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Genetic Analysis of Harvest Index and It Components, Grain Yield and Total Dry Weight[1]

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Summary

Grain yield, total dry weight and harvest index were recorded in six cultivars used as the parents and $15F_1$ populations among them. Analysis of the data showed that overdominance was present in all the three characters. The $H_2/4H_1$ ratio for grain yield (0.227) and total dry weight (0.215) suggested a symmetric distribution of positive and negative alleles in the parents. But the raio for harvest index (0.181) suggested asymmetric distribution. In contrast, the proportions of dominant and recessive genes in the parents given by the KD/KR ratio suggested asymmetrical distributions for grain yield and total dry weight and symmetrical distribution for harvest index.

The number of gene groups controlling grain yield and total dry weight was at least one for each, but that for harvest index was at least two. The narrow-sense heritabilities estimated for grain yield, total dry weight and harvest index were 37%, 44% and 48%, respectively. The heritability of harvest index was not lower than those of grain yield and total dry weight.

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Genetic Anaysis of Harvest Index and It Components, Grain Yield and Total Dry Weight

Fu-Hsiung Lin

Introduction

Although the genetic control of harvest index is an important aspect of differential partitioning of photosynthate, little information is available on the pattern of variation of this attribute in segregating populations following crosses. The genetic control of harvest index must be explained before we can outline a resonable breeding procedure by the use of this trait. Although harvest index can range between zero to nearly 100 percent, most studies with small grains reported ranges from 30 to 60 percent. Its biological ceiling would be around 60 percent.

Bhatt (1976) reported that in wheat crosses high harvest index was partially dominant over lower values and the action of genes governing harvest index was largely additive. Rossielle and Frey (1977) also reported in oat that harvest index showed primarily additive gene action. In rice the additive gene action and unidirectional positive dominance was found as shown in the percentage of panicle weight (Murai and Kinoshita 1986). In Taiwan little information is available about this character. Therefore, this experiment was to examine the inheritance pattern of harvest index and related traits from a set of half-diallel crosses among six rice cultivars.

Materials and Methods

Harvest index is the ratio of grain yield to total dry weight. To learn about the mode of inheritance of these traits, variations in grain yield, total dry weight and harvest index were investigated in a set of diallel crosses of 6 rice cultivars listed in Table 1. The parents and their F_1 plants (15 combinations, not including reciprocal crosses) were tested in a randomized complete block design with four replications in the second crop of 1983. The spacing used was 25 cm x 20 cm. The total amount of fertilizers applied by one basal and two topdressings was N: 100 kg/ha, P_2O_5 : 80 kg/ha and K_2O: 60 kg/ha. The plots were protected from diseases and insects as needed. At maturity, 8 plants per row excluding border ones were harvested to record grain yield, total dry weight and harvest index.

Diallel tables were compiled for the parents and F_1 values of the three characters. Analysis of variance of the data showed significant differences due to treatments. Mean values transformed into natural logarithms were used for further

Table 1. Origin and characteristics of the parents

Parents (Cultivars)	Origin	Grain yield (g/plant)	Total dry weight (g/plant)	Harvest index (%)
Kaohsiung sen yu 303	Kaohsiung Taiwan	13.6	34.4	39.5
Taichung sen 10	Taichung Taiwan	11.9	28.1	42.3
Kaohsiung sen 7	Kaohsiung Taiwan	11.1	23.5	47.3
Ming-down	Native variety of Taiwan	12.6	33.4	37.8
Tung-Mee-Tsang	Native variety of Taiwan	8.9	20.9	42.7
Pai-Kuo-Ching-Yu	Native variety of Taiwan	10.4	26.9	38.5

statistical analysis. The graphical analysis was done according to the method suggested by Hayman (1954). The variance-covariance (Vr/Wr) graphs were prepared by taking the Vr values along the X-axis and Wr values along the Y-axis. The distance between the origin and the point of intersect of the regression line with the Wr axis provides a measure of average degree of dominance. The order of the array points along the regression line provides information on the distribution of dominant and recessive genes among the parents. The relationship of the order of dominance (Wr + Vr) among the parents for each trait was determined by the standardized deviation graph of parental measurement (Yr) and the order of dominance (Wr + Vr) of the parents based on the formulas of Johnson (1963).

Genetic parameters were estimated according to components of variance analysis, the method suggested by Hayman (1954). The following parameters were obtained from diallel analysis and ratios were estimated from genetic components of variation.

D = Additive effects

F = Mean of co-variation of additive and dominance effects over arrays

H_1 = Dominance effects

H_2 = Dominance indicating asymmetry of positive and negative effects

h^2 = Dominance effects over all loci

E = Error

$(H_1/D)^{1/2}$ = Mean degree of dominance over all loci

$H_2/4H_1$ = Proportion of positive and negative alleles

KD/KR = Ratio of dominant and recessive genes in all parents

h^2/H_2 = Effective factors

r(Yr, Wr + Vr) = Correlation between the parental order of dominance and parental measurement.

Computation was made after the data were transformed into natural logarithms. Then, harvest index is represented by grain yield minus total dry weight.

Results and Discussion

The results from the analysis of variance (Table 2) showed significant genotypic differences among progenies for the characters of grain yield, total dry weight and harvest index.

The non-significant t^2 confirmed the validity of the hypothesis postulated for diallel analysis. The Vr/Wr graphs (Figs 1, 3, 5) for harvest index (b = 0.239 ± 0.215), grain yield (b = 0.258 ± 0.171) and total dry weight (b = 0.351 ± 0.196) showed that the regression of Wr on Vr deviated significantly from the unit slope, indicating the prevalence of epistasis for all three traits. Although Kempthorne (1956) and Gilbert (1958) have objected to the elimination of interacting arrays as suggested by Hayman (1954b). Breese (cf Hayman, 1963) stated that the removal of arrays in order to improve regression is not an integral part of Vr, Wr analysis, however, elimination of interacting arrays facilitates the discovery of parents which contribute most to the epistatic effects.

The wide scatter of array points for all the traits in the graphical analysis revealed wide genetic diversity among the parents. In the distribution of array points for harvest index, the parents Ming-Down and Kaohsiung sen 7 were closed to the point of origin indicating that they have excess of dominant genes, whereas Pai-Kuo-Ching-Yu being situated farthest from origin carries the maximum number of recessive genes. The scatter of array points for grain yield indicated that the parents fall into two different groups Ming-Down, Pai-Kuo-Ching-Yu and Tung-Mee-Tsang have a large number of dominant alleles, whereas Kaohsiung sen 7, Kaohsiung sen yu 303 and Taichung sen 10 have a large number of recessive alleles. The pattern of array points for total dry weight revealed that Ming-Down and Tung-Mee-Tsang have the maximum concentration of dominant alleles whereas Kaohsiung sen 7 has the largest number of recessive alleles. On the basis of the distribution of array points, the presence of dominant and recessive genes for various characters in the parental lines is summarized in Table 3.

The regression line for grain yield and total dry weight intersecting the Wr axis below the point of origin indicates overdominance for these characters. For harvest index, the regression line intersected the Wr axis above the origin indicating partial dominance.

The standardized deviation graphs (Fig 2, 4, 6) of parental order of dominance (Wr + Vr) and parental measurements (Yr) showed that parent Ming-Down had dominant genes and Kaohsiung sen yu 303, Taichung sen 10 had recessive genes for high grain yield. For low grain yield Pai-Kuo-Ching-Yu and Tung-Mee-Tsang had dominant genes and Kaohsiung sen 7 had recessive genes. For large total dry weight, Ming-Down had dominant genes, but Kaohsiung sen yu 303, and Taichung sen 10 had recessive genes. For less total dry weight Tung-Mee-Tsang had dominant genes, Kaohsiung sen 7 and Pai-Kuo-Ching-Yu had recessive genes. For high harvest index, Kaohsiung sen 7 and Tung-Mee-Tsang had dominant genes, Taichung sen 10 had recessive genes. The parent Ming-Down had dominant genes and Pai-Kuo-Ching-Yu possessed recessive genes for low harvest index.

The genetic components of variation and their ratios are presented in Tables 4 and 5, respectively. The estimates of additive genetic variance (D) was significant only for harvest index, but the dominance components (H_1 and H_2) were highly significant for all three traits. Non-significant estimates of F values indicated that the dominant and recessive alleles contributed equally for the three traits. The E components were not significant. Ratios computed from these genetic components provided further information on the degree, order and direction of dominance for the traits. The estimates of net dominance (h^2) were significant and positive for all three traits, indicating that the direction of dominance tended towards positive side.

Overdominance was indicated for all of grain yield, total dry weight and harvest index. The $(H_1/D)^{1/2}$ ratio in harvest index (1.8252) is not in conformity with the result obtained from graphical analysis which showed partial dominance. Such a discrepancy between the two approaches is possible as the variance components method furnishes only an overall estimate of dominance. The $H_2/4H_1$ ratio for grain yield (0.2272) and total dry weight (0.2145) showed symmetric distribution of positive and negative alleles in the parents. For harvest index, however, the distribution of positive and negative alleles was asymmetric ($H_2/4H_1 = 0.1812$).

The proportion of dominant and recessive genes in the parents given by KD/KR were not equal to unity for grain yield and total dry weight. This indicated that there was some asymmetry in the distribution of dominant and recessive genes in the parents for these two traits, whereas for harvest index, the value was close to unity indicating symmetry distribution of dominant and recessive genes among parents.

The number of gene groups controlling grain yield and total dry weight was one at the least, but that for harvest index was at least two. The number of genes controlling grain yield and total dry weight estimated in this experiment was too small as compared with previous reports (e.g., Li and Chang, 1970). The narrow sense heritabilities were 37%, 44% and 48% for grain yield, total dry weight and harvest index, respectively.

The results from graphical and genetic components analysis discussed above should be compared with caution, as the premises for diallel analysis were not fully met. Gilbert (1958) made a critical evaluation of diallel techniques and raised questions about the assumptions which limit its application each by each. From the analysis of variance components it can be safely concluded that overdominance was present in all three characters studied. This suggests that the potential of selection for high harvest index genotypes in hybrid populations is high.

Array	Variety	Vr	Wr
1	KSSY303	0.009	0.002
2	TCS10	0.011	0.003
3	KSS7	0.003	0.002
4	MD	0.005	0.003
5	TMT	0.005	0.0001
6	PKCY	0.012	0.006

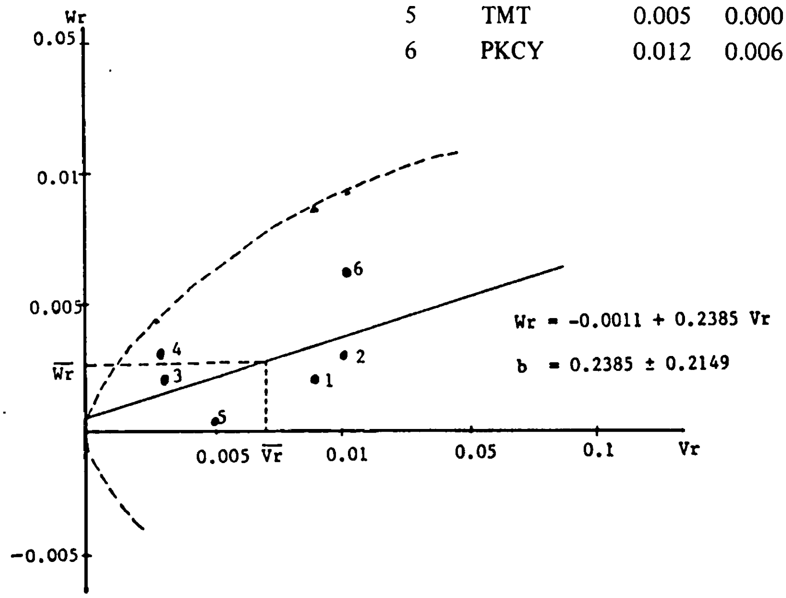
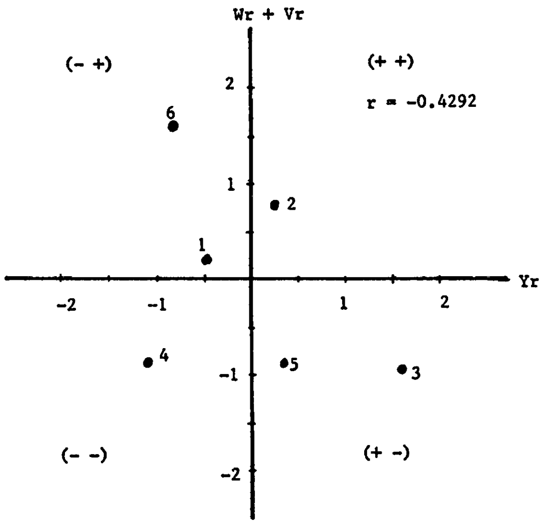


Fig 1. Covariance (Wr) and variance (Vr) graph of harvest index in six-parent diallel analysis



Array	Variety	Wr + Vr	Yr
3	KSS7	–0.97	1.65
5	TMT	–0.93	0.45
4	MD	–0.87	–1.07
1	KSSY303	0.23	–0.47
2	TCS10	0.82	0.26
6	PKCY	1.65	–0.82

Fig 2. Standardized deviation graph between parental mean (Yr) and order of dominance (Wr + Vr) for harvest index in six-parent diallel cross

Array	Variety	Vr	Wr
1	KSSY303	0.131	0.016
2	TCS10	0.113	0.016
3	PKCY	0.147	0.044
4	MD	0.070	0.002
5	TMT	0.080	0.022
6	KSS7	0.076	0.024

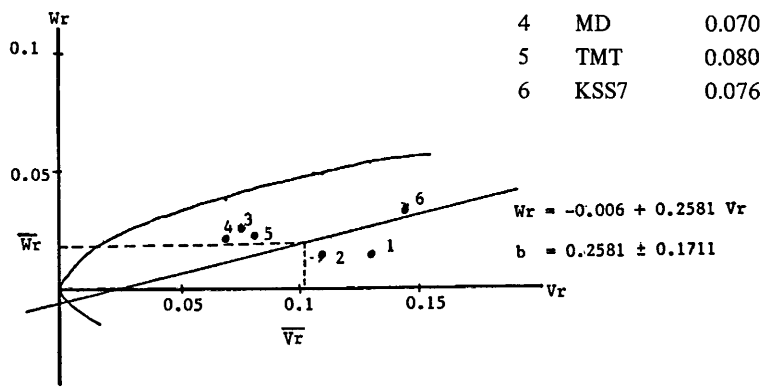


Fig 3. Covariance (Wr) and variance (Vr) graph of grain yield in six-parent diallel analysis

Array	Variety	Wr + Vr	Yr
4	MD	−1.25	0.63
6	PKCY	−0.55	−0.56
5	TMT	−0.13	−1.58
2	TCS10	0.14	0.25
1	KSSY303	0.57	1.32
3	KSS 7	1.62	− 0.06

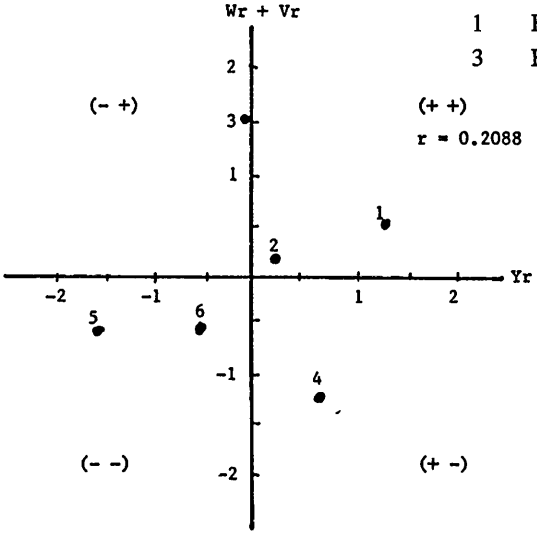


Fig 4. Standardized deviation graph between parental mean (Yr) and order of dominance (Wr + Vr) for grain yield in six-parent diallel cross

Array	Variety	Vr	Wr
1	KSSY303	0.138	0.014
2	TCS10	0.125	0.025
3	KSS7	0.164	0.063
4	MD	0.059	0.003
5	TMT	0.069	0.021
6	PKCY	0.100	0.042

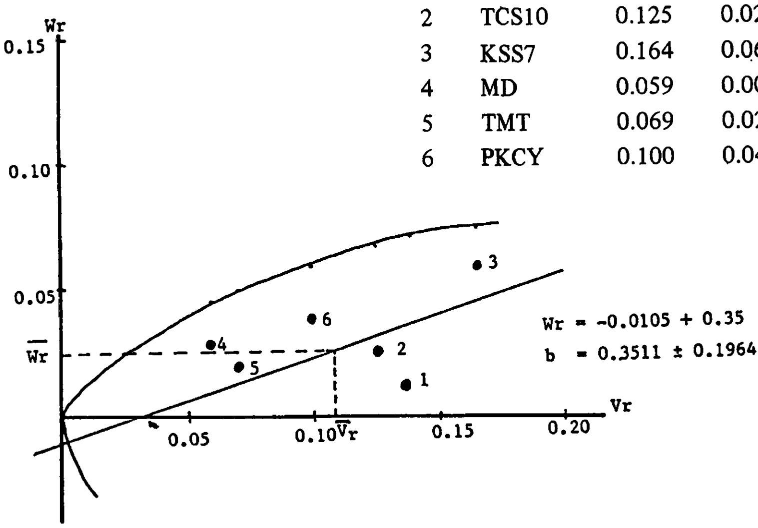


Fig 5. Covariance (Wr) and variance (Vr) graph of total dry weight in six-parent diallel analysis

Array	Variety	Wr + Vr	Yr
4	MD	−1.31	0.95
5	TMT	−0.83	−1.41
6	PKCY	0.08	−0.07
2	TCS10	0.23	0.08
1	KSSY303	0.26	1.22
3	KSS7	1.56	−0.78

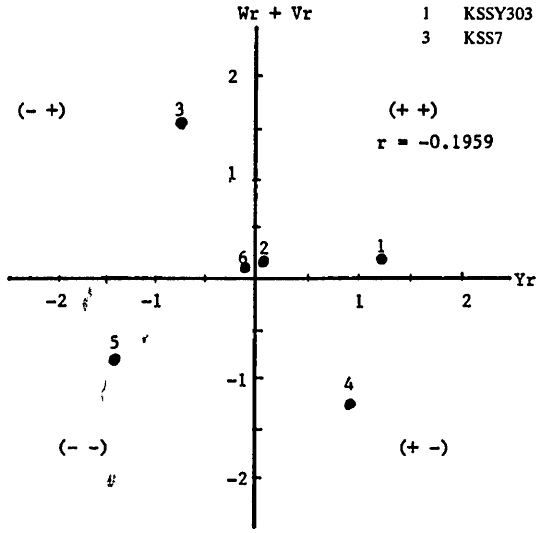


Fig 6. Standardized deviation graph between parental mean (Yr) and order of dominance (Wr + Vr) for total dry weight in six-parent diallel cross

Table 2. Analysis of variance for grain yield, total dry weight and harvest index in a 6 x 6 half-diallel crosses of rice with natural logarithm transformed data

Source of Variation	d.f.	Mean squares		
		Grain yield	Total dry weight	Harvest index
Block	2	0.10	0.07	0.01
Cross Combination	20	6.96*	7.24**	0.56**
Error	40	1.57	1.10	0.11
Total	62	8.63	8.40	0.68

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

Table 3. Concentration of dominant and recessive genes for three chracters in parental lines

Characters	Most dominant genes	Most recessive genes
Grain yield	Ming-Down	Kaohsiung sen 7
Total dry weight	Ming-Down Tung-Mee-Tsang	Kaohsiung sen 7
Harvest index	Kaohsiung sen 7 Ming-Down	Pai-Kuo-Ching-Yu

Table 4. Estimates of genetic components of variance for grain yield, total dry weight and harvest index with natural logarithm transformed data

Components	Characters		
	Grain yield	Total dry weight	Harvest index
D	0.080	0.0269	0.0063*
F	−0.0571	−0.0515	0.0020
H_1	0.293**	0.321**	0.0210**
H_2	0.2664**	0.2759**	0.0161**
h^2	0.5444**	0.3026**	0.0348**
E	0.0132	0.0093	0.0009

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

D – Additive effects; F – Mean of co-variation of additive and dominance effects over arrays; H_1 – Dominance effects;

H_2 – Dominance indicating asymmetry of positive and negative effects;

h^2 – Dominance effects over all loci; E – Error.

Table 5. Genetic components and narrow-sense heritabilites for grain yield, total dry weight and harvest index, with natural logarithm transformed data

Components	Characters		
	Grain yield	Total dry weight	Harvest index
$(H_1/D)^{1/2}$	6.0499	3.4559	1.8252
$H_2/4H_1$	0.2272	0.2145	0.1852
KD/KR	0.2582	0.5663	1.1951
$K = h^2/H_2$	0.0438	1.0967	2.1681
Heritability			
Narrow Sense	0.3655	0.4422	0.4830
Broad Sense	0.5950	0.9340	0.9032
r (Yr, Wr + Vr)	0.2088	−0.1959	−0.4292

$(H_1/D)^{1/2}$ – Mean degree of dominance over all loci; $H_2/4H_1$ – Proportion of positive and negative alleles; KD/KR – Ratio of dominant and recessive genes in all parents; h^2/H_2 – Effective factors; r (Yr, Wr + Vr) – Correlation between the parental order of dominance and parental measurement.

Literature Cited

1. Bhatt, G. M. 1976. Variation of harvest index in several wheat crosses. Euphytica 25: 41–50.
2. Gilbert, M. 1958. Diallel cross in plant breeding. Heredity 12: 477–492.
3. Hayman, B. I. 1954. The theory and analysis of diallel crosses. Genetics 39: 789–809.
4. Li. C. C. and T. T. Chang, 1970. Diallel analysis of agronomic traits in rice (oryza sativa L.). Bot. Bull. Academia Sinica 11: 61–78.
5. Murai, K. and T. Kinoshita, 1986. Diallel analysis of traits concerning yield in rice. Japan. J. Breed. 36: 7–15.
6. Rossielle, A. A. and K. J. Frey, 1977. Inheritance of harvest index and related traits in oats. Crop. Sci. 17: 23–28.

水稻收穫指數、穀產量及總乾物重之遺傳分析[1]

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摘 要

本試驗係利用半互交法分析六個水稻品種高雄秈育303號、台中秈10號、高雄秈7號，白穀清油、敏黨及凍米占及其半互交之15個F_1組合個體之收穫指數、谷產量及總乾物重遺傳分離情形。分析結果顯示收穫指數、谷產量及總乾物重三個性狀爲超顯性。谷產量及總乾物重$H_2/4H_1$之比各爲0.227及0.215顯示親本正負相對因子之分佈爲對稱性，但收穫指數$H_2/4H_1$之比爲0.181，呈不對稱分佈。相反的由KD／KR之比顯示之顯性及隱性因子之比率，谷產量及總乾物重呈不對稱分佈，收穫指數爲對稱分佈。

控制谷產量及總乾物重之因子數目至少有一對，而控制收穫指數之因子對數則至少有二對。谷產量、總乾物重及收穫指數之狹義遺傳率估計值各爲37％，44％及48％。收穫指數之遺傳率估值並不比谷產量及總乾物重爲低。

1. 花蓮區農業改良場研究報告第 34 號。
2. 場長。