants were selected at random from each parent and F_2 population respectively in each spacing. Data for all traits were obtained on each plant as follows: heading date recorded in days from transplanting to the date when the first ear emerged, plant height, number of panicles per plant, panicle length, panicle weight, number of grains per panicle, weight of 100 grains, and grain yield per plant. Data thus collected for both parents and F_2 population in each spacing were analyzed for each trait by the analysis of variance and for each pair of traits by the analysis of covariance, based on the data of individual plants. Heritability estimates and correlation coefficients were computed from variance and covariance components by the same procedure used in the previous study (Chang, 1964).

EXPERIMENTAL RESULTS

Effect of Spacing on Agronomic Traits of Rice Plant

Means of eight agronomic traits of both parents and F_2 population in each spacing treatment are given in Table 2. The effects of spacing treatments upon the agronomic traits of parental varieties and F_2 plants were quite remarkable. Means of number of panicles and grain yield per plant showed a drastic decrease with the increase of planting density, while close spacing caused only a slight decrease in the means of plant height, panicle weight, and number of grains per panicle. Heading date and 100-grain weight were not affected by spacing.

The average number of panicles per plant of F_2 population was smaller than parental varieties in each spacing, whereas the means for the other characters were located in general midway between those of both parents. Parental differences in the means of heading date, plant height, number of panicles per plant, number of grains per panicle, and grain yield per plant reduced with increased planting density, especially the number of panicles per plant at close spacing where difference between both parents almost disappeared completely.

However, differences of parental varieties in the means of panicle length, panicle weight, and 100-grain weight increased as plants were being spaced closer together.

Table 2. Means of 8 agronomic traits for both parents and F_2 population grown under 3 spacings in the second crop of 1965.

Character	Wide spacing			Standard spacing			Close spacing		
	P_1*	P_2**	F_2	P_1	P_2	F_2	P_1	P_2	F_2
Heading date (days)	60.0	46.8	50.5	59.9	46.4	50.4	57.7	48.4	50.6
Plant height (cm)	106.5	86.0	96.4	106.2	85.5	93.9	105.9	87.4	93.6
Panicles per plant	17.2	19.3	17.2	11.4	14.0	10.8	6.6	6.8	6.0
Panicle length (cm)	21.2	19.5	19.7	19.5	16.8	18.5	20.4	17.1	18.2
Panicle weight (g)	3.6	2.3	3.0	2.8	1.9	2.6	3.1	1.9	2.6
Grains per panicle	146.6	76.7	108.2	122.4	69.1	96.7	131.4	65.0	92.5
Weight per 100-grain (g)	2.6	3.0	2.9	2.7	2.9	2.9	2.7	3.0	2.9
Grain yield per plant (g)	49.8	33.2	39.6	29.5	22.6	24.9	19.7	12.0	14.6

* P_1=Tainan 3. ** P_2=Pi No. 4.

Estimates of Heritability

Heritabilities in the broad sense for 8 agronomic traits in each spacing calculated as the percent genotypic portion of the total F_2 variance, are presented in Table 3. Estimates of heritability generally decreased with increased planting density. Differences between wide and standard spacings in heritability estimates were less than those between wide and close spacings. The number of panicles per plant at wide spacing were twice as large as that of standard spacing and 20 times larger than that of close one. The rates of decrease in heritability estimates for the other traits with increased planting density were more or less slower and the heritabilities of wide spacing were only slightly larger than those of standard spacing and 2 to 4 times larger than those of close one.

Table 3. Heritability estimates for 8 agronomic traits of F_2 plant grown under 3 spacings in the second crop of 1965.

Character	Wide spacing (%)	Standard spacing (%)	Close spacing (%)
Heading date	86.38	65.39	42.99
Plant height	75.34	71.50	48.89
Panicles per plant	40.39	17.59	1.92
Panicle length	58.16	60.12	17.68
Panicle weight	58.06	38.46	29.17
Grains per panicle	59.74	47.65	26.10
Weight per 100-grain	79.41	44.83	15.23
Grain yield per plant	44.12	50.67	24.73

Table 4. Genotypic, phenotypic, and environmental correlations between 8 agronmic traits of F_2 plants grown under 3 spacings in the second crop of 1965.

Traits correlated	Wide spacing			Standard spacing			Close spacing		
	r_G	r_P	r_E	r_G	r_P	r_E	r_G	r_P	r_E
Heading date and									
plant height	.382	.348**	−.065	.454	.377**	−.222	.339	.231**	−.084
panicles per plant	−.202	−.252	−.257	−.363	−.271**	−.041	−.287	−.166	.042
panicle length	.218	.186	−.076	.236	.176*	−.103	.219	.044	−.322**
panicle weight	.330	.272**	−.233	.557	.337**	−.438**	.268	.149	−.127
grains per panicle	.435	.353**	−.367*	.546	.355**	−.398**	.436	.285**	−.055
weight per 100-grain	−.046	−.045	−.026	−.048	−.020	.091	−.139	−.131	−.115
grain yield per plant	.005	−.036	−.361*	.208	.103	−.328*	.208	.122	−.074
Plant height and									
panicles per plant	.137	.116	.017	.131	.121	.114	.276	.202*	.077
panicle length	.489	.473**	.386**	.663	.596**	.254	.062	.070	.228
panicle weight	.538	.497**	.236	.754	.643**	.255	.709	.554**	.176
grains per panicle	.487	.470**	.365*	.835	.709**	.186	.687	.572**	.303*
weight per 100-grain	−.021	−.007	.136	.042	.041	.041	−.138	−.062	.105
grain yield per plant	.410	.366**	.179	.590	.534**	.295*	.629	.510**	.236
Panicles per plant and									
panicle length	.157	.127	.002	.194	.207*	.260	−.208	−.103	.041
panicle weight	.060	.051	.014	.117	.097	.061	−.062	−.098	−.153
grain per panicle	.091	.099	.133	.046	.107	.245	.052	.011	−.051
weight per 100-grain	−.104	−.075	.104	.120	−.001	−.265	.094	−.101	−.372**
grain yield per plant	.561	.563**	.568**	.653	.649**	.671**	.841	.816**	.792**
Panicle length and									
panicle weight	.796	.765**	.609**	.812	.752**	.574**	.577	.627**	.719**
grains per panicle	.731	.700**	.542**	.822	.773**	.606**	.415	.547**	.776**
weight per 100-grain	.012	.025	.125	.070	.088	.154	−.121	−.039	.093
grain yield per plant	.657	.589	.314*	.654	.630**	.541**	.106	.195*	.348*
Panicle weight and									
grains per panicle	.957	.921**	.734**	.878	.854**	.790**	.947	.881**	.754**
weight per 100-grain	.341	.326**	.240	.122	.105	.059	−.326	−.082	.357**
grain yield per plant	.748	.698**	.516**	.729	.708**	.651**	.260	.350**	.638**
Grains per panicle and									
weight per 100-grain	−.107	−.097	−.029	−.112	−.096	−.049	−.457	−.383**	.023
grain yield per plant	.767	.711**	.484**	.813	.781**	.680**	.530	.467	.349*
Weight per 100-grain and									
grain yield per plant	−.055	−.021	.187	.021	.009	−.194	−.147	−.151	−.160
Degree of freedom		109	43		114	53		114	53

* Correlations significant at 5% level.

** Correlations significant at 1% level.

In each spacing treatment, estimates of heritability for heading date, plant height, panicle length and number of grains per panicle were generally high, whereas those of panicle weight, weight of 100 grains, grain yield per plant and number of panicles per plant were relatively low. However, heritability estimates for 100-grain weight and panicle weight were quite high under the condition of wide spacing.

Genotypic, Phenotypic, and Environmental Correlations

Genotypic, phenotypic, and environmental correlations measured over 3 spacings between all possible pairs of 8 traits are given in Table 4. Genotypic correlations were generally higher than the corresponding phenotypic correlations. Environmental correlations were larger than either genotypic or phenotypic correlations in certain combinations and smaller in the other ones. Genotypic and phenotypic correlations between various pairs of 3 spacings had like signs with the following exceptions, i.e., negative phenotypic correlations between heading date and grain yield per plant in wide spacing, and between panicles per plant and weight of 100-grain in standard and close spacings to their corresponding positive genotypic correlations. In general, more phenotypic correlations were found to be significant in standard spacing than in the other two.

Heading date gave negative environmental correlations with the rest of 7 traits in all spacings. The genotypic and phenotypic correlations between heading date and other traits were rather small in magnitude, especially in close spacing. Associations of plant height with both panicle weight and grains per panicle were high, particularly in standard and close spacings. The size of genetic correlations between plant height and grain yield, as well as all 3 correlations between panicles per plant and grain yield per plant increased as plants were being closely spaced together. Genotypic and phenotypic correlations between panicle length and panicle weight, grains per panicle, and grain yield per plant were high in standard spacing, but the magnitude of correlations decreased when population increased or decreased. Correlations between panicle weight and grains per panicle showed the highest values in all spacings, the phenotypic and environmental correlations being highly significant. Grain yield per plant was found to be closely associated with both panicle weight and grains per panicle, especially in wide and standard spacings. Weight per 100-grain was negatively correlated with other traits in close spacing while some positive associations were found in the other two.

DISCUSSION

Parental varieties, Tainan 3 and Pi No. 4 differ quite greatly in agronmic characters and a sufficient segregation in F_2 population for 8 traits measured in this experiment was available. Agronomic traits showed different responses to spacing indicating that the ability to make adjustment to spacing varied with characters. Panicles and grain yield were found to be more easily influenced by spacing than others which is in agreement with the result of Chang (1965). Difference in panicle per plant among parental and F_2 plant was negligible under close spacing. Kariya and Yamamoto (1963) also suggested that rice varieties tend to become a similar type under close spacing, as far as tillering is concerned. Since competition is more intense under densely planted condition, the reduction in average values of agronomic traits observed in this experiment may be partly attributable to the effect of competition.

Estimates of heritability for heading date, plant height, and grains per panicle were generally higher than panicles and grain yield per plant which were similar to the results reported by other workers (Bollich, 1957; Toriyama and Futsuhara, 1958; Oung and Chang, 1958; Chang, 1960; Nei, 1960). Heritabilities for weight of panicle and 100-grain were also considered to be low (Matsuo, 1956) as was the case in standard and low spacings of this study, but these estimates were quite high under wide spacing, indicating that the variability of these two traits in F_2 population is rather great under the growing conditions of wide spacing. It was noticed that heritability values decreased as population density increased which may be attributable to either the decrease in F_2 genotypic variance or the increase in environmental one. The smallest heritability value obtained in this experiment was 1.91 for panicles per plant under close spacing showing that there was practically no genotypic variance left in total F_2 variance after the removal of environmental one. Under close spacing where competition is rather intense, low heritabilities of several agronomic traits in close spacing will unquestionably render selection for these traits more difficult. Since competitive ability is generally not correlated with productive traits (Yamada, 1950; Oka and Sakai, 1956), and density response (Sakai and Iyama, 1966), genotypes of high yielding and density response are not necessarily strong competitors. Efficiency of selection for these tratis under dense planting would, therefore, be reduced.

Heritabilites and correlations obtained in this experiment appeared different in size and, in some comparisons, in the direction with those of another cross reported in the previous study (Chang, 1964). This indicates that certain estimates of heritability and correlation may be characteristic of certain population in a certain planting and that there would be no reason to expect consistent values in other segregation populations. Akemine and Kumagai (1958) also reported that heritabilities and correlations of certain agronomic traits changed with time of planting.

The estimates of heritability and genetic relationships which exist among different traits must be considered in a breeding program. Gotoh and Osanai (1959) suggested that if a high heritability estimate of a given character is obtainable under a particular set of conditions, the efficiency of selection for this character could be enhanced in this environment. In this experiment, grain yield per plant was genetically correlated with panicles per plant and plant height in close spacing; and with grains per panicle, panicle weight, and panicle length in wide and standard spacings. Since heritability estimate for panicles per plant was extremely small in close spacing, more effective selection for grain yield in F_2 population may probably be made through selecting tall plants. In wide spacing, grains per panicle appeared to have the highest estimate of heritability, therefore, emphasis should be placed on the selection of plants with more grains per panicle. As for standard spacing, heritabilities for both grains per panicle and panicle weight were lower than that for panicle length, plants high in grain yield may be better obtained by selecting plants with long panicles. Considering the magnitude of heritability and association of characters obtained in this study, it seems highly likely that selection for grain yield in F_2 population would be more effective in wide spacing than in the other two. Kobori (1963) reported that selection on ear weight per plant is more effective under the condition of sparse planting. Sakamoto *et. al.* (1963) also observed that panicle weight per plant of the population cultured in low planting density was significantly higher than the population grown in high planting density.

SUMMARY

Eight agronomic traits of a rice cross, Tainae 3 × Pi No. 4, were studied in in the F_2 population in the second crop of 1965 to 3 spacings, i.e., wide, standard, and close spacings with distance between rows and hills of 25 × 40, 25 × 20, and 25 × 10, respectively. Data for all traits were obtained on individual plants randomly selected.

Close spacing caused a drastic decrease in panicles and grain yield per plant whereas plant height, panicle weight, and grains per panicle decreased very slightly. Heading date and weight of 100-grain were practically not affected by spacing.

Estimates of heritability for panicles and grain yield per plant were low largely due to the low genotypic variance of F_2 population. Heritabilities for other traits were in general higher. Heritability estimates for traits in wide and standard spacings were larger than those in close spacing.

Grain yield per plant was closely associated with panicles per plant and plant height in close spacing, and with grains per panicle, panicle weight, and panicle length in wide and standard spacing.

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栽植密度影響水稻什交第二代後裔主要農藝性狀遺傳力及相關之研究

張　萬　來

摘　要

水稻品種臺南 3 號，Pi No 4 及其雜交第二代後裔分別種植於三種不同栽植密度卽疏植（行株距25×40分分），標準植（行株距25×20公分）及密植（行株距25×10公分）並從各栽植密度隨機選取單株調查有關農藝性狀。

每株穗數及每株谷重均隨栽植密度之增加而急減，株高，穗長與每穗粒數亦有遞減現象，生育日數及百粒重受栽植密度影響甚微。

每株穗數及每株谷重之遺傳力較低，而其他農藝性狀之遺傳力則較高，在疏植及標準環境下估計之遺傳力，一般言之，均較密植處理者爲高。

在密植區每株谷重與每株穗數及株高具有密切正相關，而在疏植及標準植區，其每株谷重與每穗粒數，穗重及穗長等性狀之相關極高。