GENIC ANALYSIS IN RICE

III. Inheritance of Mutations Induced by Irradiations in Rice[1]

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Studies on the radiation induced mutations in rice have been made in various fields, such as radiosensitivity (Nishimura 1953, Yamagata *et al.* 1960), comparison of different kinds of radiations (Matsuo *et al.* 1958, Yamaguchi 1958), genetics of variation (Oka *et al.* 1958), cytological analysis (Chang 1955, Nagamatsu 1950, Chao *et al.* 1960, Katayama 1961) and induced aberrant plants (Yamagata and Syakudo 1960), *etc.*

The writer (Hsieh 1957, 1960) formally investigated artificially induced chromosomal mutations in rice. From the same radiation treatment, various mutant plants with different morphological characters were obtained. Most of the mutant characters such as dwarfness, narrow and rolled leaves, spreading, compact spiklet, *etc.* were found to have bred true. In order to know the genetic behavior of these mutant characters and the relationship they bear to the genes which are already made known and designated, intercrosses between mutant strains and other gene marker strains were made. In the present study, it was found that the majority of induced mutants were due to recessive gene mutation, though a few dominant mutations were also found. Linkages between one of the dwarf mutant genes and the liguleless gene *lg*, and between another dwarf gene and one of the apiculus color genes *C* were found. The results of investigation are reported in this paper.

Material and Method

About 150 mutant strains from R_2 generation of five rice varieties (Taichung No. 65, Chianan No. 8, Kaoshung No. 27, Taichung No. 155 and Chianunyu No. 242) were selected and planted as different lines for several generations. 21 strains among them were further selected and intercrossed. The F_1 and F_2 plants were grown in the paddy field of Taiwan Agricultural Research Institute during the period of 1960–1961. Regarding the material, the writer is obliged to professor C. H. Hwang of Taiwan Provincial Chung-Hsin University

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who sent the seeds to the Brookhaven National Laboratory of U. S. A. for radiation treatment in May 1959 and transferred the selected mutant strains to the writer. gene marker strains were kindly provided by Dr. Jodon of Crowley Rice Experiment Station of U. S. A. In addition to this, four local varieties were also used as the cross parents. The material used is shown in Table 1.

Table 1. List of analysing strains

Strains	Original variety	Description
D-8-1	Chianan No. 8	Grassy dwarf (30 cm in height), with profused tillering (about 50 tillers on the average), leaves narrow and colored in light yellow.
D-8-5	Chianan No. 8	Dwarf (50 cm in height), slight spreading.
D-8-7	Chianan No. 8	Dwarf (60 cm in height), slight spreading.
D-8-8	Chianan No. 8	Dwarf (60 cm in height), resembling D-65-1.
D-8-16	Chianan No. 8	Dwarf (50 cm in height), slight spreading
D-27-9	Kaoshung No. 27	Grassy dwarf (30 cm in height), leaves colored in light yellow, with profused tillering (about 50 tillers on the average).
D-65-1	Taichung No. 65	Dwarf (61 cm in height), slight spreading, compact panicles with small grains.
D-65-2	Taichung No. 65	Dwarf (55 cm in height), sinuous neck.
D-65-3	Taichung No. 65	Double dwarf derived from D-65-1 × D-65-2 (30 cm in height), sinuous neck.
D-65-7	Taichung No. 65	Dwarf (50 cm in height), rolled leaves.
D-155-5	Taichung No. 155	Dwarf (35 cm in height), narrow rolled leaves.
D-155-8	Taichung No. 155	Dwarf (35 cm in height), narrow leaves.
D-242-2	Chianunyu No. 242	Grassy dwarf (30 cm in height), with profused tillering (about 50 tillers on the average).
La-8-4	Chianan No. 8	Lazy, normal height (87 cm).
La-8-25	Chianan No. 8	Lazy, normal height (87 cm).
M-8-7	Chianan No. 8	Lax panicles, sinuous neck.
M-27-5	Kaoshung No. 27	Normal height (80 cm), purple lemma and palea.
M-65-6	Taichung No. 65	Normal height (87 cm), golden lemma and palea.
M-155-5	Taichung No. 155	Dwarf, narrow rolled leaves.
Sp-8-25	Chianan No. 8	Spreading of panicle rachilla.
Sp-65-6	Taichung No. 65	Spreading of panicle rachilla, tawny lemma and palea.
P-123	Taichung No. 65	Normal (untreated).
P-163	Nungyu-gl. No. 8	Normal, glutinous endosperm (untreated).
P-167	Pai-kan-tao	Liguleless (untreated).
J-308	Mu-yosetu-tao	Liguleless (untreated).
7102	Jodon's marker	Purple leaf blade (untreated).
7186	Jodon's marker	Lazy (untreated).
7154	Jodon's marker	Brittle culm (untreated).
7227	Jodon's marker	Glutinous endosperm (untreated).
7252	Jodon's marker	Purple pericarp (untreated).

Experimental Results

1. *Inheritance of dwarfness*

Most of the induced dwarfs so far reported were recessive (Jodon 1957, Hsieh 1960), though dominant dwarf was also reported by Sugimoto (1923). The F_1 of normal×dwarf as well as its reciprocal cross, appeared to be of normal height, and the F_2 segregated into 3 normal and 1 dwarf plants as shown in Table 2. This indicates that dwarfness is due to a single recessive gene mutation.

Table 2. Segregation ratios for dwarfness in F_2.

Crosses	Normal	Dwarf	Total	Segregation ratio	X^2	P
P-123×D-65-1	201	72	273	3:1	0.202	0.5–0.7
P-123×D-65-2	122	43	165	3:1	0.009	0.7–0.8
P-138×D-155-8	238	62	300	3:1	3.004	0.05–0.10
P-138×D-242-2	242	65	307	3:1	2.199	0.10–0.20
P-167×D-155-5	236	61	297	3:1	3.153	0.05–0.10
P-167×D-155-8	241	74	315	3:1	0.382	0.5–0.7
P-163×M-155-5	220	80	300	3:1	0.444	0.5–0.7
D-65-1×La-8-4	225	72	297	3:1	0.085	0.7–0.8
D-65-2×M-65-6	167	66	233	3:1	1.275	0.2–0.3
D-65-2×P-123	215	79	294	3:1	0.549	0.5–0.7
D-65-3×D-65-1	179	60	239	3:1	0.002	0.9–0.95
D-155-5×7102	228	70	298	3:1	0.362	0.5–0.7
M-8-9×7252	297	101	398	3:1	0.030	0.8–0.9
M-8-7×7102	217	78	295	3:1	0.327	0.5–0.7
M-242-1×7186	242	58	300	3:1	5.138	0.02–0.05
7227×D-155-5	224	76	300	3:1	0.013	0.8–0.9

In order to know whether these mutant genes are independent of one another, intercrosses between dwarf plants were made. Nine F_1s between dwarf strains, all appeared to be of normal height (fig. 1). The F_2 segregated into 9 normal, 3 dwarf-I, 3 dwarf-II, and 1 double recessive types as shown in Table 3. The three dwarf types could readily identified by their height and appearance (fig. 2). Measurement for plant height, panicle number and other characters of these segregates as compared with the parental strains, are given in Table 4. The double recessive plants were apparently lower in height than the parental dwarfs but had a larger number of tillers and panicles.

The above given data indicate that dwarf-I and dwarf-II have different genes for their dwarfness which are independent of each other. This type of genetic relation between two dwarf strains of rice have early been reported by Akemine (1925) and by Jodon (1934). Whether some of the genes found by the present writer are the same ones as reported by other workers is yet to be tested. It seems that a number of dominant genes are necessary for normal growth.

Table 3. Segregation of different dwarf types in F_2s of intercross between dwarf mutants

Crosses	Normal	Dwarf —I	Dwarf —II	Double dwarf	Total	Segregation ratio	X^2	P
	++	$+D_1$	$+D_2$	D_1D_2				
D-65-1 × D-65-2	166	42	50	24	282	9:3:3:1	5.042	0.1-0.2
D-65-1 × D-75-7	158	67	52	21	298	9:3:3:1	3.338	0.3-0.5
D-65-2 × D-8-7	176	57	55	10	298	9:3:3:1	4.446	0.2-0.3
D-65-2 × D-155-5	170	60	59	15	304	9:3:3:1	1.076	0.7-0.8
D-65-2 × D-8-5	186	53	47	11	297	9:3:3:1	6.713	0.05-0.10
D-65-2 × D-8-8	189	48	41	19	297	9:3:3:1	7.828	0.02-0.03
D-65-2 × D-8-16	173	56	49	16	294	9:3:3:1	1.353	0.7-0.8
D-65-2 × La-8-25	167	48	65	23	303	9:3:3:1	3.457	0.3-0.5
D-8-1 × D-242-2	181	53	52	11	297	9:3:3:1	4.617	0.2-0.3

Table 4. Agronomic characters of four segregants from F_2 of D-65-1 × D-65-2

	Plant height (cm)	Number of tiller	Number of panicle (cm)	Length of panicle	Weight of panicle (g)	Length of boot leaf (cm)	Width of boot leaf (cm)	Fertility (%)
Normal type (++)	87.0±4.6	8.6±1.4	7.1±1.2	19.0±1.2	3.6±0.5	26.4±4.0	1.3±0.61	92.0±3.3
D-65-1 type ($+D_1$)	61.0±5.1	8.7±2.2	6.7±1.9	13.5±1.0	3.3±0.7	24.2±3.6	1.4±0.93	82.5±7.4
D-65-2 type ($+D_2$)	55.5±3.5	12.0±3.5	10.8±2.7	13.6±1.1	2.5±0.4	24.1±3.8	1.2±0.67	78.6±3.8
New type (D_1D_2)	31.4±1.7	13.2±4.5	12.0±0.2	7.3±0.2	1.2±0.2	20.2±2.7	1.2±0.25	44.0±0.2

Both of the strains D-242-2 and D-29-7 were of dwarf types, being about 30 cm in height and having a larger number of tillers than the normal. The F_1 between these two strains showed normal growth with respect to plant height as well as tiller numbers. In F_2, there were 9 normal, 6 dwarf and 1 intermediate types (Table 5). The new type was about 70 cm high and had leaves about 1 cm in width, and a small number of tillers (2-3). The leaf color was darkish green. This new type apparently resulted from genic interaction, though it was quite different from the double recessive plant mentioned in the previous paragraph.

Table 5. Segregation for plant height in F_2 of D-244-2 × D-27-9

	Normal	Dwarf	Intermediate with less tiller number	Total
Observed	94	76	7	177
Calculated (9:6:1)	99.56	66.38	11.06	177

$X^2 = 3.295$ $0.1 > P > 0.05$

2. *Inheritance of other mutant characters*

(a) Ripening tawny lemma and palea

Strain Sp-65-6 was a mutant induced by thermal neutron treatment. The lemma and palea were green at heading but turned into a brown or tawny color in the whole surface of hulls at maturity. This character resembled what Jodon (1948) had described as golden hulls but the color tone was somewhat lighter. In the cross D-65-2×Sp-65-6, a segregation ratio of 3 tawny to 1 straw white in hull color was observed, showing that this mutation is controlled by a dominant gene. According to Nagao (1951) tawny coloration at lemma and palea is controlled by the genes C^B *sp Rp*. Since the genotype of the original strain Taichung No. 65 is C^{Br} *sp rp* (Hsieh 1960), tawny hull color in the strain Sp-65-6 may be due to dominant mutations from C^{Br} to C^B and from *rp* to *Rp*.

Table 6. Segregation for tawny lemma and palea in F_2 of D-65-2×Sp-65-6

	Ripening tawny	Straw	Total
Observed	177	56	233
Calculated (3:1)	174.75	58.25	233

$X^2=0.116$ $0.7>P>0.8$

(b) Spreading and laziness

The spreading of tillers was found to occur in different grades in certain dwarf strains. An extreme case in which the spreading angle was larger and the tillers lay almost prostrate on the ground was named "Lazy" by Jodon (1948), and "Moture" by Japanese workers (Morinaga and Fukushima 1943, Nagao 1951). The stems of the strains D-8-5, D-8-8 and D-8-16 showed slight spreading (at about an angle of 30°). Such a slightly spread character was found to be controlled by a single recessive gene, as shown in Table 7.

Toble 7. Segregation for spreading habit (at about an angle of 30°)

Crosses	Normal (3)		Spreading (1)		Total	Segregation ratio	X^2	P
	Obs.	Cal.	Obs.	Cal.				
D-65-2×D-8-5	235	222.75	62	74.25	297	3:1	2.695	0.1-0.2
D-65-2×D-8-8	223	217.50	67	72.50	290	3:1	0.566	0.3-0.5
D-65-2×D-8-16	222	217.50	68	72.50	290	3:1	0.279	0.5-0.7

The strains La-8-9 and La-8-25 were of lazy types (fig. 4). In their cross with a "moture" strain H-25 of Dr. Nagao as well as with 7186, a lazy strain from Dr. Jodon, both the F_1 and F_2 showed lazy type and no segregation was found. In crosses between lazy type and the normal, a segregation ratio of 3 normal to 1 lazy plants was observed (Table 8). Evidently the lazy gene induced by irradiation was also a single recessive, though it might be located at the same locus as reported by Dr. Nagao and by Dr. Jodon.

Table 8. Segregation for laziness in F_2

Crosses	Normal		Lazy		Total	Segregation ratio	X^2	P
	Obs.	Cal.	Obs.	Cal.				
P-138 × La-8-9	224	225.0	76	75.0	300	3:1	0.017	0.8–0.9
P-167 × La-8-25	236	238.5	82	79.5	318	3:1	0.105	0.7–0.8
D-65-2 × La-8-25	219	225.0	81	75.0	300	3:1	0.640	0.5–0.7
M-242-2 × 7186	234	225.0	66	75.0	300	3:1	1.440	0.2–0.3

The rachilla of the strains Sp-8-25 and Sp-65-6 were spreading, the whole panicle showing an open appearance (fig. 5). It can be seen from Table 9 that the spreading panicles were also due to a recessive gene. However, the gene for spreading panicle seemed to have nothing to do with that for spreading of tillers, because both Sp-65-6 and Sp-8-25 did not show laziness.

Table 9. Segregation for spreading of panicle rachilla in F_2

Crosses	Normal		Spreading panicle		Total	Segregation ratio	X^2	P
	Obs.	Cal.	Obs.	Cal.				
D-65-2 × Sp-65-6	189	175.50	45	58.50	234	3:1	4.154	0.02–0.05
P-167 × Sp-8-25	237	239.25	82	79.75	319	3:1	0.085	0.7–0.8

(c) Narrow rolled leaf

In some strains, the leaves were very narrow as compared with the normal ones. In some others such as D-65-7, M-155-5, etc., narrow leaves were rolled up in varying degrees. When plants having narrow rolled leaves were crossed with the normal ones, the F_2 segregated into 3 normal and 1 narrow roll-

Table 10. Segregation for narrow rolled leaf in F_2

Crosses	Normal		Narrow rolled leaf		Total	Segregation ratio	X^2	P
	Obs.	Cal.	Obs.	Cal.				
D-65-1 × D-65-7	228	225	72	75	300	3:1	0.16	0.5–0.7
P-163 × M-155-5	220	225	80	75	300	3:1	0.04	0.8–0.9
M-8-7 × P-163	224	225	76	75	300	3:1	0.02	0.8–0.9
M-8-7 × 7154	231	225	69	75	300	3:1	0.64	0.3–0.5

leafed plants as shown in Table 10. Whether or not the gene for rolled leaf in the strains D-65-7, M-8-7 is located at the same locus as that in strain 9783 (Jodon's marker) is left for further study.

3. *Linkage between dwarf genes and other mutant genes.*

In order to know whether the mutant genes described in the previous paragraph are linked with the genes already known and designated, test of independence was carried out. The chi-square values found are given in Table 11. As the table shows, there was linkage between the liguleless gene *lg* and the dwarf gene in the strain D-155-8. The strain D-155-8, about 35 cm in height and having narrow leaves, colored in dark blue but not rolled, was derived from radiation-treated seeds of Taichung No. 155. The gene symbol d_9 was putatively given by the writer for this character. Though this dwarf mutation was due to a recessive gene, the number of dwarf plants in F_2 was always less than the expectation when it was crossed with a normal strain. This will be taken up later in the discussion. The recombination value between these two genes was estimated to be 19.3% in repulsion phase.

Table 11. Test of independence of genes

Crosses	Gene pair Aa Bb	Combined character				Total	X^2
		AB	Ab	aB	ab		
P-138 × D-155-8	Wx/wx, La/la	187	50	51	13	301	0.019
P-138- D-242-6	Wx/wx, D/d	179	44	59	2	284	10.218**
P-138 × M-27-5	Wx/wx Rd/rd	161	51	50	11	273	1.010
P-138 × La-8-8	Wx/wx, La/la	193	32	64	10	299	0.024
P-167 × D-155-5	Lg/lg, D/d	158	64	46	31	296	3.032
P-167 × D-155-8	Lg/lg, D/d	168	56	73	2	299	17.816**
P-167 × Sp-8-25	Lg/lg, La/la	182	67	54	15	318	0.759
D-65-2 × M-65-7	Rp/rp, Pi/pi	127	50	40	16	233	0.001
D-242-2 × 7102	Ps_1/ps_1, D/d	129	23	2	10	164	4.224
D-242-2 × 7102	Ps_1/ps_1, Pl/pl	88	61	22	13	184	0.178
D-242-2 × 7102	C/c, Sp/sp, D/d	147	37	77	38	299	6.367*
J-308 × D-155-5	Lg/lg, D/d	162	56	49	28	295	3.212

The strain D-242-2 was derived from Chianunyu No. 242, a popular Ponlai variety in Taiwan. It was a grassy dwarf (30 cm in height) with profused tillering (about 50 tillers on the average) and had pale yellow leaves. As shown in Tables 11 and 12 the dwarf gene in this strain was linked with either of the two apiculus coloration genes *C* and *Sp*. The recombination value between the dwarf gene and the apiculus color gene was 35.3% in the cross with strains 7101. Further, the dwarf gene in D-242-2 was found to be linked with the glutinous endosperm gene *wx* with a recombination value of 24.2%. This gene is designated by the writer as d_4 because, as will be discussed later on, the gene seemes to be identical with Nagao's (1959) d_4.

Table 12. The F_1 genotypes and recombination values

Linked genes	Crosses	F_1 genotype	Phase	Combined character				Total	Recombination value (%)	x^2	Linkage group
				AB	Ab	aB	ab				
d_9-lg (3:1) (3:1)	P-167× D-155-8	$\frac{d_9\text{-}lg}{D_9\text{-}Lg}$	R	168 (152.1)	56 (72.5)	73 (72.5)	2 (2.2)	299	19.3±3.97	5.402	II
d_4-C (3:1) (9:7)	D-242-2× 7101	$\frac{d_4\text{-}c\ sp}{D_4\text{-}C\ Sp}$	C	147 (135.6)	77 (88.63)	37 (32.57)	38 (42.17)	299	35.3±3.43	3.497	I
d_4-wx (3:1) (3:1)	P-138× D-242-2	$\frac{d_4\text{-}wx}{D_4\text{-}Wx}$	R	179 (146.18)	44 (66.81)	59 (66.81)	2 (4.18)	284	24.3±3.97	17.206	I

Discussion

The spontaneously occurred dwarfness in rice is usually due to a single recessive gene as can be normally tested by a cross of normal×dwarf (Parnell *et al.* 1922, Akemine 1925, Nagai 1926, Yamaguchi 1927, Jones 1937, Nagao 1952). The dwarf mutant induced by irradiation in the present study all show single recessive inheritance and no dominant dwarf as reported by Sugimoto (1923) was found. This indicates that the nature of mutations is quite similar in both artificially induced and spontaneously occurred mutants.

It should be noticed that the dwarf mutants show a wide range of variation in height as well as in appearance, probably being controlled by different genes which may occupy different loci. Akemine (1925) crossed "Daikoku" and "Ebisu" dwarfs; the F_1 showed normal appearance, but in F_2 9 normal, 3 "Ebisu", 3 "Daikoku" and 1 "Small Daikoku" were segregated. The similar phenomenon was reported by Jodon *et al.* (1943) in their cross of "Grassy dwarf"×"Thickset dwarf" plants. In the present study, the same results are also obtained in nine crosses among eleven dwarfs. This may suggest that dwarf genes carried by the eleven strains are all situated at different loci. It seems that a number of dwarf genes are responsible for the growth of plant height and they need further analysis. Kadam (1936) made crosses among eleven dwarf varieties of rice and described five different types, four of which were represented by genes derived from a single variety, among which d_2 was proved to be more common. Nagao (1952) analyzed the gene compositions of five dwarf forms in which he found that at least eight genes (d_1—d_8) were involved.

According to Nagao and Takahashi (1959), the gene for tillering dwarf d_4 is linked both with one of the apiculus color genes C and with the gene *gl* (or *wx*) with a recombination value of 38.2% and 21.5%, respectively. The recombination value estimated in the present study is comparable to those given by Nagao and Takahashi (1959). Therefore, it may be assumed that the *d* gene in strain D-242-2 is identical with Nagao's d_4, of group I.

In addition, according to Nagao and Takahashi (1959), the recombination value between d_2 and *lg* was 45% and that between d_3 and *lg* was 39.7%. In the present study, however, the recombination value between the genes *d* and *lg* in strain D-155-8 is 19.3% which apparently can not be compared with the two values just mentioned. It seems that the *d* gene in strain D-155-8 may not be identical with any of Nagao's eight genes (d_1-d_8), and therefore the new designation d_9 is putatively given by the writer. It may be a new locus which probably belongs to Nagao's group II. Using these newly found genes, the linkage group can be analyzed more intensively.

Further, in the cross between the normal and the dwarf (D-155-8, etc.), the F_2 always shows a reduced number in the recessive class, thus constituting a source of disturbance in estimating the segregation ratio and recombination value. Jodon *et al.* (1943) reported a deficiency in dwarf class in a cross of normal×thickset dwarf rice when grown in the field, but no deficiency of dwarf plant was seen when grown on absorbent cotton in the laboratory. He considered that it was due to the slow seedling elongation and root growth of the dwarf plant caused by drowning out at first flooding. Morinaga and Fukushima (1943) also reported a deficiency of dwarf type in a cross of a normal and a spontaneously occurred dwarf forms. They explained this as due to low frequency of dwarf plant as well as to loss of dwarf plants at the time of transplanting. In the present study, the reduced number of recessive class may be due to the same reason given by Morinaga *et al.* and not likely due to gametic selection, in view of the high fertility (70-80%) shown by the F_1 plants. For this reason special care will be paid in the future experiment to prevent the loss of dwarf plant in the field.

Summary

From 150 mutant strains of rice induced by radiations, 21 were picked out for genetical study. They were intercrossed or crossed with the normal strains, and the segregation pattern of various traits in F_2 were investigated.

Most of the mutant characters such as dwarfness, spreading panicle, laziness, narrow-rolled leaf, *etc.* showed monogenic inheritance. In an intercross of two dwarfs, the F_1 showed normal plant height, but in F_2 9 normal, 3 dwarf-I, 3 dwarf-II and 1 double recessive dwarf were segregated, indicating that dwarf-I and dwarf-II had different genes for their dwarfness which were independent of each other.

Linkage was found between the liguleless gene *lg* and a *d* gene in strain D-155-8 with a recombination value of 19.3%. It was assumed that the *d* gene in D-155-8 for which the gene symbol d_9 was given by the writer was situated in a new locus which might belong to Nagao's group II. Further, linkage between another *d* gene and one of the apiculus color gene *C* with 35.3% recombination value was found in a grassy strain D-242-2 which was derived from Chianunyu No. 242. It was assumed that the *d* gene in strain D-242-2 would correspond to Nagao's (1959) d_4 gene.

稻之遺傳因子分析

Ⅲ 放射線處理後所發生的突變稻之遺傳

謝 順 景

就放射線處理後所發生的突變稻150系統中任選21系統，舉行互交及與正常稻雜交，並研究其雜交後代各性狀之分離情形。

大部分之突變性狀，例如矮性，散開穗，散開株型，細捲葉等表示單隱性遺傳。兩種不同矮稻互交時，F_1 表示正常植高，F_2 則分離出9正常：3矮Ⅰ:3矮Ⅱ:1雙隱性矮稻，表示矮1及矮Ⅱ之遺傳因子爲互相獨立之兩種不同的遺傳因子所控制。

D-155-8 系統之矮性因子與無葉舌因子 *lg* 間有連鎖關係，其交叉値爲 19.3%。D-155-8之 *d* 因子可能爲一新遺傳因子，位於長尾氏(1959)之第二連鎖羣。另外在 D-242-2系統之 *d* 因子與稃尖着色因子 *C* 有連鎖，其交叉値爲 35.3 %。此因子又與糯性因子 *gl* (或w_x) 連鎖，其交叉値爲24.2%。D-242-2 之 *d* 因子在染色體上之位置認爲與長尾氏 (1954) 之 d_4 相同 (摘要)。

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Fig. 1. Two dwarf mutants derived from Taichung No. 65 and their F_1 plants: Left, D-65-1; middle, F_1; right, D-65-2.

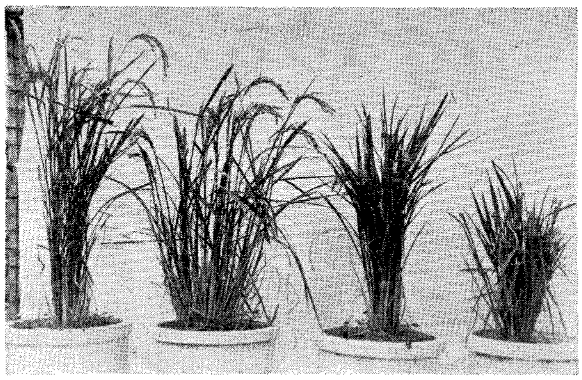

Fig. 2. Four segregants in F_2 from cross between two dwarf mutants. From left to right: normal, D-65-1 type, D-65-2 type and a new double recessive type.

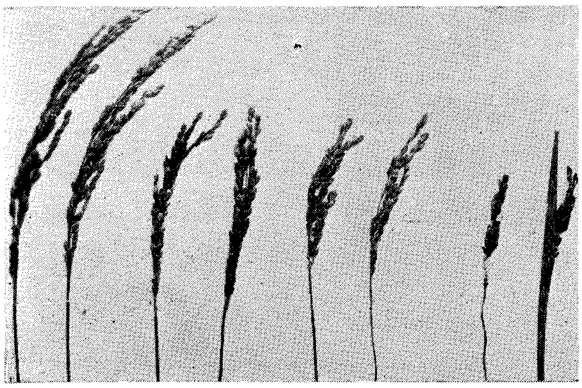

Fig. 3. Four kinds of panicles in F_2 of D-65-1 × D-65-2. The double recessive type (right) shows enclosed panicle and sinuous neck.

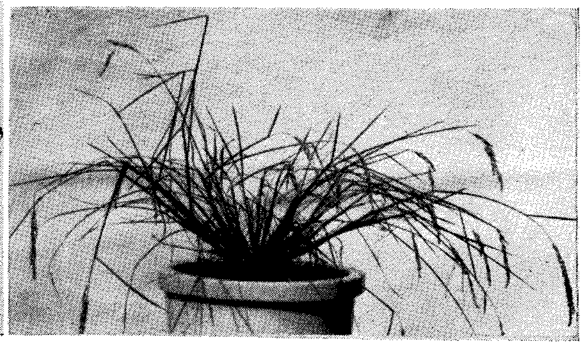

Fig. 4. Lazy mutant derived from Chianan No. 8.

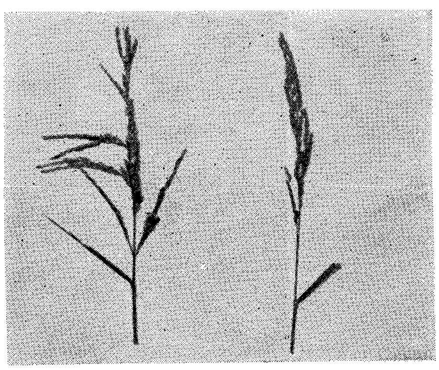

Fig. 5. Spreading (Sp-65-6) and normal panicles.