Inheritance of Floating Ability in Rice*

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Diallel crosses were made among 10 rice varieties which vary in degrees of floating ability. The F_1 and F_2 generations were tested at the Huntra Deep Water Rice Exp. Station in Ayutthaya in 1975 and 1976, respectively.

The F_1 plants of crosses between floating and ordinary lowland rice varieties showed intermediate tolerance to 150 cm deep water indicating that floating ability was a partially dominant character. Most F_2 populations showed continuous distribution for floating ability suggesting that several genes were responsible for this character although damages by heavy rain and injury by crabs disturbed to draw accurate conclusions from the F_2 experiment.

These results suggest that rice varieties with different degrees of floating ability could be developed to cope with the various flooding conditions distributed in Asia.

Introduction

Rice ecotypes such as floating rice, deep water rice (in a narrow sense), and tidal swamp rice have helped farmers to grow rice even under extremely deep (1 to 4 meters) and deep (0.5 to 1 meter) inundation and in coastal swamp areas (0.5 to 1 meter deep water) around Asia (JACKSON *et al.* 1972; OKA 1975; NOORSYAMSI *et al.* 1975). Some varieties which have been identified their submergence tolerance are also expected to be useful in the areas where sudden floods often destroy crops (VERGARA *et al.* 1975).

Since the water control over vast areas will involve extremely costly development project, improvement of rice production by means of breeding new varieties and adopting better cultural practices should be continued in the deep water regions (ISLAM 1974).

The present experiments intended to study the genetic basis of floating ability in rice to supply information on the practical breeding work.

The term, "deep water rice", has been used in a broad sense to include all types of rice in deep water areas in recent international cooperation for improvement of "deep water rice" (BRRI 1975; IRRI 1977). In this report, the term, "floating ability", was adopted because the tests were conducted under the maximum water depth of 150 cm.

Materials and Methods

Varieties used

Ten rice varieties and experimental lines representing 5 different levels of floating ability were chosen as parents of diallel crosses including reciprocals. Their names and floating ability are given in Table 1. The F_1 and F_2 individuals were successively tested for floating ability in large tanks at the Huntra Deep Water Rice Experiment Station.

Pond test

The standard techniques for testing floating ability established at the Huntra Deep Water

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Table 1. Floating ability scores of F_1 plants and their parents

Type	Female parents	Male parents (abbreviated)										Tot.
		DW8	LMN	KNN	PG	NCL	T442	TPG	KDM	NPY	RD1	
FR	Deep Water 8	5	5	5	5	5	5	5	5	4	3	47
	Leb Mue Nahng 111	5	5	5	5	5	4	4	3	4	4	44
	Khao Nahng Nuey 11	5	5	5	4	4	4	4	3	3	4	41
	Pin Gaew 56	4	5	5	5	5	5	4	3	4	4	44
	Nahng Chalawng	5	5	4	4	4	4	4	2	2	3	37
FD	T442-57	5	4	4	4	4	3	3	2	1	1	31
SF	Tapow Gaew 161	4	4	4	4	3	2	2	2	2	1	28
TT	Khao Dawk Mali 105	5	4	4	4	2	2	1	1	1	1	25
	Nahng Prayah 132	4	3	3	3	2	2	1	1	1	1	21
SD	Rice Division 1	3	3	3	3	3	1	1	1	1	0	19
Total		45	43	42	41	37	32	29	23	23	22	337

Note. FR : Floating rice, FD : Floating dwarf, SF : Semi-floating, TT : Traditional tall varieties and SD : Semi-dwarf. Scores 5 to 0 indicate elongation ability-5 : good-0 : poor.

Deep Water 8 was introduced from Bangladesh and probably belonged to Habiganj Aman VIII variety. The other varieties are of Thailand origin.

Rice Exp. Station were reported by SOPHONSAKULGAEW (1977). These included sowing pre-germinated seeds in a raised bed in the bottom of an empty pond and allowing seedlings to grow for 1 month before increasing the water depth. After 30 days, the water level was raised 10cm every other day until a maximum level of 150~170cm was attained. Scoring for floating ability was accomplished by comparison of the performance of 3 check varieties consisting of ordinary semi-dwarf (RD1), a deep water tolerant semi-dwarf ("floating dwarf" line, T442) and a true floating variety (Pin Gaew 56) as biological scales. RD1 could not keep pace with rising water level when it reached about 90cm. Score 0 was given for such class of floating ability. T442 showed only several sheets of leaves standing or floating on the water when the depth reached 150cm. Score 3 was given for this degree of ability. PG56 showed about 50cm of its top standing above water when depth reached 150~170cm and score 5 was given. Due to limited amounts of seed, F_1 plants were not directly sown in this experiments but were transplanted after growing in pots for 24 days.

Six plants of each parental variety and one F_1 plant of each cross were used in the first test conducted during the dry season (February to April) of 1975. The F_2 generation test consisted of about 20 to 50 plants of each parent and 100 F_2 individuals per cross. This test was performed during the rainy season (June to August) of 1976.

Results

Results of the F_1 test are shown in Table 1. Crosses among deep water rice varieties showed good ability score whereas those which originated from crosses of ordinary rice varieties showed almost no ability. Those F_1 plants which derived from crosses between floating and ordinary non-deep water forms were generally intermediate in ability scores. The existence of partially dominant genes is suggested by their intermediate performance.

The diallel table of F_1 was subjected to the analyses according to the method of HAYMAN (1954), assuming that floating ability was governed by polygenes. Results of the variance analysis are shown in Table 2. Additive effect of polygenes (Item (a) in the table) showed overwhelmingly larger variance than the other components.

Many of the F_2 populations were damaged by heavy rains during germination and less than 100 plants per cross could be tested. Table 3 shows a part of F_2 results. Parental varieties showed a wide distribution of scores partly due to uneven germination and cutting off the plants by crabs.

Although such a fluctuation in varieties limits an interpretation of F_2 results, it appears that most F_2 populations tend to show a continuous distribution with a single peak. This may suggest that a number of genes are involved in floating ability. Two crosses, DW 8×T 442 and DW 8×RD

Table 2. Analysis of variance of F_1 diallel table

Item	SS	df	MS	F
a	166.72	9	18.52	91.35**
b	21.59	45	0.48	2.37**
b ₁	0.81	1	0.81	4.00n.s.
b ₂	1.16	9	0.13	—
b ₃	19.63	35	0.56	2.77**
c	1.7	9	0.19	—
d	7.3	36	0.20	—

- Note. (a) variation between the mean effects of each parental line,
 (b) variation in the reciprocal sums not ascribable to (a),
 (b₁) mean dominance,
 (b₂) further dominance due to each parental line,
 (b₃) remaining discrepancy in the specific reciprocal sum,
 (c) average maternal effect of each parental line,
 (d) variation in the reciprocal differences not ascribable to (c), used here as the common error.

** : Significant F value at 1% level.

Table 3. Frequency distribution of F_2 plants along score of floating ability in comparison with their parents

Type	Parents	Floating ability						Total	Mean	M.P.
		0	1	2	3	4	5			
F×F	DW 8×LMN	3	1	0	4	29	61	98	4.4	4.4
F×FD	DW 8×T 442	6	14	19	14	19	9	81	2.7	3.1
F×S	LMN×TPG	0	4	2	38	46	10	100	3.6	3.4
F×S	NCL×TPG	0	8	17	42	27	4	98	3.0	2.8
F×T	KNN×KDM	1	7	34	26	17	7	92	2.8	2.9
F×T	LMN×NPY	0	2	13	51	29	5	100	3.2	2.8
F×D	DW 8×RD 1	11	20	16	16	7	24	94	2.6	2.5
F×D	NCL×RD 1	4	21	26	24	15	6	96	2.4	1.8
FD×T	T 442×KDM	22	36	21	16	4	0	99	1.4	1.5
FD×D	T 442×RD 1	4	14	17	6	1	0	42	1.7	1.1
S×T	TPG×NPY	3	27	41	20	1	0	92	1.9	1.9
T×D	KDM×RD 1	13	38	38	2	0	0	91	1.3	0.8
F	DW 8	0	0	0	6	12	32	50	4.5	
F	LMN	0	1	3	2	4	22	32	4.3	
F	KNN	0	1	0	4	6	24	35	4.5	
F	NCL	1	3	5	12	7	6	34	3.1	
FD	T 442	3	11	4	9	0	0	27	1.7	
S	TPG	1	1	9	8	1	1	21	2.5	
T	KDM	3	9	6	0	0	0	18	1.2	
T	NPY	0	20	7	0	0	0	27	1.3	
D	RD 1	12	5	1	0	0	0	18	0.4	

Note. For abbreviations of type and parental varieties, see Table 1.

M.P.: Mid parent value, namely $M.P. = (P_1 + P_2)/2$.

1, showed a bi-modal distribution or a like. It is noteworthy that both T 442 and RD 1 may have a recessive semi-dwarf gene and DW 8 has the strongest floating ability and a remote origin among the varieties used.

The mean scores for floating ability of each F_2 population coincided reasonably well with the expected mid-parental values pointing to the additive nature of deep water tolerance again.

Discussion

Genetic basis of deep water tolerance and its implication

Deep water tolerance may be divided into several aspects according to the conditions of flooding or inundation; floating ability (ability to grow keeping pace with rising water level of more than 100~150 cm), deep water tolerance in a narrower sense (tolerance to 50~100 cm deep water), submergence tolerance (tolerance to sudden floods prolonging for a few days) and some other tolerances to adverse conditions (such as salt tolerance and tolerance to acid sulfate soil) accompanied with deep water.

Genetic analyses have been made mostly on the floating ability and few genetic studies were conducted on the other types of deep water tolerance.

RAMIAH and RAMASWAMI (1941) reported that floating ability was controlled by duplicate recessive genes. Their results could not be confirmed by our methodology and the discrepancy may be due to the difference in materials and classification methods.

MORISHIMA, HINATA and OKA (1962) suggested that several genes might be involved for floating ability. Our results corroborated their inference.

PRECHACHART *et al.* (1975) and SUPAJOJ *et al.* (1977) reported that hybrid populations derived from the crosses between floating and non-floating rice varieties segregated only a small portion of true floating type and more number of intermediate types. They refrained from concluding on dominance or recessiveness of floating ability.

Partial dominance and multi-geneic nature of floating ability were identified by our

Table 4. Variation among individual plants of parental varieties in floating ability (F_1 experiment, 1975).

Type	Variety	Plant number						Mean
		1	2	3	4	5	6	
	Deep Water 8	5	5	5	5	5	5	5.0
	Leb Mue Nahng 111	5	5	5	4	4	5	4.7
FR	Khao Nahng Nuey 11	5	5	5	4	4	4	4.5
	Pin Gaew 56	5	5	5	5	5	5	5.0
	Nahng Chalawng	4	0*	4	4	4	3	3.8
FD	T 442-57	3	2	0*	3	3	0*	2.8
SF	Tapow Gaew 161	2	2	2	2	1	1	1.7
TT	Khao Dawk Mali 105	0	1	1	0	1	1	0.7
	Nahng Prayah 132	1	0	1	1	0	1	0.7
SD	Rice Division 1	0	0	0	0	0	0	0.0

Note.*: Injured by crabs and omitted from calculation.

experiments. The latter may appear inconclusive since the accidents, rain and crabs, made the environmental fluctuation in F_2 experiment considerably large. However, the environmental variation in F_1 experiment was almost negligible (Table 4) and the partial dominance of floating ability was considered to be established fairly well. Although only one F_1 plant per cross was used, it could be taken as a replication within the type of rice such as true floating and non-floating rice.

From our results, (1) selection

of floating ability from the early generation and (2) breeding varieties with different degrees of floating ability are considered to be possible.

Physiological basis of deep water tolerance

Physiological interpretations provided for deep water tolerance include the following; (1) IAA (Indole acetic acid) accumulation under anaerobic conditions (YAMADA 1954; TANAKA 1961) (2) mobility of carbohydrate compounds in floating rice under submerged conditions (YAMAGUCHI *et al.* 1963) (3) increase in GA (Gibberellic acid) like substances after submergence (YAMAGUCHI 1974) (4) accumulation of inorganic elements such as K, Fe, and P (YAMAGUCHI 1976; LIM *et al.* 1979) (5) a possible increase in ABA (Abscissic acid) level other than GA (SAENGPECH *et al.* 1975) (6) a possible relation between submergence tolerance and ethylene production (HAMAMURA 1978). Detailed analyses on submergence tolerance in relation to respiration and environmental factors were given by YAMADA (1959) and VERGARA *et al.* (1976).

Although these interpretations require further examinations, it is likely that complex gene systems concern the synthesis of these growth regulating substances in response to submergence.

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イネにおける浮稲性の遺伝

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浮稲性の遺伝様式を知る目的で、数段階の浮稲性程度にわたる 10 品種間の相互交雑を行い、 F_1 , F_2 個体の浮稲性を、タイ国アユタヤ県ハントラ深水稲試験場の深さ 150~170 cm の池における検定によって調査した。

浮稲と非浮稲の交雑の F_1 個体は、ほぼ両親の中間程度の浮稲性を示したので (第 1 表)、浮稲性は部分優性の形質であると考えられる。

浮稲性をポリジーン形質と仮定して、 F_1 のダイアレル表の分散分析を行うと、相加的効果が他の効果より圧倒的に大きい (第 2 表)。

結果を示した F_2 集団のうち、多くは単頂の連続的な分布を示し、多数の遺伝子の関与が推測された。半矮性遺伝子を持つと思われる、T 442, RD 1 とバングラデシュの品種 DW 8 の交雑による 2 集団では二頂曲線またはそれに近い分布が見られた (第 3 表)。

F_2 実験においては、発芽期の雨と増水期のカニの食害によって、親品種の環境変異がかなり大きくなり、精度の点で再検討を要するが、 F_1 実験では親品種内の個体間変異は小さかった (第 4 表)。

部分優性の多数個の遺伝子が浮稲性に関与するとすれば、(1) 浮稲性に関する選抜は初期世代から開始してもよく、また (2) 種々の程度の浮稲性程度を備える品種を育成することができると考えられる。

なお広義の深水抵抗性は、浮稲性、狭義の深水抵抗性 (即ち 50~100 cm 程度の深水に対する抵抗性)、冠水抵抗性、その他、海岸湿地の深水地帯の稲に要される塩水抵抗性などの諸局面を含むと考えられるが、浮稲性以外はほとんど遺伝的解析がなされていない。