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COMPARISON OF YIELD STABILITY AMONG PURE, MIXED, AND HYBRID POPULATIONS OF RICE[1]

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Abstract

Using three Indica and five Japonica rice varieties; pure varieties, mixture of two varieties, and F_2 populations were evaluated for their year-seasonal stability in grain yields. In both Indica and Japonica groups, the order of mean grain yield productivity was F_2>mixture>pure, and the order was also given in the stability of yield as expresed by regression coefficient on environmental means in the Indica group, but the order was reversed in the Japonica type. This indicated that the relationship between grain yield and its response to the year-seasonal change differed with rice types.

Introduction

High mean value and low variability of grain yield are desired characters. These two characters are often correlated, e.g., maize yield (Eberhart *et al.* 1966), plant height of *Nicotiana rustica* (Perkins *et al.* 1968), height, flowering time, leaf number and fresh weight of *Arabidopsis thaliana* (Westerman *et al.* 1970; Westerman 1971; Wu 1974), and growth rate of *Schizophyllum commune* (Fripp *et al*, 1973).

In the present study, attempts were made to obtain information on the effect of the genetic background of populations on year-seasonal stability of grain yield in rice.

Materials and Methods

Two series of experiments, one with Indica and the other with Japonica varieties, were conducted, each including pure, mixed and F_2 hybrids populations

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as shown in Table 1.

Table 1. *Experimental materials*

Population	Expt. of Indica type	Expt. of Japonica type
Pure	V_1: Taichung Native 1 V_2: Hsinchu-ai-chueh-chien V_3: IR-8	V_1: C 236 V_2: Tainan 1 V_3: Tainan 4 V_4: Tainan 5 V_5: Hsinchu 56
Mixed	M_1: V_1+V_2 M_2: V_1+V_3 M_3: V_2+V_3	M_1: V_1+V_2 M_2: V_1+V_3 M_3: V_1+V_4 M_4: V_1+V_5
F_2 hybrid	H_1: $V_1\times V_2$ H_2: $V_1\times V_3$ H_3: $V_2\times V_3$	H_1: $V_1\times V_2$ H_2: $V_1\times V_3$ H_3: $V_1\times V_4$ H_4: $V_1\times V_5$

They were tested in the first (winter) and the second (summer) crop-seasons for two and four years to the Japonica and the Indica varieties, respectively, at the Chiayi Agricultural Experiment Station (23.5°N latitude). A randomized complete block design with four replications was used in each experiment.

The linear regression of population means on environmental values were computed. The environmental value was estimated from the average yield of all populations in the given season and year. The model used for computation is $Y_{ij}=\mu_i+b_i\varepsilon_j+d_{ij}$, where Y_{ij} is the yield of ith population at the jth environment, μ_i is the mean yield of the ith population over-all environments, b_i is the regression coefficient representing the response of the ith population to varying environmental values, ε_j is the jth environmental value as shown by its deviation from the mean value for over-all environments, and d_{ij} is the deviation from regression of the ith population at the jth environment. From this analysis, two measures of yield of year-seasonary stability are evolved, i.e., regression coefficient ($\hat{b}_i$) and deviation mean square ($\hat{\sigma}^2_{d_{ij}}$). The significance test of these two measures can be tested using the error mean square from combined analysis of variances for all populations, as given by Finlay *et al.* (1963) and Eberhart *et al.* (1966).

Results and Discussion

Combined analysis of variance

The mean grain yields (ton/ha) for different stands (pure, mixture and F_2 hybrid population) of each population in Indica and Japonica series obtained at varied environment are listed in Tables 2 and 3, respectively.

Table 2. *Yield data for different stands of each population in Indica series at vary environments (ton/ha)*

		1969		1970		1971		1972	
		I	II	I	II	I	II	I	II
Pure	V_1	6.43	4.22	4.89	5.66	6.40	7.20	4.61	5.89
	V_2	6.20	4.47	5.41	5.58	7.09	7.93	4.54	5.64
	V_3	5.73	4.45	5.32	6.46	5.78	7.61	4.86	5.69
	$\bar{V}$	6.12	4.38	5.21	5.90	6.42	7.58	4.67	5.74
Mixed	M_1	6.58	4.43	5.35	5.67	6.87	7.17	5.60	5.93
	M_2	6.70	4.27	5.27	5.60	6.53	7.50	5.38	5.61
	M_3	6.46	4.20	5.46	5.77	7.08	7.66	5.34	5.51
	$\bar{M}$	6.58	4.30	5.36	5.68	6.83	7.44	5.44	5.68
F_2 hybrid	H_1	6.87	4.67	5.43	5.95	7.06	7.24	6.06	6.24
	H_2	6.73	5.03	5.81	6.85	6.79	8.25	6.23	5.75
	H_3	6.40	4.58	5.51	6.46	7.24	8.21	6.39	5.88
	$\bar{H}$	6.67	4.76	5.58	6.42	7.03	7.90	6.23	5.96
Environmental mean		6.46	4.48	5.38	6.00	6.76	7.64	5.45	5.79

The data for each crop season were pooled together, and the combined analysis of variance was made for each experiment. The results are shown in Table 4, which shows that: (1) In both Indica and Japonica types, the variance due to year was highly significant. (2) The variance due to crop season was significant in the Japonica type, but insignificant in Indicas. (3) The interaction between year and crop season also significantly affected grain yield in both type. The interaction variance was greater than those due to year or crop season. (4) The variance due to stands were all significant, this indicates the significant difference existed between mean values of the pure, mixed and hybrid stands, the mean grain yield of F_2 population being the highest. (5) The interaction variance between environment and population was significant in the Indica experiment but not significant in the Japonica, suggesting that the grain yield of Indica variety was more easily affected by

Table 3. *Yield data for different stands of each population in Japonica series at vary environments (ton/ha)*

		1971		1972	
		I	II	I	II
Pure	V_1	5.76	4.76	4.73	5.34
	V_2	5.33	4.38	4.08	4.44
	V_3	5.93	4.75	4.86	5.03
	V_4	5.28	4.56	4.83	4.56
	V_5	5.53	4.41	4.78	4.95
	$\bar{V}$	5.57	4.57	4.66	4.86
Mixed	M_1	5.58	4.61	5.03	5.03
	M_2	6.07	4.62	4.71	4.97
	M_3	5.62	4.71	4.54	4.91
	M_4	5.78	4.56	4.78	4.97
	$\bar{M}$	5.76	4.63	4.77	4.97
F_2 hybrid	H_1	6.22	4.69	5.44	5.14
	H_2	6.17	4.83	5.18	5.16
	H_3	6.11	4.75	5.42	5.21
	H_4	6.33	4.87	5.28	5.08
	$\bar{H}$	6.21	4.79	5.33	5.15
Environmental mean		5.82	4.65	4.90	4.98

the environment. In the Japonica variety, only the interaction of crop season and population groups was significant. This indicates that the difference due to groups was easily affected by the season.

Regression on environmental means

The results of the analysis of variance following the method given by Eberhart's method (1966) are shown in Table 5. The pooled deviation and the residual error of each population were non-significant when tested against the experimental error, as the estimated value of sensitivity (regression coefficient) did not differ much among populations. The interaction between population and environment was also insignificant when it was tested against the mean square of pooled deviation. Therefore, the linear sensitivity of each population had same estimated value.

The estimated value of mean value, regression coefficient, deviation mean square and significant test for each population are presented in Table 6. The significant test of their differences also made and we obtained that the differ-

Table 4. *The analysis of variance of grain yield*

Variation	Indica series			Japonica series		
	df	MS	F	df	MS	F
Environment (Env.)	7	5,371,912.37	96.53**	3	2,154,483.13	51.40**
Year (Y)	3	7,558,728.40	135.83**	1	737,443.60	17.59**
Season (S)	1	11,781.10	0.21	1	2,437,140.60	58.13**
Y×S	3	4,971,806.80	89.34**	1	3,288,865.20	78.45**
Block within year and season (Error 1)	24	55,648.98		12	41,924.75	
Population group (P)	8	359,697.50	14.93**	12	156,907.33	6.63**
Bet. group	2	1,301,709.50	54.04**	2	609,956.60	25.78**
Within group	6	45,693.50	1.90	10	66,297.47	2.80**
Within pure	2	50,011.10	2.08	4	156,905.48	6.63**
Within mixed	2	13,137.90	0.55	3	10,338.53	0.44
Within hybrid	2	73,931.50	3.07*	3	1,385.80	0.06
Env.×P	56	73,485.51	3.05**	36	20,750.49	0.88
Env.×Bet. group	14	116,395.18	4.83**	6	44,351.74	1.88
Env.×Wit. group	42	59,182.29	2.46**	30	16,030.24	0.68
Env.×Wit. pure	14	91,246.50	3.79**	12	22,020.10	0.93
Env.×Wit. mixed	14	21,290.42	0.88	9	17,371.87	0.73
Env.×Wit. hybrid	14	65,009.95	2.70**	9	6,702.13	0.28
Y×P	24	71,683.62	2.98**	12	17,620.43	0.75
Y×Bet. group	6	54,980.68	2.28*	2	3,204.25	0.14
Y×Wit. group	18	77,251.22	3.21**	10	20,503.66	0.87
Y×Wit. pure	6	121,554.28	5.05**	4	23,051.08	0.97
Y×Wit. mixed	6	34,991.88	1.45	3	24,750.23	1.05
Y×Wit. hybrid	6	75,207.50	3.12**	3	12,863.97	0.54
S×P	8	24,969.61	5.19**	12	29,939.43	1.27
S×Bet. group	2	333,263.95	13.86**	2	126,174.56	5.33**
S×Wit. group	6	55,538.17	2.31*	10	10,692.40	0.45
S×Wit. pure	2	110,779.20	4.60*	4	12,524.53	0.53
S×Wit. mixed	2	2,526.60	0.11	3	12,480.23	0.53
S×Wit. hybrid	2	53,308.70	2.21	3	6,461.90	0.27
Y×S×P	24	58,126.04	2.41**	12	14,669.51	0.62
Y×S×Bet. group	6	105,519.95	4.38**	2	3,676.38	0.16
Y×S×Wit. group	18	43,328.07	1.76*	10	16,894.67	0.71
Y×S×Wit. pure	6	54,427.82	2.26*	4	30,484.70	1.29
Y×S×Wit. mixed	6	13,843.57	0.58	3	14,885.61	0.63
Y×S×Wit. hybrid	6	58,712.81	2.44*	3	780.52	0.03
Error 2	192	24,088.01		144	23,658.83	
Total	287	176,155.50		207	62,817.99	

* and **: Significant at 5% and 1% level, respectively.

Table 5. *ANOVA for stability parameters*

Variation	Indica series			Japonica series		
	df	MS	F	df	MS	F
Population (P)	8	89,924.37	5.24**	12	39,231.41	7.92**
Env.+P×Env.	63	165,549.90	9.65**	39	46,222.67	9.33**
Env. (linear)	1	9,400,846 64	548.13**	1	1,616,247.92	326.36**
P×Env. (linear)	8	12,831.26	0.75	12	4,806.19	0.97
Pooled deviation	54	17,150.87	0.71	26	4,952.38	9.21
V_1	6	15,491.65	0.64	2	11,333.03	0.48
V_2	6	24,499.52	1.02	2	11,600.15	0.49
V_3	6	38,883.29	1.61	2	833.86	0.04
V_4				2	4,309.97	0.18
V_5				2	2,706.47	0.11
M_1	6	8,767.81	0.35	2	2,511.80	0.11
M_2	6	6,161.09	0.26	2	2,026.34	0.09
M_3	6	5,672.40	0.24	2	6,563.60	0.28
M_4				2	428.70	0.02
H_1	6	15,690.22	0.65	2	10,330.58	0.44
H_2	6	19,611.86	0.81	2	506.65	0.02
H_3	6	19,580.02	0.82	2	7,393.56	0 31
H_4				2	3,786.19	0.16
Block within year & season	24	55,648.98		12	41,924.75	
Error	192	24,088.01		144	23,658.83	

**: Significant at 1% level.

ences in regression coefficient were non-significant between any two populations of Indica type. In the Japonica rice, four comparisons showed differences at 5% significant level. The relationships between regression coefficient and mean grain yield are shown in Figs. 1 and 2. The variation trends of mean grain yield and regression coefficient differed among the three population groups. In Indica, hybrid populations ($\bar{H}$) seemly had a high mean grain yield and a low sensitivity; the pure varieties ($\bar{V}$) had a low grain yield and a high sensitivity. This similar to high stability of F_1 hybrid in *N. rustica* observed by Perkins *et al.* (1968). In Japonica, the situation was reversed and the stability positively correlated to mean yield. This indicates that the genetic systems are involved in the control of the mean expression and sensitivity to the environmental changes. This pattern has been reported to the plant height of pure lines of *N. rustica* obtained by Perkins *et al.* (1968) as well as yield stability of barley obtained by Finlay *et al.* (1963) and by Wu (1974) in the fresh weight of *Arabidopsis thaliana.*

Table 6. *The mean yield, regression coefficient and deviation mean square of each population*

Population	Indica series				Japonica series			
		Yield (ton/ha)	Reg. coef. (b)	Deviation MS		Yield (ton/ha)	Reg. coef. (b)	Deviation MS
Pure	$\bar{V}$	5.753	1.028**	0.404	$\bar{V}$	4.915	0.880**	0.011
	V_1	5.663	1.018**	0.581	V_1	5.145	0.875	0.142
	V_2	5.858	1.174**	0.919	V_2	4.558	0.964	0.145
	V_3	5.738	0.890**	1.458	V_3	5.143	1.049**	0.011
					V_4	4.810	0.617	0.039
					V_5	4.918	0.896**	0.034
Mixed	$\bar{M}$	5.913	1.015**	0.154	$\bar{M}$	5.030	0.993**	0.008
	M_1	5.950	0.901**	0.329	M_1	5.063	0.751**	0.031
	M_2	5.855	1.024**	0.231	M_2	5.090	1.301**	0.025
	M_3	5.935	1.120**	0.213	M_3	4.945	0.875	0.082
					M_4	5.020	1.041**	0.005
F_2 hybrid	$\bar{H}$	6.317	0.958**	0.268	$\bar{H}$	5.368	1.157**	0.049
	H_1	6.190	0.850**	0.588	H_1	5.373	1.191	0.129
	H_2	6.428	0.946**	0.735	H_2	5.335	1.129**	0.006
	H_3	6.333	1.077**	0.734	H_3	5.373	1.058*	0.092
					H_4	5.390	1.248**	0.047

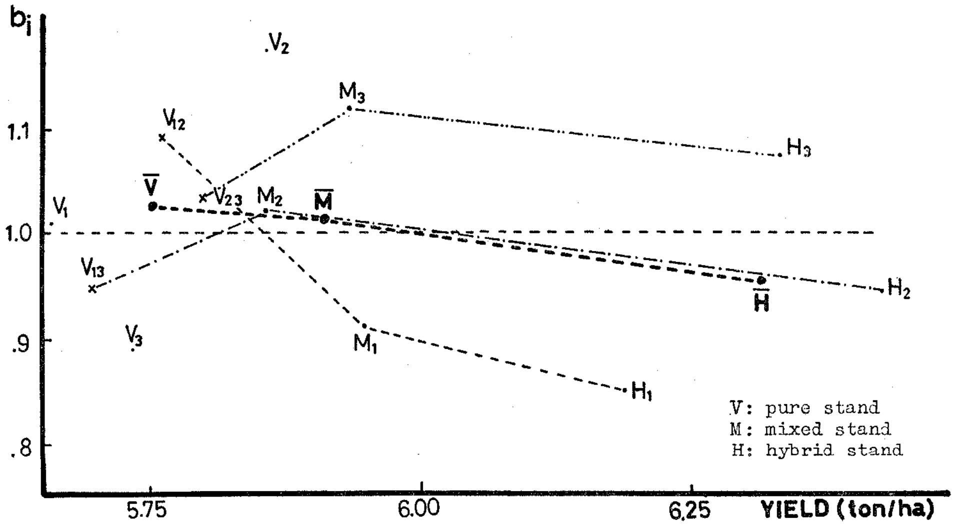

Fig. 1. The relationship of mean yield and yield stability (bi) for Indica type.

Comparing the Indica and Japonica types, we found that the relationship between mean grain yield and linear sensitivity markedly differed. So, each

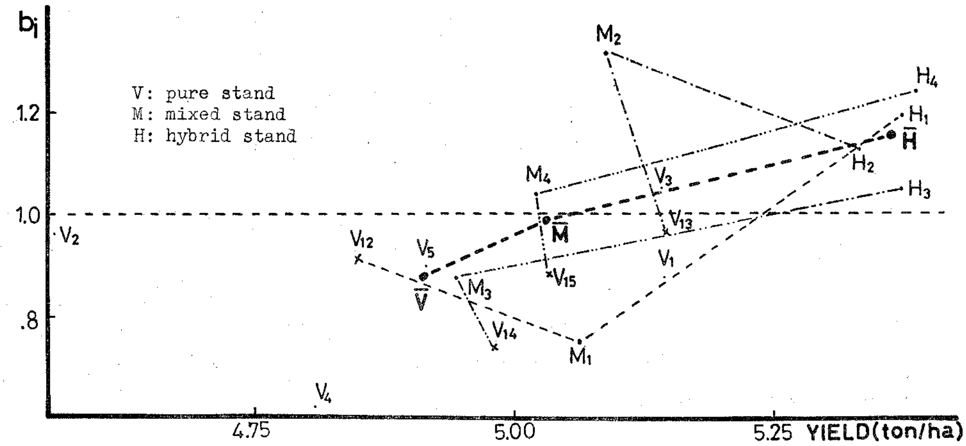

Fig. 2. The relationship of mean yield and rield stability (*bi*) for Japonica type.

combination of varieties and/or genotypes, as well as the environments should be treated as a separate case.

As shown in Fig. 1, the combination of Taichung Native 1 and Hsinchu-ai-chueh-chien increased grain yield and stability in both mixed and F_2 population. In Fig. 2, only one combination, C236 and Tainan 1, increased grain yield and stability in the mixed population. Hence, it does not seem to obtain a high-yielding population with a low sensitivity from mixtures and hybrids of those different Japonica varieties. Perhaps, competition exerts an advance effect.

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水稻不同遺傳組成集團之產量及其安定性之比較

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本研究在探討秈，稉稻各三種不同遺傳組成集團，即單一品種（或品系）集團 (V)，二品種等量混植集團 (M) 及其 F_2 雜種集團 (H) 的產量及其安定性之關係。主要結果有；(1) 兩型稻的產量在年度間的變化甚大，期作間的變化則以稉稻較大。(2) 兩型稻的生產力皆以 F_2 雜種集團最大，混植集團次之，但其安定性在秈稻型品種時以 F_2 雜種集團最大，純質集團最小，而稉稻型品種時則相反。因此產量及其安定性間的關係因稻型的不同而異，且可能分別由不同的遺傳體系所支配。