Breeding of Short-Culm Wheat Variety by γ-Ray

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Seven new wheat varieties produced with the aid of induced mutations have been reported up to 1973. According to the report[2], mutagens used were X-rays, γ-rays and thermal neutrons. Improved attributes of the varieties were high yielding, early maturity, short straw, high disease resistance, high winter hardiness and/or good grain quality.

Since 1959, the author has been making radiation breeding on a Japanese wheat variety, Igachikugo-Oregon, for shortening the culm length. As the consequence of the breeding, a strain was released as a new mutant variety in 1969. The variety, Zenkouzi-Komugi, was excellent in ripening date, plant type, lodging resistance, yielding capacity and milling quality, while its flour quality, disease resistance, cold resistance, etc. were similar to those of the original variety.

The successful results and some problems encountered in this breeding will be briefly described.

Choice of original variety[4]

The original variety, Igachikugo-Oregon, is superior in flour quality for vermicelli use, but inferior in lodging resistance and yield capacity. In order to improve the lodging resistance, cross breedings had extensively been carried out by several breeders for many years using the original variety as a parent.

The results of many trials, however, seemed to indicate that the improvement of lodging resistance of this variety, without impairing the good flour quality, was almost impossible. As a final and only method, mutation breeding was employed. As in other successful cases, the choice of a variety in which many characters other than a character are excellent as the parent variety was considered to be a requisite for success in mutation breeding.

Mutagen and dosage[3]

Although a principal reason of the choice of γ-ray was its wide use in the national institutes in Japan, γ-ray was thought to be sufficient for the purpose of the induction of mutations.

Determination of a suitable radiation dosage for each breeding material is the first step in the radiation breeding program. As the result of the investigations on the variation of radiosensitivities among 13 varieties which are widely cultivated in Japan (Table 1), there was no marked difference on the radiosensitivity among the tested varieties. LD-50

Table 1. Radiosensitivity

	Germination* (%)			Survival* (%)			Seedling weight* (%)		
Dose KR	30	40	50	30	40	50	30	40	50
Resistant varieties	96	69	28	87	21	2	25	—	—
Sensitive varieties	93	49	15	69	7	—	19	—	—

* Control as 100

Table 2. Breeding program

Year	Generation	No. of tested			No. of selected				Remarks
		families	strains	plants	families	strains	plants	ears	
1959-60	R_1			700			546	1508	2-3 ears were taken from each R_1 plant
1960-61	R_2	546	1508	1508×25	546	1508	1968		1-8 plants were screened from each R_2 strain
1961-62	R_3	1508	1968	1968×25	233	278	292		Selection of short-culm strains
1962-63	R_4	278	292	292×50	35	36	108		Selection of short-culm strains
1963-64	R_5	36	108	108×50	15	15	45		Preliminary yield test
1964-65	R_6	15	45	45×50	6	6	18		Preliminary yield test Tests of physiological characters
1965-66	R_7	6	18	18×50	5	5	15		Test of ecological adaptability
1966-67	R_8	5	15	15×50	1	1	3		Local test of adaptability Nominated as Tōzan No. 1
1967-68	R_9	1	3	3×50	1	1	3		Released as Zenkouzi-Komugi

was about 35 kr. Therefore, irradiation dose which gave a great number of M_1 survivals was considered to be 30 kr. The dose employed in our breeding, accordingly, was 30 kr.

Breeding program[4]

The outline of our breeding is indicated in Table 2. Irradiated seeds were grown on nursery at a narrow spacing, 3×3 cm, to inhibit auxillary tillering. In selecting short-culm mutants, speltoids, compactoids. spread plant types and sterile plants were discarded owing to their undesirable agronomic characteristics, even if they were short in culm length. The true bred short-culm strains in this breeding were obtained in rather later generations, R_4 or R_5.

Frequency and spectrum of induced mutations[3]

Number of the strains in which one or more variants segregated in R_2 and R_3 was scored (Table 3). Rate of mutated strains was 62% of the tested strains. The rate is very high as compared with the other crops, for example barley. However, the predominant mutations were those on ear characters or heading date (lateness). Rate of the strains with the desirable mutations such as short-culm and early heading mutations was 11% of the tested strains. Spectrum can be seen in the table.

Table 3. Frequency and spectrum of mutations

Character mutated	No. of strains mutated	Rate of strains mutated (%)	Rate of* characters mutated (%)
Late heading	181	13.9	22.2
Speltoid	83	6.4	10.2
Sterility	41	3.1	5.0
Compactoid	35	2.7	4.3
Open culm	17	1.3	2.1
Narrow leaf	13	1.0	1.6
Long culm	12	0.9	1.5
Subcompactoid	215	16.5	26.4
Short culm	123	9.4	15.1
Waxless	33	2.5	4.0
Early heading	26	2.0	3.2
White glume	11	0.8	1.3
Awnless	5	0.4	0.6
Others	20	1.5	2.5
Total	815	62.4	100.0
No. of strains tested	1,305		

* Rate of strains with mutations on respective characters

Agronomic characteristics of promising short-culm strains[4]

Agronomic characteristics of promising

Table 4. Agronomic characteristics of promising short-culm strains

(in difference from the original variety)

No. of strains	Maturity date (days)	Culm length (cm)	Ear length (cm)	No. of ears per m²	Lodging resistance	Close or open of culm	Yield per a (kg)	Property of grain	Milling quality	Flour quality
1	0	−9	−0.2	−46	M	M	−4	HA	B	B
2	−1	−8	−0.3	−50	H	M	0	HA	B	VG
3	−2	−8	−0.6	−66	M	M	0	M	B	B
4	−2	−4	−1.3	+26	VH	C	+6	SO	VG	B
5	−1	−10	−0.6	−38	VH	C	+3	SO	VG	B
6	−1	−4	−0.2	+13	L	C	+1	M	G	B
7	−1	−9	−0.1	−49	L	O	−8	HA	B	B
8	+1	−17	−0.6	+48	VH	O	+6	M	VG	G
9	−1	−10	−0.8	−39	M	M	−4	HA	B	B
10	−1	−8	−0.6	−20	L	M	−3	M	G	B
11	0	−9	−0.8	−58	L	M	−2	M	G	B
12	−2	−7	−0.8	0	M	M	−1	M	B	B
13	0	−10	−1.6	−50	M	M	+1	HA	B	B
14	+1	−11	−1.9	−18	M	M	−3	M	G	B
15	−1	−10	−2.6	+43	M	O	+4	M	G	B
16	−1	−6	−0.4	−63	M	M	−2	HA	B	B
17	0	−11	−0.8	−103	L	M	−3	HA	B	VG
18	0	−7	−0.6	−43	L	M	+1	M	B	B
Original variety	0	0	0	0	VL	O	0	HA	G	G

VH, H, M, L, VL, C, O, HA, SO, VG, G and B denote abbreviations of very high, high, medium, low, very low, close, open, hard, soft, very good, good and bad respectively.
Every minus sign indicates later ripening, shorter culm, shorter ear, smaller number of ears, and inferior yield.

short-culm strains in R_6 were investigated (Table 4). The short-culm strains were generally superior in lodging resistance and plant type, but tended to be accompanied by some undesirable agronomic characteristics, such as late ripening, low flour quality, low milling quality and low yielding.

However, only one strain (No. 8 in Table 4) was fortunately excellent in all the tested characteristics, which was later approved as a new variety. In view of the low frequency of desirable mutations, as many strains as possible should be raised to obtain superior mutants which occur rarely.

Frequent occurrences of anomalous meiotic divisions[1)]

Various abnormal chromosome pairings, especially tetravalents, were observed in most

Table 5. Frequencies of abnormal chromosome pairings and aneuploids in R_4 and R_5 short-culm strains

Generation	Frequency of strains with			Frequency of plants with			
	Abnormal chromosome pairing plant (%)	Aneuploid (%)	Anomalous meiosis plant (%)	Abnormal chromosome pairing (%)	Tetravalent (%)	Aneuploidy (%)	Anomalous meiosis (%)
R_4	47.8	17.4	60.9	27.5	23.8	7.5	35.0
R_5	22.7	9.1	31.8	13.9	12.7	2.5	16.5

of the selected short-culm strains in R_4 and R_5 (Table 5). In the investigations of offspring derived from plants with tetravalents, tetravalents were responsible for variations of agronomic characteristics, including short-culm length.

Therefore, both the high frequency of occurrences of mutations in R_2 or R_3 and the delayed establishment of true breeding mutant strains were considered to be due to the tetravalents in many cases.

The strain released as a new variety was also derived from a R_5 strain with plants showing complicated chromosome pairings. The reconstruction of chromosome structures, mainly by reciprocal translocation, many thus be efficient in breeding method in bread wheat.

References

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