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Studies on the Classification and the Geographical Distribution
of the Japanese Barley Varieties. II
Correlative Inheritance of Some Quantitative
Characters with the Ear Types.

By

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I. Introduction

Dr. TAKEZAKI (1927) in his extensive work on the quantitative inheritance of ear and awn characters, confirmed that the Japanese six-rowed barley, exclusive of a group of varieties lacking lateral florets appendages, were classified into eight distinct ear-awn types which differed in their genotypic constitution of three gene pairs, Hh, Ee and Aa, each responsible for determining the length and property of ear and awn.

In the course of the study on the classification of the Japanese barley from a somewhat different angle of approach, the present writer confirmed Dr. TAKEZAKI's classification of the ear-awn types to be quite true in effect. The Japanese barley varieties, as indicated in the author's preceding paper (1942), were classified according to the characteristics of the coleoptile into two distinct groups, the long (normal) and the short (uzu or semi-brachytic), between which marked differences were recognized in the quantitative as well as qualitative characters not only of the seedlings, but also

of the adult plant parts.* Moreover, it was later ascertained^(26, 27) that both the normal and the "uzu" varietal groups were each subdivided into four ear-awn types differentiating sharply in the ear density as well as in the awn length. (Plate XXV)

In these comparative studies between varietal groups of the normal and the "uzu" habits of growth, and between that of the lax and the dense ear, the writer drew particular interest to the fact that the "uzu" and the dense ear groups were apparently smaller in size of various plant parts than the other groups compared. From this, an analytical study was begun on the inheritance of some important quantitative characters in relation to the ear types. In this paper are presented the summarized results obtained from a series of investigations thus set forth since 1941, with some remarks on the applicability of the obtained results for simplifying the contemporary breeding procedure of the Japanese barley varieties.

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II. Materials and Methods

Thirty seven mutual crossings were made between thirty varieties of barley comprising representatives of the four ear types, namely, the normal-lax, the normal-dense, the uzu-lax, and the uzu-dense, and all of their F₁ plants were grown and investigated in the following year. Among them, eighteen crosses were held for the F₂ generation, of which four were carried through the F₃ generation to determine the F₂ genotypes. In this report, the results of the following four crosses studied in most detail are presented as types, because the other crosses gave quite similar results.

Cross No.	Female parents (ear type)		Male parents (ear type)
1.	Bizenwase Sai No.1 (Uzu-lax)	×	Bizenwase No.36 (Normal-dense)
2.	Bozu (Uzu-lax)	×	Hayakiso No.2 (Normal-dense)
3.	Mitsukiko No.1 (Normal-lax)	×	Sekitori (Uzu-dense)
4.	Natsudaikonmugi (Normal-lax)	×	Chikurin (Uzu-dense)

Hybrids and their progenies, together with their parents, were grown 10 cm apart each in rows in the experimental field, under the customary management of this Institute. It was necessary, however, to determine the end length of the coleop-

* In the first report this form of barley was described as the short type in contrast with the long type. In order to avoid confusion, however, a Japanese name "uzu" is used in this paper according to SO, OGURA and IMAI who first used this name for the same group of barley as this. At the same time an English name, semi-brachytic, is also given for this, because of the close similarity in general appearance with the "brachytic" which arised spontaneously by a mutation at a different locus (SWENSON 1940).

tile of each individuals as precisely as possible prior to the field planting, and for this purpose, all of the seeds were sown in glazed vessels containing sterilized sand nearly saturated with tap water, and were allowed to grow in the laboratory condition of illumination of about 100 lux in the day hours. When the coleoptile had fully elongated after eight to ten days, the seedlings were carefully removed for measuring coleoptile length. These plants were transplanted in the field according to their coleoptile length.

For the determination of the length of rachis internode, ear and culm, a standard ear and culm was selected for measurement according to Dr. TAKEZAKI's recommended method. The lengths of rachilla, empty glume (inclusive of awn) and grain were measured from the spikelets born on the middle portion of the median rows in the standard ear.

III. Experimental results

1. Inheritance of the ear types.

A. *The normal versus the uzu character* : It has already been demonstrated by SO, OGURA and IMAI (1919) and MIYAKE and IMAI (1922) that the uzu or semi-brachytic habit of growth was inherited as a simple Mendelian recessive character, and the result here obtained also ascertained this fact. The F₁ plants of the several crosses between normal and normal, as well as between normal and uzu yielded all normal plants, while the crosses between uzu and uzu were all uzu.

The segregation in F₂ for normal and uzu in the crosses between normal and uzu varieties are shown in Table 1. It indicates the character pair segregates into a 3 : 1 ratio, the normal being dominant over the uzu. The recommended symbol Uz uz of NAGAO and TAKAHASHI (1946) were adopted for this character pair.

Table 1. Segregation in the F₂ generation for normal vs. uzu character.

Crosses	Number of plants		Total	χ^2 *	P
	Normal	Uzu			
Six-rowed Chevalier × Yanehadaka	245	80	325	0.0256	0.93
Natsudaikonmugi × Yanehadaka	260	72	332	1.9437	0.16
Yamaguchi Hadaka × Chikurin	355	100	455	2.2161	0.13
Yakko No. 52 × Manmuth	231	68	299	0.8127	0.37

* On the basis of 3 : 1 ratio.

B. *The lax versus the dense ear character* : So far as the materials used in this experiment were concerned, ear density of the F₁ plants in the crosses between lax and dense ear varieties were always alike to those of the lax parents: the lax apparently being dominant over the dense. Distinction of the lax from the dense was quite apparent among the F₂ segregates of the normal type, while there accompanied some difficulty in the uzu type of segregates.

Table 2. Observed F₂ phenotypes for the lax vs. dense ear character.

Crosses	Number of plants		Total	χ^2 *	P
	Lax	Dense			
Russian No. 41118 × Kosaba No. 1	251	79	330	0.1814	0.67
Oita Hadaka × Zairai Tambo	232	74	306	0.1088	0.74

* On the basis of 3:1 ratio.

In Table 2 are shown the F₂ segregation of the lax and the dense characters. It indicates a single gene difference of the lax and the dense ear. This is designated as L 1.

C. *Interrelation of the character pairs, normal versus uzu and lax versus dense:* A test of interrelationship of the two allelic characters were made on eight crosses of varieties differing each from other in both characters under consideration. The F₁ plants of these crosses were all normal lax type, just as was expected. The phenotypic segregation in F₂ of the crosses No. 1 to No. 4 are shown in Table 3.

It is easily recognizable in Table 3 that normal vs. uzu and lax vs. dense characters are governed by two independently inherited gene pairs, Uzuz and L1. The result of the F₃ segregation test given in Table 4 indicates also a good agreement between the observed and the calculated ratios for independent inheritance.

Table 3. Segregation in the F₂ generation for normal vs. uzu and lax vs. dense in the crosses No. 1-No. 4.

Cross No.	Observed number				Total	χ^2 *	P
	Normal		Uzu				
	lax	dense	lax	dense			
1.	225	68	65	20	369	4.3921	0.23
2.	101	44	35	12	192	2.2592	0.53
3.	200	75	55	22	352	3.0808	0.38
4.	77	31	22	6	136	2.4352	0.47

* On the basis of 9:3:3:1 ratio.

Table 4. Observed F₂ genotypes for normal vs. uzu and lax vs. dense as determined by the F₃ segregation.

Cross No.	Number of plants of indicated genotypes										Total	χ^2	P
	U ₂ U ₂ LL	U ₂ U ₂ Ll	U ₂ u ₂ LL	U ₂ u ₂ Ll	u ₂ U ₂ ll	u ₂ U ₂ ll	u ₂ u ₂ LL	u ₂ u ₂ Ll	u ₂ u ₂ ll				
1.	27	50	45	103	24	44	17	39	20	359	5.5124	0.70	
2.	9	25	27	40	14	30	8	27	12	192	6.0496	0.64	
3.	18	45	60	77	30	45	17	38	22	352	12.0114	0.15	
4.	9	20	12	35	14	17	9	13	6	136	7.4117	0.49	

Table 6. Mean lengths of rachis internode and ear of F_2 genotypes in the crosses No. 1 and No. 2 as determined by the F_3 segregation.

Characters & Cross No.	UzUz	UzUz	Uzuz	Uzuz	UzUz	Uzuz	uzuz	uzuz	uzuz	
	LL	Ll	Ll	Ll	ll	ll	LL	Ll	ll	
rachis internode length(mm)	1	3.07	2.91	2.94	2.82	1.98	1.84	1.87	1.77	1.31
	2	3.97	3.60	3.68	3.60	2.62	2.43	2.28	2.49	1.60
ear length(mm)	1	81.2	75.9	78.2	76.4	55.4	52.1	54.8	48.1	38.9
	2	89.6	86.0	84.7	86.0	60.0	61.9	59.1	58.9	42.0

relation with the ear types: with respect to these characters the normal-lax class is always the longest and the uzu-dense class the shortest; while the other two classes, the normal-dense and the uzu-lax, both showed no significant difference, being intermediate between the former two classes. Moreover in Fig. 1, the frequency histogram regarding the rachis internode length of each classes are discrete at large, when the uzu and the normal groups are separately drawn, indicating that the classification of the ear types is not difficult. In these examples shown in Table 5 and 6, the magnitude of the effects of the dominant genes, Uz and L on the ear length as well as on the rachis internode length, as compared with that of the respective recessive ones was recognized to be almost equal, and their lengths become approximately 1.45-1.50 times longer when either of the dominant genes, Uz or L, is present. At this point, it is of interest to compare this with the results of Dr. TAKEZAKI (1927). He indicated the effects of genes H and E multiplicative to the value C, a basic gene complex, and the qualifying values of H and E for ear length were calculated as 1.43 ± 0.059 and 1.465 ± 0.060 , respectively. Considering the similarity in their linkage relation and also in their actions, therefore, it seems quite reasonable to conclude that the genes, Uz and L, which are being dealt with in this study, are identical with H and E of Dr. TAKEZAKI. Also, the effects of the both genes on the rachis internode length are equal at large to those on the ear length, although an ear length is essentially the product of rachis internode length and number of nodes.

There is perceived in Table 6 the presence of slight discrepancies in the length of rachis internode and of the ear among the different genotypes which were classified as the same respective phenotypic classes. It may be noted here that the decline of these values is roughly proportional to the degree of heterozygosity of the dominant Uz and L genes, although their differences are generally so slight that they are statistically insignificant.

3. Inheritance of the coleoptile length in relation to the ear types.

As shown in the previous reports the coleoptile length of a plant is remarkably variable according to the growing conditions, but the mean length of a variety grown in a definite condition is quite stable, and therefore, this is regarded as a heritable character peculiar to a variety.

In Table 7 are given the mean coleoptile lengths of the F_1 plants and their parents of the crosses No. 1 to No. 4, which indicates that the coleoptile of F_1 are almost equal to or slightly longer than that of the normal type parents, and so it is whenever the seedlings are grown under markedly different conditions.

The mode of inheritance of the coleoptile length is somewhat different from those of the rachis internode length and the ear length. In Fig. 2, the frequency distribution of the end length of the coleoptile in F₂ is typically bimodal, but not trimodal

Table 7. Mean coleoptile lengths of the parents and F₁ plants grown in the laboratory (mm).

Cross No. & Name of variety	Genotype	Coleoptile length	
		parents	F ₁
1. Bizenwase Sai No. 1 Bizenwase No. 36	uzuzLL	13.8±2.09	26.9±3.14
	UzUzll	22.9±2.91	
2. Bozu Hayakiso No. 2	uzuzLL	13.0±5.00	27.9±2.37
	UzUzll	28.0±2.47	
3. Mitsukiko No. 1 Sekitori	UzUzLL	27.8±2.19 (75.8±7.48)*	28.1±1.67 (75.5±6.75)
	uzuzll	13.2±1.09 (34.2±2.97)	
4. Natsudaikonmugi Chikurin	UzUzLL	30.6±2.50	32.8±1.30
	uzuzll	17.4±1.65	

* Coleoptile lengths of the same materials grown in the darkness are given in parenthesis.

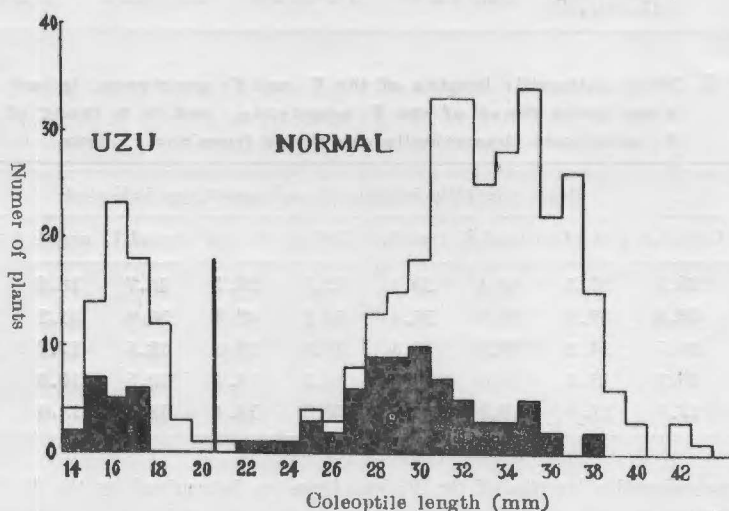


Fig. 2. Variation histogram of the F₂ individuals in Bizenwase Sai No. 1 X Bizenwase No. 36 cross (Cross No. 1) with respect to the coleoptile lengths, showing individuals with dense ear in black, those with lax ear white.

as in the case of rachis internode length. And, it was found that all the individuals with coleoptile shorter than 20 cm. were the uzu type, while those with coleoptile longer than 21 mm. were the normal type. Moreover, the difference was not so pro-

nounced with respect to their coleoptile length of the lax and the dense groups in F_2 generation, although the lax was obviously longer than the dense. Mean coleoptile lengths of the four ear types classified in each of the four crosses are shown in Table 8, which verifies the above statement to be true in other crosses. In other words the effect of the gene Uz on the coleoptile length is by far stronger than that of the gene L , and the presence of Uz makes the coleoptile about twice as long as the uz . However, coleoptile length is markedly influenced by the growing condition of the seedlings, and there is a tendency of the qualifying value to decrease in proportion as the coleoptile length becomes shorter.

Table 8. Mean coleoptile lengths of the parents and the F_2 phenotypes in the crosses No. 1 to No. 4.

Cross No.	Mean coleoptile length in mm.				
	parents	Normal		Uzu	
		lax	dense	lax	dense
1.	20.0±1.67 30.2±2.36	34.0±3.17	30.2±3.25	16.8±1.40	15.8±0.99
2.	16.6±2.10 32.5±2.85	33.8±4.35	28.6±3.70	17.9±2.30	15.4±2.02
3.	15.8±1.36 10.7±2.42	15.0±1.98	13.8±2.00	10.4±1.51	9.9±1.14
4.	22.9±2.77 11.3±1.37	20.3±3.96	19.5±3.10	12.2±2.11	11.2±2.73

Table 9. Mean coleoptile lengths of the F_2 and F_3 genotypes; in row a are given those of the F_2 genotypes, and in b those of F_3 genotypes theoretically calculated from the F_3 data.

Cross No.	Mean coleoptile lengths of each genotypes indicated									
	$UzUzLL$	$UzUzLl$	$UzuzLL$	$UzuzLl$	$UzUzll$	$Uzuzll$	$uzuzLL$	$uzuzLl$	$uzuzll$	
1	a	36.1	35.3	33.4	33.1	32.1	29.1	16.7	16.8	15.8
	b	58.4	57.9	55.9	55.4	53.1	47.8	30.9	31.2	27.4
2	a	34.7	34.2	33.9	33.3	29.9	28.0	18.6	17.7	15.4
3	a	15.7	15.3	15.0	14.7	14.1	13.7	10.5	10.3	9.9
4	a	22.9	21.6	18.8	19.6	20.8	18.4	12.6	12.0	11.2

The mean coleoptile lengths of the F_2 genotypes as determined by the F_3 test are presented in Table 9.

According to the data shown in Table 9, it is evident that the presence or absence of the dominant genes Uz and L affects markedly upon the coleoptile length, just as in the case of F_2 stated above. However, the dominancy of the both genes over the genes uz and l can not be conceived to be complete, because genotypes singly or doubly heterozygous for Uz or L , are generally shorter, though very slight, in their coleoptile than homozygous genotypes. This was further supported by measuring the coleoptile lengths of 30 or more seeds taken from each of the F_2 individuals in the

cross No. 1 and sown in absolute darkness at 20° C, where the normal and the uzu individuals of each strain in F₃ generation were distinguished and the mean length of each were determined. The genotypic constitutions of each strain, on the other hand, were confirmed by the ordinary F₃ test. The mean coleoptile lengths of the nine genotypes involved in the F₃ were able to be theoretically calculated on the assumption that the segregation of the two pairs of the genes would occur in expected ratio and the different genotypes involved in the respective F₂ genotypes would be as follows :

F ₂ genotypes	Respective F ₃ genotypes and their ratios involved.
UzUzLL	1 UzUzLL
UzUzLl	($\frac{1}{4}$ UzUzLL + $\frac{1}{2}$ UzUzLl + $\frac{1}{4}$ UzUzll)
UzuzLL	($\frac{1}{4}$ UzUzLL + $\frac{1}{2}$ UzuzLL) + ($\frac{1}{4}$ uzuzLL)
UzuzLl	($\frac{1}{16}$ UzUzLL + $\frac{1}{8}$ UzUzLl + $\frac{1}{8}$ UzuzLL + $\frac{1}{4}$ UzuzLl + $\frac{1}{16}$ UzUzll + $\frac{1}{8}$ Uzuzll) + ($\frac{1}{16}$ uzuzLL + $\frac{1}{8}$ uzuzLl + $\frac{1}{16}$ uzuzll)
UzUzll	1 UzUzll
Uzuzll	($\frac{1}{4}$ UzUzll + $\frac{1}{2}$ Uzuzll) + ($\frac{1}{4}$ uzuzll)
uzuzLL	1 uzuzLL
uzuzLl	($\frac{1}{4}$ uzuzLL + $\frac{1}{2}$ uzuzLl + $\frac{1}{4}$ uzuzll)
uzuzll	1 uzuzll

The result obtained is listed in column b of Table 9, which is apparently similar to the F₂ genotypes. The difference in the absolute value of the coleoptile length is mainly due to the varied condition under which the seedlings were grown.

4. Correlative inheritance of the culm length with the ear types.

Culm lengths of all of the F₁ plants in the crosses involving Uzuz and Ll genes were generally somewhat longer than those of the normal type parents, the long culm being dominant over the short.

Table 10. Mean culm lengths of the parents and the F₂ phenotypes in the crosses No. 1 to No. 3. (unit mm)

Cross No.	Parents	Normal		Uzu	
		lax	dense	lax	dense
1.	79.3±3.48	113.7±6.40	99.9± 7.54	73.5±7.14	61.3±5.98
	99.9±5.70				
2.	70.2±4.35	98.1±8.98	90.4±10.50	72.2±9.18	64.6±7.77
	97.4±3.77				
3.	79.3±3.90	85.4±6.38	77.6± 5.55	67.3±5.94	56.1±4.90
	65.5±2.41				

In Table 10 are presented the mean culm lengths for each ear type classified among the F₂ segregates in the crosses No. 1 ~ No. 3. It is obvious that the normal-lax class is the tallest of all, followed in the order of the normal-dense, the uzu-lax and the uzu-dense. The magnitude of the difference in culm length between the nor-

mal and the uzu is considerably larger than that between the lax and the dense. It is therefore possible to conclude that the presence or absence of the gene Uz, as compared to the gene L, exerts stronger influence upon the culm length, which is a similar relation as was found in the coleoptile length. It is also noted from the F₃ data shown in Table 11 that the effects of the genes Uz and L in heterozygous conditions on the culm length was less than those present in homozygous conditions.

Table 11. Mean culm lengths of the F₂ genotypes in the crosses No. 1 to No. 3. (unit cm.)

Cross No.	Mean culm length in cm.									
	UzUzLL	UzUzLl	UzuzLL	UzuzLl	UzUzll	Uzuzll	uzuzLL	uzuzLl	uzuzll	
1.	115.0	114.6	113.5	113.1	104.4	96.9	76.1	72.4	61.3	
2.	98.4	99.6	95.9	98.7	90.0	90.6	71.7	72.2	64.6	
3.	89.0	87.7	83.8	83.7	80.3	75.8	67.9	67.1	56.1	

5. *Differences between the normal and the uzu forms on some other quantitative characters.*

It was mentioned that striking differences occur on various other plant parts between the normal and the uzu varietal groups. An attempt was therefore made to determine whether similar relations can be recognized in the hybrid progenies of the normal and the uzu variety crosses. In Table 12 are shown the mean lengths of the empty glume inclusive of awn, axis of the basal bristle (rachilla) and the grain on

Table 12. Mean lengths of the empty glume (inclusive of its awn), axis of the basal bristle (rachilla) and the grain for the normal and the uzu forms in the F₂ of the three crosses. (unit mm.)

Characters tested	Cross No.*	Parents		F ₂ phenotypes	
		Normal	Uzu	Normal	Uzu
Empty glume length	5	19.8	8.2	18.1 ± 2.02	8.9 ± 1.18
	6	15.5	7.6	16.0 ± 0.93	7.4 ± 0.91
	7	21.0	7.1	16.3 ± 2.66	8.5 ± 1.06
Rachilla length	5	3.80	1.11	2.34 ± 0.4542	1.38 ± 0.1898
	6	2.81	1.05	2.25 ± 0.3298	1.03 ± 0.1893
	7	3.56	1.16	2.84 ± 0.4551	1.44 ± 0.2013
Grain length	5	8.06	6.90	8.14 ± 0.4653	7.29 ± 0.4104
	6	11.38	8.68	10.88 ± 0.3788	9.45 ± 0.3435
	7	7.08	6.37	7.18 ± 0.4969	6.48 ± 0.2981

* Cross No. 5 ... Wasehadaka (uzu) × Tammi (normal)
 No. 6 ... Indian barley (normal) × Sakigake (uzu)
 No. 7 ... Kairyobozu (uzu) × Líguleless (normal)

the normal and the uzu form classified under the F₂ individuals for the three crosses. The results revealed that the normal type was almost twice as long as the uzu type

with respect to the lengths of the empty glume and the axis of the basal bristle, while the grain length of the normal type was only slightly longer than that of the uzu types.

IV. Discussion

It was confirmed in this and the foregoing investigations ^(25, 26, 27) that four kinds of distinct ear types, classified among the Japanese barley varieties were chiefly determined by the two pairs of independently inherited genes, Uzuz for normal vs. uzu and L1 for lax vs. dense ear character.

There is no need to stress on the confirmation of the results regarding the normal and the uzu characters, because this is entirely in accord with the data hitherto published. However, investigation on the ear density are not always agreeable. With respect to the classification of the ear density, at least three different systems have been proposed. LINNÉ was the first to classify barley according to the ear density into two groups, the lax and the dense, and this system has been succeeded by BRAVEN RÜMKE, NOWACKI, ZADE, TAKEDA, TAKEZAKI and others. However, KÖRNICKE (1885) subdivided the dense group into two, viz. the dense and the very dense, and this had been further extended by ATTERBERG (1899) and also by the Russian school to be the establishment of trisecting system, in which lax, medium and dense groups were placed in the same order. On the other hand, HARLAN (1918) and other American barley specialists presented a different opinion that this character had only a descriptive value on account of the difficulty in classifying varieties or hybrid strains that varied continuously as to this character.

The inheritance of ear density in barley seems more complicate, and the results of the studies on this subject are exceedingly diverse. UBISCH (1916, '19) explained the results of crosses between some European and Japanese varieties on the basis of main gene L and two modifiers, M and N. In this, either of the modifiers, perhaps M, is suspected of corresponding to Uz in this study. ANDO (1918) indicated the monogenic inheritance of the density in Japanese barley crosses, and similar results were also obtained by BIFFEN (1907) and NEATBY (1922, '29). Although SO, OGURA and IMAI (1919) and MIYAKE (1922) assumed three or two different genes involved in a linkage group being responsible for this character; HOR (1924) threw some doubts on this conclusion, suspecting that these three or two genes might be identical. The coincidence of TAKEZAKI'S opinion with the present result was stated before. Thus, monogenic inheritance of the ear density has been established by these investigators on one hand, several contradicting results have also been published on the other hand. HAYES and HARLAN (1918, cited from MATSUURA 1933) revealed that several main genes were responsible for ear density, together with minor genes, and Huber (1929, '31) found three lax genes, L₁, L₂, L₃, and a compact gene C. According to LUNDEN (1981), the lax ear character was determined by two main genes. WEXELSEN (1983) in his detailed quantitative studies, discovered six different genes, L₁-L₆ for lax ear, each varying from others in its qualifying value for the rachis internode length.

It is admitted therefore from the above mentioned results, that the classification

of ear types has remained unsolved, and the mode of inheritance of the ear density, too, has never been thoroughly understood as yet. However, so far as the Japanese barley are concerned, it may be justified that they are distinctly classified into two groups, namely, lax and dense, with very rarely intermediate type, and moreover, the fact that the lax ear behaves singly dominant over the dense in all cases has also been demonstrated, which will afford the basis of accounting for the clear cut difference between the lax and the dense varieties.

The next question to be discussed is how the correlative inheritance of some quantitative characters of various plant parts occur with the ear types. Is this phenomenon simply due to the pleiotropism of Uzuz and L1 genes exerting different magnitude of effects upon different parts of plants? Or, is it brought about by many other genes present for the respective quantitative characters, which are closely or completely linked with the two gene pairs? It is difficult to decide either of them being more plausible for the explanation of the phenomenon. Because, the materials used as parents for crossing are not in a simple relation of a mutant and its progenitor, so that all of the differences observed between F₂ phenotypes may not wholly be attributed to the genic differences under consideration. Furthermore, small number of newly established recombination types, if any, can not be detected in such cases as quantitative genes are concerned. However, it may be rather better at present to explain this phenomenon on the basis of pleiotropic hypothesis, for it is generally accepted that a gene exerts more or less manifold effects upon seemingly indifferent parts of an organism, and that the dwarf growth is intrinsically understood as the simultaneous diminution of lengths in different parts. The brachytic mutant in barley studied by SWENSON (1940) affords a good example. This form of barley that is definitely known to have originated by a spontaneous mutation is characterized by the marked diminution in size of various plant parts in comparison with its normal progenitor, just as is the uzu barley to the normal one. And, the brachytic form is so similar to the uzu in many respect that it is indistinguishable from the latter at its adult stage. Moreover as stated before, SO, OGURA and IMAI (1919) and MIYAKE and IMAI (1922) defined the uzu as a pleiotropic one, and TAKEZAKI (1927) confirmed that Hh (=Uzuz) as well as Ee (=L1) simultaneously altered various size characters of ear.

V. Significance of the present results upon the future breeding of Japanese barley.

It has already been clarified that the geographical distribution of the normal and the uzu or semi-brachytic types of barley in Japan is very distinct: the normal type is mainly cultivated in the northern and in the southernmost parts, while the uzu type occupies the central and the southern parts with warm and mild climate. It is also noted that normal-lax type is restricted to Hokkaido and Tohoku districts and the normal-dense ear type is distributed in the districts south of Hokuriku, inclusive. Such geographical regularities of the ear type distribution suggest ecological adaptability of the respective genes or genotypes for each geographical regions, and therefore this may serve as a criterion in selecting adaptive strains for these regions, although it is obscure

whether adaptive values of these genotypes are determined directly by these genes involved. Moreover, this investigation revealed that important characters such as ear density, ear length, culm length and others are pleiotropically affected by these gene pairs. It is no exaggeration, therefore, to state that these two pairs of genes are of the primary importance and particular attention should be paid for them in the barley breeding praxis in Japan.

From a technical point of view, the results here obtained are also of interest for Japanese breeders. It was shown that each of these genes markedly affects various characters of the seedling, so the genetic constitution of each individual of a certain hybrid progenies is to be predicted even in its youngest stage, and consequently nursery selection of required genotypes is possible to a certain extent. In the following, some explanations are given for the applicable cases of the "coleoptile method" for the purpose of simplifying barley breeding procedure.

(1) The "coleoptile method" here proposed is applicable only for the cases of dealing with the hybrid progenies, the parents of which differ in the characters of normal versus uzu and lax versus dense or in both character pairs.

(2) Application to F₁ generation: In cases when the crosses have been planned as uzu varieties being pollinated by normal parents, success of the crosses can be verified at their seedling stage, because the coleoptiles of the F₁ seedlings are always to be as long as those of the male parents.

(3) Application to F₂ generation:

a. As easily understood in Fig. 2, F₂ individuals, carefully grown under a uniform condition, are able to be classified distinctly into normal and uzu groups according to their coleoptile length, and either of both groups can be separated out prior to transplanting into breeding garden. Moreover, nursery selection of the lax or the dense ear forms is also possible to a certain extent, since the dense-eared individuals in F₂ generation are in general shorter in their coleoptile length than the lax ones. The probabilities of obtaining the respective desired phenotypes when selecting one quarter of individuals with the longest or the shortest coleoptile, as compared to the random method of taking the same number of plants which is designated 100 %, will be as follows (The data are calculated from eight crosses):

When selecting one quarter of individuals with the shortest coleoptile, probabilities for obtaining		When selecting one quarter of individuals with the longest coleoptile, probabilities for obtaining	
uzu-dense %	Normal-dense %	Uzu-lax %	Normal-lax %
150±8.24	165±10.56	122±3.18	123±1.75

SEKIZUKA (1948) emphasized the advantage of selecting the uzu or the normal individuals among the F₂ progenies at the nursery bed before transplanting. Growing F₁ plants outdoors in nursery box according to the customary method in the Agricultural Experiment Station, he distinguished uzu individuals from the normal ones by the differences in the length and the form of the first foliage leaf with 90 percent or more accuracy. In the writer's opinion, based on the laboratory as well as field tests

done more extensively, the following method seems to be more advantageous for this purpose: The seeds should be sown in a sand bed and the seedlings grown in a glass incubator kept at about 25°C and placed in a sunny room. One or two days after the emergence of the first leaf from the coleoptile tip, the uzu plants can easily be discriminated from the normal ones, since uzu individuals are all characterized not only by the shortness of the coleoptile and the whole length of seedling, but also by the presence of the projection near the apex of the coleoptile, which is peculiar to this form; the normal ones, by far, are longer in both characters and lack projection on the coleoptile.

b. For the genic analysis as well as for the breeding praxis, it is convenient to grow the individuals of the same ear type in a group in the experimental field, and this can be done to a certain extent by transplanting the F₂ seedling according to their coleoptile length.

(4) Application to F₃ generation: While uzu individuals always breed true, two thirds of F₃ strains, which were phenotypically normal in F₂ generation, are to be segregated again in a 3 normal and 1 uzu ratio. Such heterozygous strain can be, however, accurately discerned from the homozygous normal ones by a simple test using a small quantity of seeds; even 20 grains will tell whether uzu individuals with short coleoptile will segregate out or not. When securing the homozygous normal strains, and when the labor and the field should be economized for the F₃ planting, these preliminary laboratory tests will be of value prior to actual plantings in the experimental plots.

Summary

The writer has already indicated that Japanese barley varieties are classified into four distinct ear-types and also that each of these ear types differ as to various quantitative characters of young and adult plant parts. This paper dealt with the results on their genetical behaviors in the hybrids.

1. It was shown that two pairs of independently inherited genes, Uzuz for normal versus uzu and L1 for lax and dense characters, were chiefly responsible for the determination of these ear types in the Japanese barley.
2. As expected from the previous studies, correlative inheritance of some quantitative characters of various plant parts with the ear types were observed; with respect to the characters tested, viz. ear, rachis internode, empty glume, grain, axis of the basal bristle (rachilla), culm and coleoptile, the normal-lax type is always the longest and the uzu-dense type the shortest, while the other two types intermediate of the two. These relations may be appropriately explained on the basis of pleiotropic hypothesis.
3. The dominancies of the effects of the genes, Uz and L on the size characters tested over their allelic genes, uz and l, seemed to be somewhat incomplete, though statistically significant differences were not always observed among genotypes homozygous and singly or doubly heterozygous for these genes.
4. It was pointed out that the "coleoptile method" here proposed would serve to simplify the breeding procedure of the Japanese barley varieties.

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PLATE XXV



Fig 3. Eight Kinds of ear-awn types distinguished among Japanese barley varieties.

