EFFECT OF GROWING CONDITIONS ON YIELD AND COMPONENTS OF YIELD IN RICE

by

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INTRODUCTION

Fertilization and spacing have been the problems of great concern to rice growers. Although these problems are not new and actually a considerable amount of work has already been done with regard to these practices, yet they still remain a challenge to the rice workers today. In Taiwan, where rice culture has been gradually moving toward the direction of heavy fertilization and high density of planting so as to further increase the unit production, these problems appear to be of particular significance. Since a number of workers have pointed out that various rice varieties respond differently to various fertility levels and planting densities (Yamada, 1961a; Chang, 1963), it seems necessary that optimum levels of fertility and planting density should be worked out for each commercial variety of rice. Chianung 242 has been among the top three leading commercial varieties in Taiwan and it seems desirable to give first priority to this variety for the solution of these problems. Also related to the problems of fertilization and planting density is the manner or shape of planting which was also shown to play an important role in the growth of rice (Wada, 1949; Ishi, 1957). The effect of planting shape on the characteristics of rice may also be worthwhile to investigate.

In recent years, however, considerable emphasis has been placed on the study of the adaptation response of rice variety to different conditions of fertility and spacing. Rice breeders are particularly interested in developing a new variety which can adapt well to heavily fertilized and closely spaced conditions. Some possible approaches to this end have been discussed by Oka and Lin (1958), and Jennings and Beachell (1964) regarding the response of rice varieties to fertilizers and by Kariya and Yamamoto (1963) regarding the planting density thereof. Plant type of rice adaptable to the tropics was also reviewed by Jennings (1964). The understanding of the relationship between yield and the components of yield in rice under different growing conditions may also be helpful toward throwing some light on the adaptability of rice. The primary purposes of this experiment, therefore, were (1) to evaluate the response of rice to three different growing conditions in terms of yield and the components of yield, and (2) to analyze the relationship between yield and the components of yield in each growing condition.

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MATERIALS AND METHODS

Two field experiments were conducted in the second crop of 1963 and the first crop of 1964 at Chiayi Agricultural Experiment Station. The dominant soil type of the paddy field used in this experiment is clay loam which is a well drained, moderately dark colored soil with pH value, organic matter and available phosphorus contents ranging from 5.3 to 5.6, 1.60 to 1.75%, and 40 to 65 kilogrms per hectare, respectively.

Chianung 242 was used exclusively in the experiment. It is a *Japonica* variety of the so-called panicle-weight type with large and heavy panicles, which is typical of this variety. The culm of this variety is rather tall, and is therefore susceptible to lodging. However, this variety is noted for its resistance to the rice blast disease (*Piricularia oryzae*) and its high yielding ability.

Three treatments of growing conditions, i. e., fertilizer rate, planting density, and planting shape, were included in the experiment. There were two rates of fertilizers, 80-40-40, and 160-80-80 kg of N, P, K applied per hectare; three spacings, 64, 96, and 128 hills per 3.3 m^2; and three shapes of planting, rectangular 1 with row space of 24 cm, rectangular 2 with 27 cm between rows, and square. The experiment was laid out in a split-plot design with rates of fertilizers labeled as the main treatments; planting density, the sub-treatments; and planting shape, the sub-subtreatments. There were five replications in the experiment. Plots were 2.5 m wide and 4 m long, each being equivalent to 1/1,000 hectare. Approximately five seedlings were planted in each hill.

Number of panicles per hill was taken at the full ripe stage by randomly counting 10 hills located at the center of each plot. Number of grains per panicle and weight of 1,000 grains were recorded for each plot based on 20 randomly sampled panicles, one from each hill. Grain yields in kilograms per plot were taken by the standard method. All data thus collected were subjected to the analysis of variance. Simple correlation coefficients between yield and each of its components were calculated for every treatment by using the treatment averages. Coefficients of determination were also calculated so as to show the percentage of yield variation determined by each component.

EXPERIMENTAL RESULTS

Treatment Effects

Effect of fertilizer rate—The high rate of fertilizers (160-80-80) resulted in more grain yield per hectare than the low one (80-40-40) in both crop seasons (Table 1). The difference of yield between different rates ef fertilizers, however, failed to reach a level of significance. The response of grain yield to the increase of fertilizers was more pronounced in the first crop of rice.

The effect of fertilizer levels on the components of yield was manifested by the increase of panicle number per hill and the reduction of the number of well-formed

Table 1. Yield and components of yield of rice variety Chianung 242 under three growing conditions in the second crop of 1963 and the first crop of 1964

Treatment	Grain yield (kg/ha)		Panicles per hill		Grains per panicle		Weight of 1,000 grains (g)	
	2nd. 1963	1st. 1964	2nd. 1963	1st. 1964	2nd. 1963	1st. 1964	2nd. 1963	1st. 1964
Fertilizer (NPK applied, kg/ha)								
80-40-40	4,724	5,742	7.7	9.2	149	116	28.9	29.5
160-80-80	4,870	5,946	8.3	10.0	147	115	28.6	29.1
L.S.D. 5%	NS	NS	NS	NS	NS	NS	0.3	NS
L.S.D. 1%	—	—	—	—	—	—	—	—
Planting density (hills/3.3 m²)								
64	4,715	5,765	10.0	11.7	155	118	28.9	29.2
96	4,792	5,827	7.7	9.3	148	115	28.6	29.3
128	4,885	5,940	6.3	7.8	141	112	28.7	29.4
L.S.D. 5%	NS	171	0.4	0.5	3	4	NS	NS
L.S.D. 1%	—	—	0.6	0.7	5	—	—	—
Planting Shape								
Rectangular 1 (row width 24 cm)	4,736	5,758	8.0	9.5	149	114	28.4	29.1
Rectangular 2 (row width 27 cm)	4,642	5,754	8.0	9.7	152	117	28.9	29.3
Square	5,014	6,020	8.0	9.7	143	115	28.8	29.5
L.S.D. 5%	148	171	NS	NS	4	NS	NS	NS
L.S.D. 1%	197	227	—	—	—	—	—	—

grains per panicle and the weight of 1,000 grains with higher rates of fertilizers (Table 1). The differences between fertilizer levels were not significant among the three components in both crops except that the weight of 1,000 grains in the second crop of 1963 was significant at the 5% level.

Effect of planting density—Results showed that grain yield responded positively with the increase of planting densities (Table 1). The effect of planting density on grain yield was significant at the 5% level in the first crop of 1964 where high planting density of 128 hills per 3.3 m^2 produced 175 kg or more grain per hectare than that of low planting density, i. e., 64 hills per 3.3 m^2. In the second crop of 1963, however, grain yields did not differ significantly among the different planting densities.

Among other yield components, the number of panicles per hill and the number of grains per panicle decreased significantly with the increase of planting densities in both crops (Table 1). The degree of reduction was similar in both crops for panicle number but it was slightly greater in the second crop than in the first insofar as the number of grains per panicle is concerned. Seed weight was least affected by the treatments.

Effect of planting shape—The data obtained for planting shape indicated that within a given planting density, the square shape of planting, with equi-distance of rows and hills, gave the highest yield; while the rectangular shape with row space fixed at 27 cm gave the lowest yield (Table 1). Differences among shapes of planting greatly exceeded the 1% level of significance in both crops.

Shape of planting did not give rise to a great change in seed weight, and panicle number apparently remained unchanged among the treatments in both crops (Table 1). However, the rectangular shape with row space fixed at 27 cm produced more grains per panicle than the other two shapes (Table 1). This difference was significant at the 5% level in the second crop of 1963, but failed to reach a significant level in the first crop of 1964.

Interactions—None of the 24 two-way tables are given. Of these only one, i. e., fertilizer rate × planting density for weight of 1,000 grains in the first crop of 1964, was significant at the 1% level. In low fertilizer rate, grain weight decreased as planting density was raised to 96 hills per 3.3 m^2 and then increased as planting density reached as high as 128 hills per 3.3 m^2; while in high one, the situation was just the opposite. Within a planting density, higher rate of fertilizers reduced weight except for the one with 96 hills per 3.3 m^2 in which seed weight was increased with the addition of more fertilizers.

Relationship Between Yield and the Components of Yield

Correlation coefficients between yield and each of the three components of yield for each treatment are given in Table 2.

Number of panicles per hill was positively correlated with yield in the second crop under all treatments except rectangular shape 2, while the correlations were mostly negative for the treatments in the first crop except the treatments of 64 hills per 3.3 m^2, rectangular shapes 1 and 2, where the correlations were positive. The correlations were significant at the 5% level in the first and second crops of 64 and 96 hills per 3.3 m^2, respectively, while in the second crop of 128 hills per 3.3 m^2, it was significant at the 1% level.

Number of grains per panicle was negatively correlated with yield in the second crop for all treatments but negatively correlated in the first crop. The correlations were significant at the 5% level in the first crop of both fertilizer rates and significant at the 1% level in the first crop of 96 hills per 3.3 m^2 and square shape of planting.

Weight of 1,000 grains was positively correlated with yield in the second crop for all treatments. In the first crop, however, no consistent trends were observed in seed weight among treatments. The correlations in the second crop were significant for all treatments except that of rectangular shape 1 which was not significant. Grain weight was not significantly correlated with yield in the first crop.

Coefficients of determination (r^2) for all significant correlatoins showed that about 10 to 32% seed yield variations could be ascribed to the effect of one particular

Table 2. Correlation coefficients and coefficients of determination between yield and components of yield of rice variety Chianung 242 for three growing conditions

Treatment	Crop season	Yield-panicle/hill		Yield-grains/panicle		Yield-grams/1,000 grains	
		r	r^2	r	r^2	r	r^2
Fertilizer (NPK applied kg/ha)							
80-40-40	2nd. 1963	+0.151	0.023	−0.262	0.069	+0.446**	0.199
	1st. 1964	−0.139	0.019	+0.370*	0.137	+0.275	0.076
160-80-80	2nd. 1963	+0.021	0.001	−0.203	0.041	+0.392**	0.154
	1st. 1964	−0.192	0.037	+0.313*	0.098	−0.147	0.022
Planting density (hills/3.3 m^2)							
64	2nd. 1963	+0.289	0.083	−0.254	0.065	+0.385*	0.148
	1st. 1964	+0.372*	0.138	+0.094	0.009	−0.060	0.004
96	2nd. 1963	+0.433*	0.187	−0.288	0.083	+0.468**	0.219
	1st. 1964	−0.265	0.070	+0.539**	0.291	+0.111	0.012
128	2nd. 1963	+0.493**	0.243	−0.059	0.004	+0.369*	0.136
	1st. 1964	−0.159	0.025	+0.341	0.117	+0.095	0.009
Planting shape							
Rectangular 1 (row width 24 cm)	2nd. 1963	+0.229	0.052	−0.183	0.033	+0.294	0.087
	1st. 1964	+0.226	0.051	+0.086	0.007	+0.268	0.072
Rectangular 2 (row width 27 cm)	2nd. 1963	−0.155	0.024	−0.139	0.019	+0.523**	0.273
	1st. 1964	+0.051	0.003	+0.729	0.078	−0.279	0.078
Square	2nd. 1963	+0.055	0.003	−0.139	0.019	+0.563**	0.317
	1st. 1964	−0.162	0.026	+0.540**	0.292	+0.058	0.003

* Significant at the 5% level. The d.f. was 43 for fertilizer and 28 for both planting density and planting shape.
** Significant at the 1% level.

component of a given treatment. Small values of coefficients of determination were obtained for correlations which were not significant.

DISCUSSION

The results of this experiment demonstrate that further increase of yield in rice can be expected by increasing fertlizers and planting densities. However, differences between fertilizer rates and among planting densities failed to reach a significant level, indicating that rice varieties available at present may not be sensitive enough in its responsiveness to addition of fertilizers and increased planting densities. Actually, Chang (1963) has already pointed out that the varietal response to nitrogen was generally poor. Since the existing commercial rice varieties have been developed without paying attention to their responsiveness to growing conditions during the process of selection, it seems natural that these varieties are rather poorly equipped with this ability, which has since become so important in recent years. A similar trend seems to prevail also in other crop varieties. Gotoh and Osanai (1959a) observed in wheat that lines selected from widely spaced planting yielded better than those from closely spaced one. Rumbaugh (1963) also reported that selection indices based upon yield component data obtained from spaced nurseries may not accurately portray the yield potentials of genotypes in solid planting of alfalfa.

It was observed that high levels of fertilizers increased leaf size and stimulated tillering, thus producing much more foliage. Close spacing also caused the same effect. The combination of heavy fertilization and close spacing, therefore, produced more internal foliar shading and lowered light transmission rate. It seems, therefore, reasonable to suggest that the insignificant effects of added fertilizers and increased planting density on grain yield may be attributable to increased mutual shading of rice plants. Yamada (1961b) concluded that under heavily fertilized and closely spaced condition, sufficient penetration of light is prerequisite to higher yield response. Tanaka (1963) also demonstrated that mutual shading increases at higher levels of nitrogen and that this mutual shading reduced the effect of the nitrogen. Generally, carbohydrate synthesis slackens, respiration increases, and grain yields are reduced when foliar shading increases (Jennings, 1964). It is, therefore, suggested that in the future breeding program, emphasis should be placed on selecting individual plants or lines, among other desirable characters, with short, sturdy straw; and erect, small, thick, and dark-green leaves as suggested by Jennings and Beachell (1964). It would also be profitable, as indicated by the correlation coefficients, that new varieties should have heavy grains in the second crop and more grains in the first one, if they are to be adaptable under heavily fertilized and closely spaced conditions. For varieties to yield more under high planting densities in the first crop, high tillering capacity seems indispensable.

Methods of breeding varieties for fertilizer and density responsiveness have been a matter of great concern to rice breeders in recent years. Oka and Lin (1958) suggested that if rice varieties with high fertilizer response are to be selected, culture of hybrid population with a high dose of fertilizer is effective for the purpose. However, Gotoh and Osanai (1959b) reached just the opposite conclusion in wheat. They concluded that to select high yielders with tolerance to heavy fertilizer applications, selection should be made under low fertility condition. In selecting rice varieties adaptable under high planting density, Kariya and Yamamoto (1963) suggested that the best method may be conducting the selection in high planting density on the basis of line means. The issue, however, is still unsettled and further investigation is necessary.

At the present time, growing rice under heavily fertilized and closely spaced conditions, maximum yield seems attainable by arranging various cultural practices in such a way so as to enable those characters which are in close association with yield to reach maximum development. This approach seems to be of particular significance for rice culture in Taiwan since the practice of heavy fertilizing and close spacing has already gained wind, but new varieties with best fertilizer and density responsivenss are not yet developed.

Correlations between yield and its components were generally of small magnitude although some of them were significant even at the 1% level. The results seem to indicate that factors other than these three components of yield may also be in operation. The coefficients of determination indicate that they could account for no more than 10 to 32% of the variations in seed yields. Matsubayashi (1963) included percentage of rippened grains as the fourth component of yield. Shibata (1964) added three more components to the yield of rice, namely, heading date, maturity date and number or days from heading date to the date when half of the plants in plots are completely prostrated.

It is of interest to note that square shape of planting gave, so far, the highest yield, while rectangular 2, the lowest. Since square shape has equal distance both between rows and between hills within rows, while rectangular 2 has wider space between rows (27 cm) than between hills within a row, it seems to indicate that low yielding ability of the latter planting shape may be due primarily to the early competition between hills at the early stage of growth. Ishi (1957) reported that square shape enables rice plants to tiller early, and provides more space for young tillers to absorb nutrients so that they can be well established at the early stage of growth. Wada (1949) also suggested that when sufficient fertilizers are available for rice plants, square shape of planting can best serve the purpose. Based on the results of this experiment, and also on the findings of these two workers, it appears probable that better yield could be expected in heavily fertilized and closely spaced paddy field, especially in the second crop, if the rice plants were transplanted in square shape. Incidentally, the trends of association between yield and the components of yield in square shaping were similar to those of high fertilizer rate and high planting densities.

SUMMARY

The effects of 2 fertilizer rates, 3 planting densities, and 3 shapes of planting on the growth of rice conducted in the second crop of 1963 and the first crop of 1964 at Chiayi Agricultural Experiment Station are reported.

Grain yields increased with increasing fertilizers and planting densities. The increase of yields was more pronounced in the first crop of rice. Differences in yields between fertilizer rates as well as among planting densities were not significant except in planting density of the first crop, 1964. Square shape of planting outyielded the other two rectangular shapes, a difference greatly exceeding the 1% level of probability in both crop seasons.

Number of panicles per hill slightly increased with added fertilizers, decreased significantly with increasing planting densities and remain almost unchanged among

planting shapes. Number of grains per panicle decreased slightly with added fertilizers, decreased significantly with increasing planting densities. Rectangular shape with row space of 27 cm significantly increased grains per panicle in the second crop. Seed weight was least affected by the treatments.

Seed weight was significantly correlated with grain yield in the second crop for fertilizer rates, planting densities, square shape and rectangular shape 2 (row space 27 cm). Grain number per panicle was significantly associated with grain yield in the first crop for fertilizer rates, high planting density, and square shape of planting. Panicle number per hill was significantly correlated with grain yield in the second crop for high planting density (96 hills/3.3 m^2) and in the first crop for low planting density. Coefficients of determination showed that about 10 to 32% of seed yield variations could be ascribed to the effects of yield components.

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生育環境對稻谷產量及其構成因素之效果

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摘　　要

本文係報告嘉義農業試驗分所在民國52年第二期作及53年第一期作舉辦施肥量，栽植密度及方式對水稻產量與其構成因素效果之試驗結果。

稻各產量隨施肥量及栽植密度之提高而增加，以第一期作產量爲最。但處理間差異，除53年第一期作栽植密度外，均未達顯著水準。栽植方式間產量差異均極顯著，尤以正方形植者，產量最高。

每株穗數多寡與施肥量形成正比，但與栽植密度成相反現象。至於栽植方式則未見有何影響。每穗粒數因增肥，密植而行遞減，惟行距27公分之長方形植，似有增加趨勢。生育環境對千粒重之影響，極度輕微。

第二期作水稻之千粒重，在施肥量，栽植密度及行距27公分之長方形植等處理，概與產量呈顯著正相關。第一期作水稻之每穗粒數，則施肥量，密植（每坪96株）及正方形植等處理下，亦與產量成顯著之正相關。在第二期作密植及第一期作疏植狀況下，穗數與產量之相關達顯著水準。決定係數指出約有10至32%之產量變異，直接受此等與產量有顯著相關之構成因素所支配。