

INDUCED MUTATION BREEDING OF RICE IN TAIWAN⁽¹⁾

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This work was started ever since 1957. There were three aims with this project: 1) to obtain erectoid plants of short stature to be responsive to heavy fertilization especially nitrogenous fertilizer; 2) to obtain early-maturing strains which would yield the same or more than their original variety so that the multiple cropping system of Taiwan can be easily handled; and 3) to obtain disease resistant mutant. In the past, three papers were published by Li and his co-workers (1961, 1962 and 1965). In 1965 the first Panel on the Coordination of Research on the Use of Induced Mutation in Rice Breeding in southeast Asia as being sponsored by IAEA was held in Bangkok. The conclusion of our report then: 1) Erectoid lines selected were found to be able to have significant increase in yield than their original variety as being tested in Taichung and Chia-yi. 2) Some of these erectoid mutants were subjected to fertilizer-response tests and one erectoid line Sh 30-21 was found to be very responsive to the application of fertilizer rather clearly. 3) None of the mutants obtained from Taichung 65 was found to be more resistant to rice blast disease after a large scale test in X_2 generation. 4) Some of the mutant lines were tested in the Island-wide Regional Test as being sponsored by the Provincial Government. Since these mutants were not erectoids, they simply could not compete with the erectoid varieties of short stature type used as checks. 5) Starting from the second crop of 1964, up to the first crop of 1965, some of the selected erectoid lines from irradiated native varieties as well as from hybrid selections of erectoid mutant lines with other erectoid varieties were tested out in regional test in and near Taichung. Two of these selected lines had significantly higher yield than the erectoid variety

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used as check. These varieties were Sh 30-21 and YH No. 1 (original designation TN 1×Sh 30-21 44-5). 6) Some of the erectoid mutants obtained from the irradiated second crop varieties (native) which were short-day plants could be grown in the first crop, indicating that they were no longer sensitive to long-day photoperiodism. 7) By hybridizing the erectoid mutant and the large-panicked mutant obtained from Taichung 65, some hybrid progenies were selected, which yielded better than their original variety and their parents. 8) None of the early lines was found to be of any promise so far.

As being mentioned before this project was done by the Institute of Botany, Academia Sinica, Taipei, in cooperation with the Department of Agronomy Chung-hsing University, Taichung, and Chia-yi Agricultural Experiment Station, Chia-yi, this report is a progress report since the report made in 1965.

Experimental Results

I. Results obtained in Taipei

1) More seeds of four rice varieties (*indica* and *japonica*) were irradiated by gamma rays and thermal neutrons which were done at Tsing-hua University. These treated seeds were planted in Taipei and their progenies will be sent to Taichung and Chia-yi for multiplication and selection later. If facilities are available, we are going to repeat these irradiation work every other two years.

Since recent experiments done on other crop plants, ethyl methanesulfonate (EMS) and methyl methanesulfonate (MMS) are proved to be good mutagenic reagent. Therefore preliminary trials were made with these reagents. More detailed work will be done in 1966 and thereafter.

2) Diallele crosses of erectoids. Attempts were made to make diallele crosses of the erectoids of short stature obtained from irradiated material as well as erectoids spontaneously obtained, which are extensively cultivated by the farmers. Thirty-five hybrid combinations were finally obtained. To our surprise, all of the hybrids obtained were erectoids of short stature even though they differed more or less in height, plant type and general vigor from one another. However, none of these hybrids was of normal height. This would indicate that erectoids of this type whether being induced or spontaneously obtained would involve a single gene. That variations shown with different hybrids would indicate the involvement of different sites of the same gene. Our results differed greatly from the erectoids in barley which were studied intensively by Hagbery (1954, 1958, 1959, and 1960). In barley more than two hundred erectoids obtained by irradiation were controlled by twenty-five different genes. Why should there be only one gene involved in all the erectoids of this type in rice, no explanation can be offered at the present.

A simple Mendelian segregation was obtained in erectoids \times normals crosses with normal type dominant over erectoides.

II. Results obtained in Taichung

1) Further results were obtained in the regional tests with erectoids of short stature obtained from native varieties (*indica*): Table 1 gives the results of the regional tests covering three crops in the successive years from 1964 and 1965. These tests covered five different districts in and round Taichung. These different districts were some ten to thirty kilometers apart. Three districts had a coverage of three crops, one had two and the other had only one. The paddy fields of all these districts were very fertile and with good irrigation except Luc-kon, where the soil is little saline and subjected all the time in the fall months to monsoon wind because of its nearness to the sea. In these general districts, formerly, the improved Horai (*japonica*) were extensively grown. It is understandable that the Horai varieties are erectoids of short stature, therefore, they are grown extensively by the farmers in the more fertile paddy fields. However, since the introduction of Taichung native No. 1 (TN) into these districts and because of its better adaptability in these more fertile paddy fields than Horai variety is now grown very extensively in these regions and in fact in other regions of this island as well. Clearly, it demonstrates that this erectoid native variety would out-yield the Horai varieties by some clear cut margin. Furthermore, it can be grown more easily than the Horai varieties. Even when irrigation water is deficient, it would not suffer as much damage as the Horai varieties would. So, in the regional

Table 1. Yield of *indica* erectoids in regional tests, 1964-1965.

Localities	Taichung native No. 1 (as ck)		KT*	Sh	IKB	YH	LC	
	kg ha	%	20-74	30-21	4-2	No. 1	25-108-30	
			%	%	%	%	%	
Taichung	2nd, 1964	5,590	100.0	117.4	109.2	107.7	113.8	—
	1st, 1965	5,340	100.0	97.9	101.7	99.5	105.7	90.4
	2nd, 1965	4,327	100.0	97.5	93.0	91.3	100.9	92.4
Luc-kon	2nd, 1964	6,940	100.0	90.8	89.9	103.0	106.3	—
	1st, 1965	6,319	100.0	105.1	108.0	103.0	108.3	91.7
	2nd, 1965	4,515	100.0	100.0	94.4	84.5	99.6	99.7
Er-lin	2nd, 1964	7,124	100.0	101.1	101.6	103.7	103.1	—
	1st, 1965	7,535	100.0	100.4	102.3	104.4	102.0	94.4
	2nd, 1965	5,660	100.0	103.7	98.9	95.1	91.5	81.4
Yuan-lin	1st, 1965	6,405	100.0	97.8	105.5	94.5	103.4	87.4
	2nd, 1965	6,120	100.0	88.2	90.8	79.0	91.1	92.8
Woo-rih	2nd, 1965	8,608	100.0	96.8	98.1	91.1	102.9	—
Average	2nd, 1964	6,551.3	100.0	103.1	100.2	104.8	107.7	—
	1st, 1965	6,399.8	100.0	100.3	104.6	100.4	104.9	91.0
	2nd, 1965	5,846.0	100.0	97.2	95.0	88.2	97.2	91.5

* KT=Keh-tze; Sh=Shung-chiang; IKB=I-kung-bau; YH=Yuan-hsing; LC=Liu-chow

test Taichung native No. 1 is used as check. In the regional tests there were five erectoid selections besides this check variety. In the first two crop seasons of 1964 and 1965 hybrid selection YH No. 1 out-yielded the check variety about 8% in the second crop of 1964 and 5% in the first crop of 1965. However, it did not do so well in the second crop in 1965. The decrease in yield 3% would not be statistically significant as compared with the check. Selection Sh 30-21 yielded consistently better than the check in the 2nd crop of 1964 and 1st crop of 1965, but it did not do too good in the second crop of the same year. This regional test is going to be continued for a year or so to ascertain whether or not any of these erectoid selections would be better than the check.

2) Hybridization between native varieties and induced mutant strains. Erectoid mutants with good performances in both plant type and yielding ability were hybridized with high-yielding native varieties in order to combine the high yielding ability with some other favorable character, for instance disease resistance etc. Over one hundred selections from thirteen combinations were isolated in F_4 generation. Those given profused tillers, relatively high fertility, clean leaves and short stature of up-right type were selected and will be promoted to the preliminary test to be carried out in 1966.

III. Results obtained in Chia-yi

1) Preliminary test.

Four varieties: Taichung 179 (T), Chianung 242 (C), I-kung-bau (IKB) and Wu-ku-chin-yu (WKCY) were treated with X-ray and thermal neutrons in 1960. However, there was not even one selection made from variety WKCY. This test included twenty-five selections from Taichung 179, twelve from Chianung 242 and six from IKB. All of these selections either from Taichung 179 or from Chianung 242 outyielded their original varieties in the M_4 generation (table 2). Some even outyielded the original variety more than 50%. It was considered to be quite hopeful at that time. However, in the first crop season of 1965, those selected strains which outyielded their original varieties then failed to repeat again in the preliminary test. There were only four selections from Taichung 179 outyielded the check Chianung 242 statistically significant, but none of the selections except one was as their original variety Taichung 179. Several selections from Chianung 242 outyielded their original variety which was used as check also but none of them would have any increase in yield of statistical significance. Similarly in the second crop of 1965 when the yield of the original variety as well as the check went down again as they did in 1964, these selections again repeated the performance of the second crop of the previous year. Many of these differences in yield were statistically significant.

Table 2. Results of the preliminary test (kg./ha.)

Varieties	1st crop, 1965			2nd crop, 1965			2nd crop, 1964
	height (cm)	tiller No.	yield %	height (cm)	tiller No.	yield %	yield %
Taichung 179			(8,765kg)			(5,200kg)	(4,300kg)
T 20-11-4	118.9	17.4	100.0**	115.3	9.1	100.0	100.0
T 3-4	113.0	18.8	85.2	111.2	10.3	102.4**	118.6
T 25-14-5	113.8	13.2	90.7	112.7	8.0	100.2**	132.5
T 3-17-3	112.7	16.4	83.8	116.5	10.2	102.8*	104.6
T 15-11-5	117.7	14.8	91.9	115.7	8.9	99.5*	104.6
T 3-1-3	119.0	17.1	80.9	117.2	11.1	96.5*	120.9
T 3-8-5	114.8	18.2	84.3	110.2	9.2	96.6	139.5
T 15-9-4	115.6	18.9	96.5*	115.7	11.2	94.2	110.5
T 5-8-3	117.0	15.8	88.2	110.1	9.7	93.7*	132.5
T 15-5-5	113.2	19.0	88.1	119.3	9.8	95.9	100.0
T 15-4	119.6	14.8	67.6	121.6	9.3	88.9	125.5
T 20-11-5	117.1	20.9	88.1	118.2	9.6	98.0**	144.1
T 15-2	105.7	17.5	83.2	105.4	10.7	93.0	109.3
T 20-13	114.3	18.7	91.3	113.2	9.4	93.9*	134.8
T 15-10-1	118.8	20.0	93.6	117.0	9.6	87.2	132.5
T 15-3-4	116.6	17.1	88.1	115.0	8.4	86.7	125.5
T 25-4-3	108.2	17.0	101.4**	108.7	9.8	101.4*	101.1
T 4-1	95.3	18.8	76.3	102.5	9.7	88.7	104.6
T 20-11	113.7	17.2	91.3	117.3	9.6	98.7*	137.2
T 15-8-2	114.6	17.7	91.6	111.0	8.7	96.2*	141.8
T 20-12-1	118.2	18.1	99.4*	111.5	9.6	96.8*	100.0
T 15-3-1	112.9	16.2	93.6	115.9	10.8	92.0	151.1
T 15-8-4	101.6	18.0	95.0	103.6	9.2	91.3	104.6
T 25-9-5	114.1	17.7	86.4	110.5	8.1	92.3	104.7
T 3-1	120.6	19.8	97.1*	117.2	8.6	85.6	153.4
T 15-5	114.6	19.3	88.1	118.9	10.6	94.7*	131.2
T 15-6-2	116.9	15.7	94.7	114.0	9.3	98.7**	132.5
T 15-6-4	120.2	17.9	95.3	119.3	9.5	92.5	111.6
T 25-7-5	114.7	18.2	93.0	117.8	9.2	95.4*	125.0
T 15-9-5	117.4	18.8	92.1	115.5	9.1	97.5**	116.2
T 15-2-4	115.2	17.2	93.9	110.6	9.7	92.7	155.8
T 15-15-1	117.1	17.9	92.7	116.2	10.3	103.3*	109.3
T 5-12-5	111.9	17.9	91.9	115.1	9.6	104.8**	130.2
T 3-1	117.0	16.9	90.4	121.8	10.7	109.1**	116.2
Chianung 242	114.7	17.9	92.1	116.6	9.0	103.2**	109.3
(Check)	115.8	16.3	82.9	111.2	9.2	96.6	132.5
C 3-4-2			(7,287.5kg)			(4,600kg)	(5,200kg)
C 25-11-4	105.7	15.4	100.0	107.1	10.5	100.0	100.0
C 25-8-5	118.5	16.0	102.7	117.0	9.0	117.9**	111.5
C 25-19-4	113.8	14.2	100.6	118.5	8.4	117.3**	128.8
C 25-20-1	111.3	12.8	88.3	114.0	8.4	112.7**	100.0
C 25-8-4	119.6	15.0	112.6	119.8	8.5	125.2**	126.9
C 3-4-11	115.5	15.0	108.9	118.3	7.4	119.2**	120.1
C 25-19-3	109.9	12.4	92.4	110.8	8.2	101.3	126.9
C 25-6-3	108.2	15.2	96.5	115.1	8.4	111.9**	122.1
C 25-20-2	118.0	13.8	106.5	120.9	7.6	115.2**	116.9
C 20-5	119.6	12.6	97.2	116.3	8.6	122.0**	118.2
C 25-1	117.3	13.7	107.1	118.4	7.9	119.8**	100.0
I-kung-bau	100.9	13.9	60.9	101.2	8.4	88.0	112.7
I 3-4	114.3	13.8	105.1	119.5	8.3	129.0**	112.7
I 15-7			(6,975kg)			(4,712.5kg)	(5,100kg)
I 4-1	133.3	17.8	100.0	121.4	11.1	100.0	100.0
I 15-6	129.2	13.7	92.1	128.6	15.5	110.8**	111.3
I 3-7	84.2	20.2	96.4	93.3	12.0	125.4**	101.9
I 3-11	127.0	15.6	89.1	109.1	12.8	106.3*	90.2
	112.8	16.9	98.9	113.8	13.3	100.0	106.9
	127.8	16.9	99.2	127.7	11.1	124.9**	88.2
	125.2	16.9	103.9	124.6	12.4	116.1**	74.5
	F = 2.3608**			F = 4.0762**			

* = significant (L. S. D. 0.05 level)

** = highly significant (L. S. D. 0.01 level)

It seems that some of the selections would fare very well in the second crop if they fail to show promise in the first crop in table 2. These selections are not erectoid, however. Selection T 25-4-3 from Taichung 179 showed poor yield in both crops of 1965. This was the only erectoides of short stature type left showed some promise in the second crop of 1964.

2) Advanced test

Selected strains gave good yield in the preliminary test of 1964 (first and second crops) were then promoted to be tested in advanced test. Table 3 gave the results of the advanced test in 1964-1965. In table 3, it could be easily seen that only strain C 15-7 outyielded its parental variety Chianung 242 (also as check) in the first crop season of 1965, while all of the selections from Chianung 242 gave better yield in 1964 than the check but all had poorer yields. This may also be explained that the check (C 242) itself yielded much better in the first crop of 1965 than that of 1964. Mutant selections of Taichung 179 and IKB on the other hand, also gave encouraging results in out-yielding their parental varieties to certain extent. However, only two strains, T 5-16 and T 20-4 were better than the check (Chianung 242). Of the

Table 3. Results of the advanced test (kg./ha.)

Varieties	1st crop, 1965			2nd crop, 1965			1st crop 1964	2nd crop 1964
	height (cm)	tiller No.	yield %	height (cm)	tiller No.	yield %	yield %	yield %
Chianung 242 (Check)			(7,437.5kg)			(3,587.5kg)	(5,300kg)	(3,675kg)
C 3-7	118.7	12.5	100.0	122.8	7.7	100.0	100.0	100.0
C 3-19	118.3	13.4	97.9	119.4	9.2	123.9**	110.2	107.5
C 4-7	119.3	13.0	92.2	120.8	8.4	123.2**	107.5	107.2
C 4-13	126.7	12.0	98.3	121.5	9.3	102.4	106.4	113.9
C 5-12	121.9	13.7	97.6	122.2	8.4	106.0	111.3	120.7
C 15-5	122.7	12.7	98.7	115.8	8.0	105.7	105.7	123.8
C 15-7	121.9	11.9	98.9	118.6	9.5	117.2*	111.7	114.8
Taichung 179	124.6	12.5	105.2	120.3	7.6	120.0**	103.0	118.0
T 3-2	115.2	15.7	100.0	105.1	9.3	100.0	100.0	100.0
T 4-10	119.4	17.1	109.9	113.7	9.8	137.6	98.4	160.6
T 5-16	120.0	14.0	107.2	120.2	10.1	119.4	96.8	101.6
T 15-9	123.0	14.0	114.9	110.4	10.0	117.6	100.8	95.7
T 20-4	122.1	15.5	109.9	113.6	7.8	112.1	115.3	92.8
T 20-7	119.1	14.0	117.3	116.9	8.3	109.8	104.8	97.0
T 20-14	114.9	15.0	100.7	107.7	8.3	111.7	87.9	105.9
T 25-5	109.5	13.9	106.9	106.7	9.2	113.8	96.7	121.2
I-Kung-Bau	121.2	16.5	106.9	117.8	9.4	122.7	99.2	100.3
I 25-6	115.8	15.1	105.6	111.9	10.7	102.9	93.5	107.5
I 25-8	138.2	13.9	100.0	137.5	10.3	100.0	(3,800.0kg)	(3,150kg)
Wu-Ku-Chin-Yu	135.2	13.3	112.7	127.1	9.9	105.1**	104.2	93.2
W 3-6	142.8	14.8	106.0	134.0	10.5	107.8**	105.8	140.0
	159.0	12.5	100.0	162.3	9.7	(3,947.0kg)	(4,000.0kg)	(3,475.0kg)
	156.0	11.6	97.2	165.3	9.2	102.2	100.0	100.0
							106.5	108.9
	F = 1.8134*			F = 2,699**				

* = Significant (L. S. D. 0.05 level)

** = highly significant (L. S. D. 0.01 level)

second crop season in 1965, six mutant strains yielded significantly better than the check variety. During the second season, yield of the check dropped to 3,587.5ka, instead of 7,4375kg/ha. as that of the first.

In general, the same conclusion can be drawn from the results obtained in the advanced test as we did with the results obtained from the preliminary test.

Summary and Conclusions

This project has been started since 1957. Sofar, five batches of seeds including several varieties of Horai (*japonica*) and native (*indica*) were treated. The radiation used included X-rays, gamma-rays and thermal neutrons of different dosages. Lately, chemical mutagenic reagents were also included such as EMS and MMS.

Some of these erectoids of short stature obtained from several native varieties were tested recently in the regional tests in the middle part of the the island near Taichung. One of these mutation lines (Sh 30-21) outyielded the extensively cultivated spontaneously obtained erectoids, Taichung native No. 1, by about 5% in 1st crop season of 1965. One hybrid selection (YH No. 1), a cross of TN No. 1 and Sh 30-21 outyielded the check about 8% in 2nd crop of 1964 and 5% in first crop of 1965. All the mutant selections however did not do so well in the second crop of 1965.

In Chia-yi Agricultural Experiment Station (at the southern part of this island) as compared with the check, some of the erectoids obtained from Horai rice varieties were of normal stature which was more or less the same as the variety from which they were derived. They performed excellently in the second crop of both 1964 and 1965, when the check variety used as well as their respective original varieties did not do too well in the second crop. However, in the first crop both the check as well as the respective original varieties from which they were derived did far better. As a result, only a few of these selections could out-yield or compare with the yield of the check. More tests would be required to validate the truth of this statement.

As a rule, the native varieties with weak straw can only be grown in the less fertile paddy fields which are as a rule not artificially irrigated, leaving the more fertile fields for the cultivation of the Horai varieties which are generally of erectoid type with short stature. Incidentally, these paddy fields are ordinarily well irrigated. Since the introduction of the TN No. 1 an erectoides of short stature into cultivation, the picture was changed completely. The *indica* varieties of this type could compete very favorably in the more fertile field of Taichung and other areas as well. This variety outyielded the Horai varieties by a large margin. With our mutational work, the erectoids

selected are generally of the same plant type as that of TN No. 1. As has been found in our experimental work all the erectoids of this general type irrespective of the varieties from which they were derived or from the erectoids of spontaneous origin are controlled by one gene. Of course, these erectoids differ quite a lot from each other in many minor characters. However, it can be stated that this erectoid gene has a pleiotropic effect. Besides controlling the plants to be of short stature, short internodes as well as of small panicles, it induces these erectoids to have profused tillering as well. Naturally, more small panicles from having increased tillering would be able to compensate for the lack of size for each panicle. As a result, erectoids obtained from *indica* varieties were rather high yielding as compared with their original varieties from which they were derived. Furthermore since they can stand up upright even in more fertile fields, naturally they can produce a phenomenal crop whereas varieties subjected to lodging can not do so under similar conditions. Conversely, erectoids of short statures selected from Horai rice varieties would not have more tillers as the original variety from which they were derived. Naturally, when the panicles were shortened, the yield of mutant selections would not be able to compare with the yield of the original varieties from which they were derived. However, these selections (erectoids of short stature) could be used in eventual hybridization work. At the present, the selections made from Horai rice were only with normal stature but could stand erect in the field with fertile soil. It seems that our results were comparable to the findings of Kawai (1963). He found positive correlations in his irradiated material of *japonica* rice Norin No. 8 between short culm and short panicle, short culm and small grain as well as short culm and low yield.

As stated before, YH No. 1 was a cross of TN No. 1 and Sh 30-21, from our regional test it out-yielded TN No. 1 by about 5-8% in two crop seasons. It was stated also that this erectoides of short stature was obtained in the third generation. However, hybrid vigor was obtained even with this kind of cross; favorable selections could be obtained in the progenies of this cross. Heterosis could be explained in many ways. One of them would be epistatic effect.

Only once we did try to select more disease resistant mutations to rice blast fungus (*Piricularia oryzae* Cav.) using Taichung 65 (*japonica*) but failed in our attempt. None of the selections were more resistant than its original variety. In the past, we did not pay too much attention to the early lines even though many of these were found.

臺灣之水稻誘變育種

李先聞 胡兆華 吳旭初

自 1957 年開始，本研究計劃先後曾經應用 X-rays, gamma rays 及熱中子線，處理五批之蓬萊及在來稻種，最近進而利用化學藥品 (Σ MS, MMS) 作誘變劑。

在來稻處理後，選得許多生育良好的品系，目前正在參加臺中地區舉行的地方適應性試驗，參試品系中霜降 30-21，在 1965 年第一期作產量超過標準品種臺中在來一號百分之五，另外一品系（暫名研興一號）由臺中在來一號×霜降 30-21 的雜交組合中選出在 1965 年第一期的產量超過百分之五，1964 年第二期約超達百分之八，可是所有的誘變品系在 1965 年第二期作的產量都未達理想。

蓬萊稻誘變育種工作，大部份是在嘉義農業試驗分所進行，選得的誘變種，植株高度和原來品種相似。1964 及 1965 兩年的第二期作，新品系的產量大部份都超過標準品種（嘉農 242 號）和臺中 179 號，可是在該兩年的第一期作，該二品種的產量甚高，祇有少數新品系的產量能超過它們。

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