INHERITANCE OF CHARACTERS IN RICE*

INTRODUCTION

THIS paper deals with studies on the inheritance of the following characters in rice: Length of glumes, absence of ligules, brittleness, shattering, dwarfness, awns, color of awns, color of glumes, color of apiculi, and earliness.

LENGTH OF GLUMES

Most varieties of rice (*Oryza sativa* L.) have short (outer) glumes. The glumes usually vary in length from one-fifth to one-third of that of the lemma and palea. However, in some varieties the glumes are nearly as long, or quite as long, as the lemma and palea. These long-glumed varieties are reported to be resistant to lodging and shattering. They are not grown on a commercial scale in the United States.

Parnell et al. and Kato and Van der Stok, according to Ikeno, obtained in F_2 populations plants with short and long glumes in a ratio of 3:1. Chao, in a cross between a glutinous long-glumed variety and a common short-glumed variety, obtained in F_2 a ratio of 15 plants with short to 1 plant with long glumes. In this case short glumes were due to dominant duplicate genetic factors. Ramiah et al. in a cross between short and long-glumed varieties, obtained F_1 plants that had glumes intermediate in length between the parents. In the F_2 populations the parental and intermediate glume lengths were obtained. These investigators placed the F_2 plants with respect to glume length in three groups, namely short, intermediate, and long, and by this arbitrary grouping they obtained approximately a 1:2:1 ratio. However, there was much variation in the length of the glumes of plants classified as intermediate. In this group the glumes varied in length from almost as short as the short-glumed parent to nearly as long as the long-glumed parent. This indicates that the plants classed as intermediate for glume length were not genetically similar and suggests that the difference between the short-glumed and the long-glumed varieties probably was due to multiple factors.

In 1926 Yosemite, a normally short-glumed variety, was crossed with "Nimai Kawa Mochi" and "Weitin", long-glumed varieties. The parents and F_1 plants were grown in 1927. The spikelets of F_1 plants from both crosses had normal short glumes.

In the F_2 population of the cross Yosemite x Nimai Kawa Mochi 1,116 plants were grown to maturity. Of these 831 plants had spikelets with short glumes and 285 plants had spikelets with long glumes. These numbers agree with a monohybrid 3:1 ratio, the deviation being only $6{\cdot}00 \pm 9{\cdot}76$ plants. Of the 1,047 Yosemite x Weitin F_2 plants 785 had

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short glumes and 262 had long glumes the deviation from a 3:1 ratio being 0 25±9 46 plants. In the total F_2 population of the two crosses there were 1,616 plants with short glumes and 547 with long glumes, the deviation from a monohybrid ratio being 6·25 ±13·59 plants.

Fifteen random F_2 progenies from the cross Yosemite x Nimai Kawa Mochi and 16 progenies from the cross Yosemite x Weitin were grown in the F_3 Of the 15 progenies, 7 segregated for short and long glumes, 3 bred true for short glumes, and 5 bred true for long glumes. Of the 16 progenies, 7 segregated for short and long glumes, 4 bred for short glumes, and 5 bred true for long glumes. The results for both groups are shown in table 1.

Table I.—Breeding behaviour of F_2 progenies from the crosses Yosemite x Nimai Kawa Mochi and Yosemite x Weitin grown in F_3 a the Biggs Rice Field Station, Biggs, Calif., 1929.

Cross	Number of progenies	Number of plants with glumes		Deviation from 3:1 ratio and probable error
		Short	Long	
Yosemite x Nimai Kawa Mochi	3	605	—	— —
	7	904	297	3·25 ±10 10
	5	—	837	— —
	4	704	—	— —
Yosemite x Weitin	7	964	346	18·50 ±10 54
	5	—	765	— —
Total for 14 segregating progenies		1,868	643	15·25 ± 14·63

In the seven segregating progenies of each cross producing plants with short and long glumes the deviations from 3:1 ratio were less than twice the probable error in all progenies, except for one in each cross. The results show that short glumes are dominant to long glumes and that the long-glumed and short-glumed varieties used in this study differ by a single genetic factor for this character.

ABSENCE OF LIGULES

In commercial rice varieties the ligules at the juncture of the leaf blade and sheath are usually well developed. A liguleless variety, "Tsutsuito", the only one known to the writer, was obtained in Japan in 1925. Tsutsuito is late-maturing, liguleless, and awnless. It was crossed with "Kotake", also late-maturing, and partly awned.

The F_1 plants had normal ligules and were partly awned like the male parent Kotake. An F_2 population, consisting of 1,024 plants was grown in 1927. Of this number 796 plants had normal ligules and 228 were liguleless, the deviation from 3:1 ratio being 28·00 ± 9·35 plants.

Fifteen random F_2 progenies were grown in the F_3 in 1928, of which 6 consisting of 989 plants, bred true for normal ligules, 5 segregated and gave 655 plants with ligules to 195 without ligules and 4 consisting of 725 plants, bred true for the liguleless character.

The five progenies that segregated in F_3 produced 655 plants with and 195 plants without ligules, the deviation from 3:1 ratio being 17·50 ± 8·51 plants. According to Ikeno, Kato found that normal ligules were dominant to the liguleless character in rice. He obtained in F_2 3 plants with normal ligules to 1 without ligules.

BRITTLENESS

The culms and leaves of commercial rice varieties vary in strength and toughness. Under normal conditions some varieties do not lodge, whereas others lodge badly. Between these two extremes there are various degrees of resistance to lodging. However, all the commercial varieties are normal in that the straw possesses a certain degree of toughness or tensile strength and is somewhat resistant to complete breaking by bending or twisting. In contrast to the normal toughness of the culms and leaves of the commercial varieties is the extreme brittleness of the culms, leaves and other parts of "Kama Irazu" a variety obtained in Japan. This variety does not lodge, although the stalks bend over under the weight of heavy panicles. However, in both the green and the mature stages the leaves and culms are so brittle that they break off at the slightest pressure. The writer was informed that the name Kama Irazu means "no need of a sickle in harvesting". This variety was so named because a standing plant gathered into the hand snaps off when given a slight twist. The panicles also are brittle and the spikelets fall off easily. In threshing, the lemma and palea often are removed and the kernel is easily broken.

In the cross Kama Irazu × Colusa (C.I ^{3} 1600, a normal variety) the F_1 plants had normal (not brittle) stalks, leaves, and panicles. In the second generation there were 479 plants with normal stalks, leaves and panicles to 156 plants with these parts brittle. The deviation from a 3:1 ratio was 2·75 ± 7·36 plants. The segregation into normal and brittle plants was very distinct. The ordinary green rice leaf often can be folded up without breaking into separate parts, but the brittle leaf is easily snapped off when bent. Owing to this fact it was possible to classify the plants even before they headed.

Twenty-five random F_2 progenies were grown in the F_3 Six of these, consisting of 292 plants, bred true for normal plants; 14 segregated, producing 453 normal plants to 142 brittle ones; and 5, consisting of 223 plants, bred true for the brittle character. The segregation of each of the 14 progenies agreed well with a ratio of 3 normal plants to 1 brittle plant, the deviation for the 14 progenies being 6·75 ± 7·12 plants.

Analyses were made of the straw and grain of Kama Irazu and of Colusa (C.I. 1600). The straw of Kama Irazu contained less ash, silica, and crude fiber than that of Colusa, but a higher percentage of lignin, nitrogen, and moisture. The chemical data do not show the cause of brittleness in Kama Irazu, but this character may be due to cell structure or arrangement.

SHATTERING

Varieties differ greatly with respect to the tightness with which the grain is held on the panicle before and after maturity. In certain varieties the grain is held so tight that threshing is difficult. In others the grain shatters very easily, even when carefully handled. Between these two extremes there probably are varieties representing all degrees of tightness.

In the United States commercially grown rice varieties are more or less resistant to shattering but do not hold the grain so firmly that they cannot be satisfactorily threshed with modern machinery. Varieties that shatter too easily are not suited for harvesting with grain binders. In countries where rice is harvested by hand and threshed by treading and flailing, varieties that shatter rather easily are grown in preference to those that shatter less readily.

Takenouchi reports that at the juncture of the rice grains and their supporting stalks there is a special tissue consisting of from 1 to 3 layers of lignified thin-walled cells. In rices that shatter easily these cells develop and dry up early, whereas in rices that shatter less easily they do not dry up so early.

According to Matsuura, Kato crossed a non-shattering rice with one that shattered easily. In the F_1 the plants were non-shattering and in the F_2 the ratio of non-shattering plants to those that shattered easily was 3:1.

The Caloro and Colusa varieties, which are extensively grown in California, do not shatter easily if properly handled. These were crossed with Chinese varieties that shattered easily. The crosses were C.I. 7075 × Colusa, C.I. 7078 × Caloro, and C.I. 7389 × Caloro.

The F_1 plants of these crosses of these plants appeared to be intermediate. They did not shatter so readily as did the Chinese varieties, and yet they did not seem to hold the grain quite so firmly as did Colusa and Caloro.

Owing to various degrees of sterility in the F_2 plants of these crosses and to the failure of many individual plants to mature grain, only part of the F_2 population was suitable for a study of the inheritance of shattering.

On the basis of the ease or difficulty of stripping the grains from the mature panicles of plants standing in the field, it was not hard to determine relative resistance to shattering. Only a few trials were necessary to reduce this determination to a fair degree of accuracy. The plants from which it was easy to remove the seed were classed as easily shattered, whereas those from which it was rather difficult to remove the seed were classed as non-shattering.

In the F_2 population from the cross C.I. 7075 × Colusa there were 29 non-shattering plants to 11 that shattered readily; from the cross C.I. 7078 × Caloro there were 99 non-shattering plants and 46 that shattered readily; and from the cross C.I. 7389 × Caloro there were 249 non-shattering plants and 109 that shattered readily. In each cross these numbers agree reasonably well with a 3:1 ratio. The deviations from this ratio in the order given were 1.00 ± 1.85 plants; 9.75 ± 3.52 plants, and 19.5 ± 5.53 plants The results that in the varieties used in this study the non-shattering and shattering characters probably differ by a single genetic factor.

DWARFNESS

Dwarf varieties of rice often are grown at rice experiment stations. While they are of no economic importance, they are of interest to plant breeders. According to Ikeno a dwarf rice plant was described by Iwasaki in 1828.

Parnell et. al first reported on studies of the inheritance of dwarfness in rice. They found that dwarfness is a simple recessive to normal. The average height of the normal parent used in their study was 49·7 inches and that of the dwarf parent 27·9 inches. The average height of the normal segregates in F_2 was 50·5 inches and of the dwarf segregates 31·2 inches.

Sugimoto states that dwarfness usually is a simple recessive to normal. He found a dwarf mutant in a true-breeding normal variety, Waseshinriki, which was a simple recessive to normal. Another dwarf appeared as a mutant in a true breeding strain isolated from a hybrid. This dwarf was dominant to normal and in the F_2 segregation produced 3 dwarf plants to 1 normal.

Akemine crossed the normal variety Akage with the dwarf varieties "Daikoku" and "Ebisu". In the F_2 segregation both crosses produced 5 normal plants to 1 dwarf. In a cross between the dwarf varieties Daikoku × Ebisu the F_1 was normal and the segregation in F_2 gave 9 normal to 3 Daikoku to 3 Ebisu to 1 new very short dwarf type, Kodaikoku. Akemine assumed that the genetic constitution of normal was AABB, Ebisu AAbb, Daikoku aaBB, and Kodaikoku aabb.

Nagai reported a dwarf mutant that was recessive to normal. This mutant showed a peculiar mode of inheritance in that in successive generations mutant individuals gradually increased in proportion to normals.

The writer obtained in Japan seed of a dwarf variety known as "Daikokune". This variety was short, rather wide, erect leaves, short culms, and a short compact panicle that looks more like a spike of wheat than a panicle of rice. It is partly awned and the kernel is short and round and enclosed by a rather coarse hull. The cross Yosemite × Daikokune was made in 1927. Yosemite is an early maturing, awnless variety of normal height.

The F_1 plants were intermediate in maturity, partly awned, normal in appearance, and somewhat taller than the normal parent. The average height of the normal parent was 38 inches, of the dwarf parent 14 inches, and of the F_1 plants 43 inches. The average length of 10 panicles of the normal variety was 4·7 inches, of the dwarf parent 2·3 inches, and of the F_1 plants 4·6 inches.

The F_2 population consisted of 677 plants that were grown to maturity of which 547 were normal and 130 were dwarf. Segregation into the two groups was very distinct. The deviation from 3:1 ratio was 39·25 ± 7·60 plants, or more than five times the probable error, whereas the deviation from 13:3 ratio was only 3·0625 ± 6·85 plants. However the segregation of random F_2 progenies grown in F_3 shows that the 3:1 ratio is correct.

In the F_2 population the average height of 100 normal segregates was 37·4 inches and the average height of 100 dwarf segregates was 16·9 inches. The average height of 42 plants of the normal variety was 32·6 inches and the average height of 42 dwarf plants was 13·9 inches. The normal and dwarf segregates in F_2 exceeded the normal and dwarf parent varieties in average height. Of 25 random F_2 progenies grown in 1930, 7 consisting of 367 plants, bred true for normal stature, 15 segregated for normal and dwarf plants, and 3, consisting of 86 plants, bred true for dwarf plants. Each of the 15 segregating progenies produced normal and dwarf plants in numbers that agreed well with a 3:1 ratio. The total for the 15 progenies was 598 normal to 181 dwarf plants, the deviation from a 3:1 ratio being 13·75 ± 8·15 plants. In the varieties used in this study dwarf character was a simple recessive to normal.

AWNS

Rice varieties may be classed as fully awned, partly awned, and awnless. In fully awned varieties all spikelets are awned but the awns often vary in length. In partly awned varieties, awned and awnless, spikelets are present on the same panicles. In true awnless varieties the awns are absent and do not develop under any conditions. In some varieties the main panicle may be awnless, whereas some of the spikelets on branch culms and later tillers may be partly awned. The extent of development of the awns in rice is controlled by climatic conditions and soil fertility as well as by genetic factors. In some crosses it is difficult to separate the awn types because climatic conditions and soil fertility have such a marked influence upon their development.

Chao, Hoshino, Jones, Mendiola, Nagai, Yamaguchi, and Kato and Van der Stok, according to Matsuura have reported that in F_1 awns are dominant or partially dominant to the awnless character in rice. A segregation in F_2 of 3 awned or partly awned plants to 1 awnless plant has been reported by Jones, Nagai, and Chao, and a ratio of 9 fully awned to 6 partly awned to 1 awnless plant by Jones. The awned group in the 15:1 ratio reported by Chao were designated as fully awned, mostly awned and rarely awned plants.

In the few crosses between fully awned and awnless varieties that have been studied by the writer, three groups of awned plants have been observed in the F_2 segregations. These are fully awned plants, partly awned plants with awns about the same length as in fully awned plants but present only on part of the spikelets on a panicle, and partly awned plants with short awns often confined to the spikelets near the tip of the panicles. The plants in this last group may be referred to as tip-awned. It appears that fully awned varieties often differ from awnless varieties by two independent genetic factors. If this is true the fully awned group from a cross between a fully awned and an awnless variety should differ from the partly awned and tip-awned groups by a single genetic factor, and the partly awned group should differ from the tip-awned group by two genetic factors. Data in support of this view are reported herein.

AWNLESS X FULLY AWNED

In the cross Colusa (awnless) x Aikoku (fully awned) the F_1 plants were partly awned. In the F_2 segregation 607 plants were classed as fully awned, partly awned and tip-awned to 71 awnless plants. The deviation from a 15:1 ratio in this case is 28·63 ± 4·25 plants. This deviation is very large.

Twenty-five random F_2 progenies were grown in F.. Five progenies produced 225 fully, partly, and tip-awned plants to 13 awnless plants. These numbers agree in those expected in a 15:1 ratio, the deviation being 1·88' ± 2·52 plants. Six progenies, consisting of 309 plants, produced fully awned, partly awned, and tip-awned plants in what appeared to be a ratio of 3 fully awned to 1 partly awned, and 3 partly awned plants to 1 tip-awned. However, the awn types in this cross could not be separated with certainty. Ten progenies produced no fully awned plants, but 347 partly awned and tip-awned plants to 120 awnless plants, deviating from a 3:1 ratio by 3·25 ± 6·31 plants. One progeny, consisting of 46 plants, appeared to be fully awned, and three progenies, consisting of 119 plants appeared to produce only partly awned or tip-awned plants. The number of random F_3 progenies was too small to yield all the possible segregations and true breeding groups that were expected. However, the results, suggest that the fully awned variety Aikoku probably differs from the awnless variety Colusa by two main genetic factors for awns.

PARTLY AWNED X FULLY AWNED

In the cross Caloro (partly awned) × Butte (fully awned) the F_1 plants were fully awned. The segregation for awns was not studied in F_2, but a study was made of the segregation of 11 random F_2 progenies grown in F_3. Each of the 11 F_2 progenies and the total of the 11 progenies produced fully awned and partly awned plants in a ratio of 3:1. In the 11 F_2 progenies there were 393 fully awned to 99 partly awned plants, the deviation from a 3:1 ratio being 24·00 ± 6·48 plants. This deviation which is more than three times the probable error, was probably due to errors in classifying the plants resulting from the natural variability of awn development. In the individual progenies there were 3 small plus deviations, 7 minus deviations, and one progeny with no deviation from the 3:1 ratio.

PARTLY AWNED X AWNLESS

Colusa, Chinese Originario, Maratelli, and Yosemite, awnless varieties, were used as female parents in crosses with Wataribune and Caloro, partly awned varieties. Yosemite, Chinese Originario and Colusa were crossed with Wataribune, Yosemite and Chinese Originario, and Maratelli was crossed with Caloro. In each of the six crosses the F_1 plants were partly awned.

Table 2.—F_2 segregation of crosses between awnless and partly awned rice varieties grown at the Biggs Rice Field Station, Biggs, Calif., 1929.

Cross		Nnumber of F_2 plants			Deviation from 3:1 ratio and probable error
Female awnless	Male partly awned	Partly awned	Awnless	Total	
Yosemite	Wataribune	450	199	649	36·75 ± 7·44
Chinese Originario	do	421	121	542	14·50 ± 6·80
Colusa	do	251	94	345	7·75 ± 5·42
Chinese Originario	Caloro	473	161	634	2·50 ± 7·35
Yosemite	do	423	178	601	27·75 ± 7·16
Maratelli	do	484	184	668	17·00 ± 7·55

The F_2 segregation of the six crosses is shown in table 2. In all crosses the number of partly awned and awnless plants agrees well with a 3:1 ratio, except for the crosses Yosemite x Wataribune and Yosemite x Caloro. The deviations in these crosses are large and suggest the possibility of a modifying factor in the Yosemite variety.

25 random F_2 progenies from the crosses Yosemite x Wataribune, Chinese Originario x Wataribune, Colusa x Wataribune and Chinese Originario x Caloro were grown in F_3. The breeding behaviour of these progenies is shown in table 3.

Table 3.—Breeding behaviour in F_3 of F_2 progenies from crosses between awnless and party awned rice varieties grown at the Biggs Rice Field Station, Biggs, Calif., 1930.

Cross		Number of F_2 progenies grown in F_3	Number of F_3 plants		Deviation from 3:1 ratio and probable error
Female, awnless	Male, partly awned		Partly awned	Awnless	
Yosemite	Wataribune	3	142	—	36·5 ± 8·04
		16	605	153	
		4	—	197	
Chinese Originario	do	6	258	—	21·50 ±7·33
		13	494	136	
		4	—	170	
Colusa	do	7	349	—	14·50 ±7·24
		11	446	168	
		7	—	360	
Chinese Originario	Caloro	11	550	—	16·50 ± 6·85
		11	429	121	
		2	—	100	

In each cross three or more F_2 progenies bred true for partly awned plants and two or more bred true for awnless plants. Of the F_2 progenies that segregated in F_3 all produced partly awned and awnless plants in a ratio of 3:1, except one or two progenies in each cross. The failure of some segregating F_2 progenies to give the expected 3:1 ratio may have been due to errors in classification or possibly to natural crossing in F_1 as the F_1 plants were not bagged. The fact that nearly all the F_2 progenies gave the expected 3:1 ratio in F_3 indicates that the partly awned and awnless varieties used, with the possible exception of Yosemite, probably differ by a single genetic factor.

The data on the inheritance of awns in crosses between an awnless and fully awned variety, a partly awned and a fully awned variety, and awnless and partly awned varieties indicate that the fully awned varieties differ from Colusa, awnless, by two independent genetic factors. Butte, fully awned, appears to differ from Caloro partly awned by a single genetic factor and Caloro and Wataribune, partly awned, appear to differ from the awnless varieties by a single genetic factor.

COLOR OF AWNS, GLUMES, AND APICULI AWNS

AWNS

Aikoku has red awns, glumes, and apiculi, whereas Colusa is awnless and has green apiculi and glumes which are straw-coloured at maturity. In the cross Colusa × Aikoku the F_1 plants had red awns, glumes and apiculi. In the F_2 population 454 plants had red awns and 153 plants had green awns. These numbers agree well with 3:1 ratio, the deviation being only 1·25 ± 7·20 plants.

Of 25 random F_2 progenies grown in F_3, 4 consisting of 185 plants, bred true for red awns; 13 produced 392 plants with red awns to 126 plants with green awns; 3 progenies, consisting of 133 plants, bred true for green awns; and of 5 remaining F_2 progenies, 3 consisting of 141 plants, segregated for red awned and awnless plants with red glumes and apiculi, and 2, consisting of 97 plants, segregated for green-awned and awnless plants with green glumes and apiculi. Each of the 13 F_2 progenies that segregated for red and green awns did so in a ratio of 3:1. In the 13 prigenies as a group the deviation from a 3:1 ratio was 3·50 ± 6·65 plants, which is a satisfactory fit.

Caloro is partly awned and has green awns and glumes. In the cross Caloro × Aikoku the F_1 plants had red awns and glumes. In the F_2 population there were 402 plants with red awns to 261 plants with green awns. These numbers are in fair agreement with a 9:7 ratio. The deviation was 29·0625 ± 8·62 plants. Of the F_2 population, 663 plants were classed as awned and 15 as awnless. One random F_2 progeny, which was classed as awnless in F_2, was partly awned in F_3. Therefore, it is probable that other plants classed as awnless in F_2 carried factors for awns but that owing to environmental conditions no awns were visible.

Of the random F_2 progenies grown in F_3, 4 consisting of 202 plants, bred true for red awns, 5 produced 143 plants with red awns to 105 plants with green awns, 9 produced 269 plants with red awns to 90 plants with green awns; and 7, consisting of 301 plants, bred true for green awns. The deviation from a 9:7 ratio for 5 of the F_2 progenies was 3·50 ± 5·27 plants, which is a satisfactory fit. The deviation from a 3:1 ratio for 9 of the F_2 progenies was 0·25 ± 5·53 plants, or almost a perfect fit.

Butte is a fully awned variety with red awns. In the cross Caloro × Butte the F_1 plants had red awns. In the segregation in F_2 271 plants had red awns to 251 plants with green awns. In this case the deviation from a 9:7 ratio is 22·625 ± 7·64 plants. Twenty random F_2 progenies were grown in F_3. Four consisting of 168 plants, bred true for red awns; 4 produced 91 plants with red awns to 63 plants with green awns, or in a ratio of 9:7; and 12 progenies consisting of 560 plants bred true for green awns.

In the cross Colusa × Aikoku the difference in awn color apparently was due to a single genetic factor, whereas in the crosses Caloro × Aikoku and Caloro × Butte the difference appeared to be due to two complementary genetic factors. The results indicated that Colusa has one complementary genetic factor in common with Aikoku and Butte. However, Caloro appears to differ in awn color from Butte and Aikoku by two complementary genetic factors.

GLUMES AND APICULI

Aikoku has red glumes and Colusa has green glumes.

In the cross Colusa x Aikoku the F_1 plants had red glumes. Segregation for color glumes in F_2 gave 504 plants with red glumes to 174 plants with green glumes. The deviation from a 3:1 ratio is $4{\cdot}50 \pm 7{\cdot}60$ plants.

Of the 25 random F_2 progenies grown in F_3, 7 consisting of 326 plants bred true for red glumes; 13 produced 450 plants with red to 163 plants green glumes; and 5 consisting of 230 plants, bred true for green glumes. Each of the 13 F_2 progenies that segregated for glume color produced plants with red and green glumes in a ratio of 3:1. The deviation from this ratio for the 13 F_3 progenies was $7{\cdot}25 \pm 7{\cdot}29$ plants.

In the cross Caloro x Aikoku, green by red glumes, the F_1 plants had red glumes. In F_2 the segregation for color of glumes gave 410 plants with red glumes to 268 with green glumes. The deviation in this cross from a 9:7 ratio was $28{\cdot}63 \pm 8{\cdot}71$ plants. In the crosses Colusa x Aikoku and Caloro x Aikoku the color of the apiculi was always the same as that of the glumes and appeared to be controlled by the same genetic factor or factors.

The red glumes of Aikoku differ from the green glumes of Colusa by a single genetic factor and from the green glumes of Caloro by two dominant complementary genetic factors. The same is true of the color of the apiculi of these varieties. In all hybrids studied the color of the apiculi of the lemma and palea was the same as that of the awns. However the writer knows of one variety with red apiculi, the awns of which are green at maturity.

COLOR OF LEMMA AND PALEA FURROWS

The cross Yosemite x Weitin, used in the study of glume length also presented an opportunity to study lemma and palea furrow color. In Weitin the lemma and palea furrows are yellowish brown, and in Yosemite they are straw colored at maturity. In F_1 plants of the cross Yosemite x Weitin the furrows were yellowish brown. Of 1,047 F_2 plants 834 had yellowish-brown and 213 had straw-colored lemma and palea furrows. These numbers agree well with a 13:3 ratio, with yellowish brown dominant to straw color, the deviation from the 13:3 ratio being $16{\cdot}69 \pm 8{\cdot}52$ plants.

Segregating F_3 progenies were not classified for color of the lemma and palea furrows. It was observed, however, that the 7 F_3 **progenies** segregating for short and long glumes also segregated for color of lemma and palea furrows. Three of the 4 F_3 progenies that bred true for short glumes had yellowish-brown lemma and palea furrows, and the other family segregated for furrow color. One of the 5 F_3 progenies that bred true for long glumes had yellowish-brown lemma and palea furrows, one progeny segregated for furrow color, and three progenies bred true for long glumes with straw colored lemma and palea furrows.

The factors for yellowish-brown color of the lemma and palea furrows and the factor for short glumes appear to be inherited independently, as shown in table 4.

Table 4.—Phenotypes observed and calculated number of F_2 plants in each group from the cross Yosemite × Weitin, grown at the Biggs Rice Field Station, Biggs, Calif., 1928.

Phenotype	Observed	Calculated	$\frac{(O-C)^2}{C}$
Short glumes, yellowish-brown lemma and palea furrows.	637	638·04	0
Short glumes, straw-colored lemma and palea furrows	148	147·24	0
Long glumes, yellowish-brown lemma and palea furrows	197	212·68	1·16
Long glumes, straw colored lemma and palea furrows	65	49·08	5·16
	1,047	1,047·04	—

EARLINESS

In the cross Colusa (an early variety) × Wataribune (a late variety) the F_1 plants and Wataribune matured on October 4 and Colusa on September 19. In the F_2 population there appeared two quite distinct groups with respect to maturity, namely, early and late. On September 6 the early plants were fully headed and starting to mature whereas the late plants were just coming into full heading. On this date the F_2 plants were classified as early and late on the basis of stage of development. There were 264 late to 81 early plants, the deviation from a 3:1 ratio being 5·25 ± 5·42 plants.

Twenty-five random F_2 progenies were grown in F_3. Six progenies, consisting of 232 plants, bred true for late maturity, 12 progenies that segregated for late and early plants produced 485 late to 186 early maturing plants, and 7 progenies, consisting of 341 plants bred true for early maturity. The deviation from a 3:1 ratio for the 12 segregating progenies was 18·25 ± 7·57 plants.

Other studies and observations on the inheritance of earliness in rice have indicated that multiple factors often are involved. It is of interest, therefore, to note the simple segregation in this case. The factorial situation for this as well as for other characters in rice varies with the varieties used.

SUMMARY

The rice crosses used in these studies were grown for three generations except those used in a study of shattering.

In the varieties studied short glumes were dominant to long glumes. The characters normal ligule, normal culm strength, and non-shattering were found to be simple dominants to absence of ligules, brittleness of culm, and shattering of grain, respectively.

The dwarf variety studied was recessive to the normal.

In the crosses awnless x fully awned, partly awned x fully awned, and partly awned x awnless varieties, the data indicate that the fully awned varieties used differ from awnless varieties by two genetic factors, fully awned varieties differ from partly awned by a single genetic factor, and partly awned varieties differ from awnless varieties by a single dominant genetic factor.

In these studies red color in the awns, glumes, and apiculi was dominant to green (straw color). Ratios of 3:1 and 9:7 were obtained, which show that the color was due to a single genetic factor and to two complementary genetic factors.

In Weitin brownish-yellow lemma and palea furrows appeared to be inherited independently of long glumes. The brownish-yellow color of lemma and palea furrows was dominant to straw color and appeared to be due to two genetic factors resulting in a 13:3 ratio.

Plants from the cross Colusa x Wataribune were obtained in the ratio of 3 late to 1 early.