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Studies on the Inheritance of Sterility in Rice.

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With 4 Plates

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CONTENTS

INTRODUCTION.

From the standpoint of biology of the present day, we are not so much interested in heredity to treat segregation of characters and assortment of genes quantitatively and turn them into mathematical from, as we are in learning the means by which the hereditary complexes are sorted out, as well as the process of the consequent manifestation of characters. The study of sterility inheritance is especially adapted to the last purpose, as therein the chief process of the manifestation of the character can be usually treated cytologically in a short period.

In 1920, the author collected in the vicinity of Akita twenty different types of sterility in the multiplication plot of a certain strain of a rice variety; and after their pedigree cultures for two years in the experimental plot of the Agricultural Experiment Station of the Prefecture of Akita, the two types, sterile and partial sterile which seemed to be of particular genetic interest were left for a farther careful study. Since the discovery of a family in 1923, which contained the semi-sterile type in the pedigree culture of the partial sterile, genetical studies have been carried out on these three types of sterility.

The field experiment was performed entirely in the station, because the variety can not be grown in Sapporo owing to a low temperature, but the cytological investigation was made in the laboratory of Division of Plant Breeding of the College of Agriculture of the Hokkaido Imperial University.

To be brief, the present paper is the result of the investigations carried out for seven years in order to discover the mechanism of the inheritance of sterillity in rice as well as the process of its occurrence.

An explanation of a few terminologies used in this paper follows. " Sterile " designates a high sterile plant with about 80 percent sterile spikelets, being sometimes described by the abbreviation " S ". The sterile was found out later in my investigations to be male sterile, the pollen grains being considerably abortive, whereas the eggs are normal and able to be fertilized by the foreign pollen. " Semi-sterile " represents a kind of partial sreriles, being sometimes denoted as " SS "; and this notation is used because just the half of its megaspores are abortive. " Partial sterile" represents a plant with about 40 percent sterile spikelets, being sometimes denoted as "PS", "Fertile" a normal plant, being sometimes denoted as " F ".

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I. On the Sterile Plant.

1. Observation on the Mode of Inheritance.

In 1920, a plant witn about 80 percent sterile spikelets was found in a multiplication plot near Akita, plants of which belonged to a strain of the rice variety, *Toyokuni*. The strain was one of these which had once become pure lines by the pedigree culture. But because the strain had been bred in the multiplication plot for a few years without excluding strictly mutants and natural hybrids, it appeared somewhat impure. Like other plants of the strain, this sterile plant was awnless and its glume-tips were green when young, changing. gradually to reddish brown toward its mature period. In this sterile plant, the fertile spikelets were scattered over its panicles, and were not confined to a definite part.

In 1921, the offspring of the sterile plant was bred in the experimental plot of the Agricultural Experiment Station of the Prefecture of Akita, and eight of 92 plants were sterile, and the remainder was fertile. Remarkable to see, all of the fertile plants as well as the sterile plants segregated into fertiles and steriles in 1922 as shown in Table 1.

The percentage of sterile plants produced by fertiles was pretty uniform, and 81 families, i.e. from S-9F to S-92F consisted of 9564 fertile plants and 3160 sterile plants, where we expect 9543 and 3181 on the 3 : 1 ratio. However, the percentage of sterile plants in the offspring of steriles was extremely variable, ranging from 7.7 to 32.7, and that of all the sterile plants in eight families, i.e. from S-1S to S-8S was 21.37. No definite Mendelian ratio was to be calculated from the segregation of plants in the offspring of steriles owing to the insufficiency of the family numbers and much variability of the numbers of fertiles and steriles in each family.

TABLE I.

Showing the percentage of sterile plants in the offspring of fertile and sterile plants, in 1922.

Pedigree no.	No. of fertile plants	No. of sterile plants	Total no. of plants	Percent of sterile plants
S-1S	45	19	64	29.7
2S	87	27	114	23.7
3S	37	18	55	32.7
4S	101	9	110	8.2
5S	72	6	78	7.7
6S	42	11	53	20.8
7S	99	45	144	31.3
8S	58	12	70	17.1
Total	541	147	688	21.37
S-9F	134	33	167	19.8
10F	118	39	157	24.8
11F	119	43	162	26.5
12F	120	44	164	26,8
13F	141	25	166	15.1
14F	89	39	128	30.5
15F	117	43	160	26.9
16F	73	15	88	17.0
17F	118	40	158	25.3
18F	120	42	162	25.9
19F	120	42	162	25.9
20F	81	23	104	22.1
21F	42	10	52	19.2
22F	121	43	164	26.2
23F	123	39	162	24.1
24F	120	30	150	20.0
25F	138	28	166	16.9
26F	125	44	169	26.0
27F	135	38	173	22.0
28F	126	39	165	23.6
29F	122	41	163	25.2
30F	122	45	167	26.9
31F	118 SS1	30	149	20.1
32F	108	55	163	33.7
33F	58	15	73	20.5
34F	126	37	163	22.7
35F	129	35	164	21.3
36F	134	32	166	19.3
37F	121	45	166	27.3
38F	124	37	161	23.0

TABLE 1. (Continued).

Pedigree no.	No. of fertile plants	No. of sterile plants	Total no. of plants	Percent of sterile plants
S-39F	119	47	166	28.3
40F	121	43	164	26.2
41F	119	36	155	23.2
42F	111	49	160	30.6
43F	117	48	165	29.1
44F	125	40	165	24.2
45F	121	41	162	25.3
46F	102	24	126	19.0
47F	121	42	163	25.8
48F	124 SS1	32	157	20.4
49F	120 SS1	43	164	26.2
50F	122	41	163	25.2
51F	84	39	123	31.7
52F	127	40	167	24.0
53F	119	48	167	28.7
54F	123	42	165	25.5
55F	128	38	166	22.9
58F	125	44	169	26.0
59F	109	30	139	21.6
60F	116	39	155	25.2
61F	116	39	155	25.2
62F	124	41	165	24.8
63F	118	45	163	27.6
64F	127	36	163	22.1
65F	121 SS1	50	172	29.1
66F	117	53	170	31.2
67F	129	44	173	25.4
68F	124	43	167	25.7
69F	105	56	161	34.8
70F	128	45	173	26.0
71F	131	39	170	22.9
72F	121	48	169	28.4
73F	115	47	162	29.0
74F	131	38	169	22.5
75F	126	43	169	25.4
76F	132	42	174	24.1
77F	143	29	172	16.9
78F	128 SS1	44	173	25.4
79F	123	47	170	27.6

TABLE I. (Continued).

Pedigree no.	No. of fertile plants	No. of sterile plants	Total no. of plants	Percent of sterile plants
S-80F	125	46	171	26.9
81F	131	41	172	23.8
82F	131	44	175	25.1
83F	45	10	55	18.2
84F	126	42	168	25.0
85F	129	42	171	24.6
86F	130	41	171	24.0
87F	120	45	165	27.3
89F	71	26	97	26.8
90F	128	43	171	25.1
91F	136	38	174	21.8
92F	133	36	169	27.1
Total	9564	3160	12724	24.83
Expect. (3 : 1)	9543	3181	12724	25.00
Dev./P.E.				0.637

From the above result, we can see that the sterile plant number in the offspring of the sterile plant is very variable, and that in the offspring of the fertile plant thrown by sterile is also somewhat variable. Thus the percentages of sterile plants in the offspring of fertiles and steriles were classified into three following classes:—The lower class is that which is under 20 percent; the middle class is that which is from 20 percent to 29 percent; and the higher class, over 30 percent.

The offspring of about 10 plants from each of some families which represented the three classes, in all 238 plants, were bred in 1923. And the results were as will be seen in Table 2, Table 3, and Table 4. The sterile plant percentage in segregating families, showing generally about 25 percent, was not correlated to that in the previous year's families. And as shown in Table 3 and Table 4, 174 families consisted of 26436 fertile plants and 8724 sterile plants, where 26370 and 8790 are expected on a 3 : 1 ratio. Thus the observed number agreed closely with the expectation.

We can therefore understand from these results that although the segregation of plants in the offspring of sterile is irregular, fertile thrown by sterile segregates always in the normal monohybrid ratio, the sterile character being recessive to the fertile.

TABLE 2.

Showing the percentage of sterile plants in the offspring of fertile plants, in 1923.

Pedigree no.	No. of fertile plants	No. of sterile plants	Total no. of plants	Percent of sterile plants
S-3S-1F	169 SS1	55	225	24.4
2F	161	62	223	27.8
3F	132	59	191	30.9
4F	145	58	203	28.6
5F	175	50	225	22.2
6F	166	52	218	23.9
4S-1F	165	55	220	25.9
2F	169	44	213	20.7
3F	131	44	175	25.1
4F	124	41	165	24.8
5F	187	0	187	0
6F	143	44	187	23.5
7F	114	33	147	22.4
8F	39	15	54	27.8
9F	131	41	172	23.8
10F	164	62	226	27.4
5S-1F	165	63	228	27.6
2F	176 SS1	55	232	23.7
3F	174 SS1	53	228	23.2
4F	173	58	231	25.1
5F	45	25	70	35.7
6F	109 SS1	31	141	22.0
7F	80	23	103	22.3
7S-1F	569	55	224	24.6
2F	170	50	220	22.7
3F	174	57	231	24.7
4F	158	59	217	27.2
5F	159	34	193	17.6
6F	181	48	229	21.0
7F	165	49	214	22.9
8F	149	61	210	29.0
9F	152	62	214	29.0
10F	167	67	234	28.6
8S-1F	41	14	55	25.9
2F	177	46	223	20.6
3F	181	46	229	20.3

TABLE 2. (Continued).

Pedigree no.	No. of fertile plants	No. of sterile plants	Total no. of plants	Percent of plants
S-8S-4F	131 SS1	34	166	20.1
5F	177	48	225	21.3
6F	174	51	225	22.7
7F	86 SS1	37	124	29.8
8F	140 SS1	50	191	26.2
9F	170 SS1	57	228	25.0
13F-1F	218	0	218	0
2F	199	0	199	0
3F	156 SS1	44	201	21.7
4F	160	50	210	23.8
5F	181	46	227	20.3
6F	157 SS1	39	197	19.8
7F	206	0	206	0
8F	180 SS1	43	224	19.2
9F	154	41	195	21.0
10F	164	43	207	20.8
17F-1F	168	62	230	27.0
2F	155	54	209	25.8
3F	171	53	224	23.7
4F	172	60	132	25.9
5F	223 SS1	0	224	0
6F	154 SS1	0	155	0
7F	158	49	207	23.7
8F	212	2	214	0.9
9F	160	59	219	26.9
10F	216 SS1	0	217	0
18F-1F	167	55	222	24.8
2F	167	59	226	26.1
3F	87	28	115	24.3
4F	130	38	168	22.6
5F	171 SS1	61	233	26.2
6F	169	55	224	24.6
7F	163	54	217	24.9
8F	160	63	223	28.3

TABLE 2. (Continued).

Pedigree no.	No. of fertile plants	No. of sterile plants	Total no. of plants	Percent of sterile plants
S-18F-9F	207	0	207	0
10F	121	47	168	28.0
19F-1F	166	54	220	24.5
2F	107 SS1	0	108	0
3F	229	0	229	0
4F	171	55	226	24.3
5F	224	0	224	0
6F	160	58	218	26.6
7F	179	0	179	0
8F	218	1	219	0.5
9F	153	63	216	29.2
10F	162	51	213	23.9
29F-1F	166	56	222	25.2
2F	157	50	207	24.2
3F	166	55	221	24.9
4F	200	0	200	0
5F	168	50	218	22.9
6F	166	53	219	24.2
7F	155	48	203	23.6
8F	225	0	225	0
9F	183	43	226	19.0
10F	132	32	164	19.5
30F-1F	153	69	222	31.1
2F	222 SS1	0	223	0
3F	167	56	223	25.1
4F	153	70	223	31.4
5F	158	65	223	29.1
6F	224	0	224	0
7F	164	64	228	28.1
8F	169	54	223	24.2
9F	157	55	212	25.9
10F	224	0	224	0
32F-1F	148	60	208	28.8
2F	228	2	230	0.9
3F	219	0	219	0
4F	220	0	220	0
5F	169	58	227	25.6
6F	160	50	210	23.
7F	152	65	217	30.0
8F	166	49	215	22.8

TABLE 2. (Continued).

Pedigree no.	No. of fertile plants	No. of sterile plants	Total no. of plants	Percent of sterile plants
S-32F-9F	178	47	225	20.9
10F	168	53	221	34.0
36F-1F	172	48	220	21.8
2F	174	52	226	23.0
3F	226	0	226	0
4F	164	62	226	27.4
5F	167	53	240	24.1
6F	171	43	214	20.1
7F	169	60	229	26.2
8F	142	45	187	24.1
9F	140	49	189	25.9
10F	168	49	217	22.6
42F-1F	193	0	193	0
2F	160	67	227	29.5
3F	227	0	227	0
4F	199	18	217	8.3
5F	157	44	201	21.9
6F	171	57	228	25.0
7F	225	0	225	0
8F	226	1	227	0.4
9F	168	59	227	26.0
10F	179	0	179	0
45F-1F	226	0	226	0
2F	169	49	218	22.5
3F	158	67	225	29.8
4F	168	51	219	23.3
5F	222	0	222	0
6F	149	56	205	27.3
7F	167	55	222	24.8
8F	219	6	225	2.7
9F	72	18	90	20.0
46F-1F	171	53	224	23.7
2F	218	0	218	0
3F	165	65	230	28.3
4F	175	59	234	25.2
5F	183	44	227	19.4
6F	230	0	230	0
7F	222	0	222	0
8F	169	62	231	26.8
9F	162	64	226	28.3
10F	169	55	224	24.6
50F-1F	153	65	218	29.8

TABLE 2. (Continued).

Pedigree no.	No. of fertile plants	No. of sterile plants	Total no. of plants	Percent of sterile plants
S-50F-2F	194	0	194	0
3F	213	0	213	0
4F	160	46	206	22.3
5F	131	41	172	23.8
6F	195	0	195	0
7F	192	0	192	0
8F	147	47	194	24.2
9F	192	0	192	0
10F	193	0	193	0
51F-1F	157	44	201	21.9
2F	134	60	194	30.9
3F	140	67	207	32.4
4F	158	45	203	22.2
54F-1F	167	41	208	19.7
2F	202	0	202	0
3F	143	59	202	29.2
4F	209	1	210	0
5F	200 SS2	0	202	0
6F	149	58	207	28.0
7F	155	54	209	25.8
8F	154	51	205	24.9
9F	206	0	206	0
10F	200	0	200	0
58F-1F	123	56	179	31.3
2F	131	39	170	22.9
3F	130	0	130	0
4F	96	41	137	29.9
5F	152	0	152	0
6F	118	40	158	25.3
7F	206	0	206	0
8F	156	54	210	25.7
9F	112	34	146	23.3
10F	158	47	205	22.9
60F-1F	161	51	212	24.1
2F	152	45	197	22.8
3F	127 SS1	75	203	21.5
4F	151	0	151	0
5F	169	0	169	0
6F	153	57	210	27.1
7F	204	0	204	0
8F	184	0	184	0

TABLE 2. (Continued).

Pedigree no.	No. of fertile plants	No. of sterile plants	Total no of plants	Percent of sterile plants
S-60F-9F	161	48	209	23.0
10F	151	45	196	23.0
61F-1F	140	69	209	33.0
2F	199	0	199	0
3F	165	55	210	26.2
4F	155	48	213	22.5
5F	142	58	200	29.0
6F	151	50	201	24.9
7F	142	61	203	30.0
8F	206	1	207	0
9F	183	14	197	7.1
10F	146	61	207	29.5
66F-1F	148	0	148	0
2F	164	0	164	0
3F	121	58	179	32.4
4F	185	0	185	0
5F	143	47	190	24.7
6F	149	44	193	22.8
7F	157	43	200	21.5
8F	147	55	202	27.2
9F	155	0	155	0
10F	99	37	136	27.2
69F-1F	146	50	196	25.5
2F	158	51	209	22.4
3F	162	46	208	22.1
4F	151	44	195	22.6
5F	158	49	207	23.7
6F	151	64	215	29.8
7F	157	45	202	22.3
8F	126	61	187	32.6
9F	137	1	138	0.7
10F	205	0	205	0
77F-1F	96 SS1	0	97	0
2F	96	0	96	0
3F	143	41	184	22.3
83F-1F	150	48	198	24.2
2F	143 SS1	44	188	23.4
3F	152	47	199	23.6
4F	127	39	166	23.5
5F	151	48	199	24.1

TABLE 2. (Continued).

Pedigree no.	No. of fertile plants	No. of sterile plants	Total no. of plants	Percent of sterile plants
S-83F-6F	190	0	190	0
7F	200	0	200	0
8F	73	15	88	17.0
9F	130	72	202	35·6
10F	144	52	196	26.5

TABLE 3.

Showing the percentage of sterile plants in the offspring of fertile plants, picking up the segregating families in the preceeding table.

Predigree no.	No. of fertile plants	No. of sterile plants	Total no. of plants	Percent of sterile plants
S-3S-1F	169 SS1	55	225	24.4
2F	161	62	223	27.8
3F	132	59	181	30.9
4F	145	58	203	28.6
5F	175	50	225	22.2
6F	166	52	218	23.9
4S-1F	165	55	220	25.0
2F	169	44	213	20.7
3F	131	44	175	25.1
4F	124	41	165	24.8
6F	143	44	187	23.5
7F	114	33	147	22.4
8F	39	15	54	27.8
9F	131	41	172	23.8
10F	164	62	226	27.4
5S-1F	165	63	228	27.6
2F	176 SS1	55	232	23.7
3F	174 SS1	53	228	23.2
4F	173	58	231	25.1
5F	45	25	70	35.7
6F	109 SS1	31	141	22.0

TABLE 3. (Continued).

Pedigree no.	No. of fertile plants	No. of sterile plants	Total no. of plants	Percent of sterile plants
S-5S-7F	80	23	103	22.3
7S-1F	169	55	224	24.6
2F	170	50	220	22.7
3F	174	57	231	24.7
4F	158	59	217	27.2
5F	159	34	193	17.6
6F	181	48	229	21.0
7F	165	49	214	22.9
8F	149	61	210	29.0
9F	152	62	214	29.0
10F	167	67	234	28.6
8S-1F	41	14	55	25.5
2F	177	46	223	20.6
3F	181	46	227	20.3
4F	134 SS1	34	169	20.1
5F	177	48	225	21.3
6F	174	51	225	22.7
7F	86 SS1	37	124	29.8
8F	140 SS1	50	191	26.2
9F	170 SS1	57	228	25.0
13F-3F	156 SS3	44	203	21.7
4F	160	50	210	23.8
5F	181	46	227	20.3
6F	157 SS1	39	197	19.8
8F	180 SS1	43	224	19.2
9F	154	41	195	21.0
10F	164	43	207	20.8
17F-1F	168	62	230	27.0
2F	155	54	209	25.8
3F	171	53	224	23.7
4F	172	60	232	25.9
7F	158	49	207	23.7
9F	160	59	219	26.9
18F-1F	167	55	222	24.8
2F	167	59	226	26.1
3F	87	28	115	24.3
4F	130	38	168	22.6

TABLE 3. (Continued).

Pedigree no.	No. of fertile plants	No. of sterile plants	Total no. of plants	Percent of sterile plants
S-18F-5F	171 SS1	61	233	26.2
6F	169	55	224	24.6
7F	163	54	217	24.9
8F	160	63	223	28.3
10F	121	47	168	28.0
19F-1F	166	54	220	24.5
4F	171	55	226	24.3
6F	160	58	218	26.6
9F	153	63	216	29.2
10F	162	51	213	23.9
29F-1F	166	56	222	25.2
2F	157	50	207	24.2
3F	166	55	221	24.9
5F	168	50	218	22.9
6F	166	53	219	24.2
7F	155	48	203	23.6
9F	183	43	226	19.0
10F	132	32	164	19.5
30F-1F	153	69	222	31.1
3F	169	56	225	25.1
4F	153	70	223	31.4
5F	158	65	223	29.1
7F	164	64	228	28.1
8F	169	54	223	24.2
9F	157	55	212	25.9
32F-1F	148	60	208	28.8
5F	169	58	227	25.6
6F	160	50	210	23.8
7F	152	65	217	30.0
8F	166	49	215	22.8
9F	178	47	225	20.9
10F	172	48	220	21.8
36F-1F	168	53	221	24.0
2F	174	52	226	23.0
4F	164	62	226	27.4
5F	167	53	220	24.1
6F	171	43	214	20.1
7F	169	60	229	26.2
8F	142	45	187	24.1
9F	140	49	189	25.9
10F	168	49	217	22.6

TABLE 3. (Continued).

Pedigree no.	No. of fertile plants	No. of sterile plants	Total no. of plants	Percent of sterile plants
S-42F-2F	160	67	227	29.5
4F	199	18	217	8.3
5F	157	44	201	21.9
6F	171	57	228	25.0
9F	168	59	227	26.0
45F-2F	169	49	218	22.5
3F	158	67	225	29.8
4F	168	51	219	23.3
6F	149	56	205	27.3
7F	167	55	222	24.8
9F	72	18	90	20.0
46F-1F	171	53	224	23.7
3F	165	65	230	28.3
4F	175	59	234	25.2
5F	183	44	227	19.4
8F	169	62	231	26.8
9F	162	64	226	28.3
10F	169	55	224	24.6
50F-1F	153	65	218	29.8
4F	160	46	206	22.3
5F	131	41	172	23.8
8F	147	47	194	24.2
51F-1F	157	44	201	21.9
2F	134	60	194	30.9
3F	140	67	207	32.4
4F	158	45	203	22.2
54F-1F	167	41	208	19.7
3F	143	59	202	29.2
6F	149	58	207	28.0
7F	155	54	209	25.8
8F	154	51	205	24.9
58F-1F	123	56	179	31.3
2F	131	39	170	22.9
4F	96	41	137	29.9
6F	118	40	158	25.3
8F	156	54	210	25.7
9F	112	34	146	23.3
10F	158	47	205	22.9
60F-1F	161	51	212	24.1
2F	152	45	197	22.8
3F	127	35	163	21.5

TABLE 3. (Continued).

Pedigree no.	No. of fertile plants	No. of sterile plants	Total no. of plants	Percent of[1] sterile plants
S-60F-6F	153	57	210	27.1
9F	161	48	209	23.0
10F	151	45	196	23.0
61F-1F	140	69	209	33.0
3F	155	55	210	26.2
4F	165	48	213	22.5
5F	142	58	200	29.0
6F	151	50	201	24.9
7F	142	61	203	30.0
9F	183	14	197	7.1
10F	146	61	207	29.5
66F-3F	121	58	179	32.4
5F	143	47	190	24.7
6F	149	44	193	22.8
7F	157	43	200	21.5
8F	147	55	202	27.2
10F	99	37	136	27.2
69F-1F	146	50	196	25.5
2F	158	51	209	24.4
3F	162	46	208	22.1
4F	151	44	195	22.6
5F	158	49	207	23.7
6F	151	64	215	29.8
7F	157	45	202	22.3
8F	126	61	187	32.6
77F-3F	143	41	184	22.3
83F-1F	150	48	198	24.2
2F	143 SS1	44	188	23.4
3F	152	47	199	23.6
4F	127	39	166	23.5
5F	151	48	199	24.1
8F	73	15	88	17.0
9F	130	72	202	35.6
10F	144	52	196	26.5

TABLE 4.

Summing up the families in the preceeding table according to the family in 1922.

Predigree no.	No. of fertile plants	No. of sterile plants	Total no. of plants.	Percent of sterile plants
S-3S	949	336	1285	26.15
4S	1180	379	1559	24.31
5S	925	308	1233	24.98
7S	1644	542	2186	24.79
8S	1284	383	1667	22.96
13F	1157	306	1463	20.92
17F	984	337	1321	25.51
18F	1336	460	1796	25.61
19F	812	281	1093	25.71
29F	1293	387	1680	23.04
30F	1121	433	1554	27.86
32F	1145	377	1522	24.77
36F	1463	466	1929	24.16
42F	855	245	1100	22.27
45F	883	296	1179	25.11
46F	1194	402	1596	25.19
50F	591	199	790	25.19
51F	589	216	805	26.83
54F	768	263	1031	25.51
58F	894	311	1205	25.81
60F	906	281	1187	23.67
61F	1224	416	1640	25.37
66F	816	284	1100	25.82
69F	1209	410	1619	25.32
77F	143	41	184	22.28
83F	1071	365	1436	25.42
Total	26436	8724	35160	24.81
Expect. (3 : 1)	26370	8790	25160	25.00
Dev./P.E.				1.205

As Table 2 shows, all fertiles produced by sterile plants except one which might have been mixed accidentally, segregated into fertiles and steriles in a 3 : 1 ratio. On the other hand, some of fertiles produced by fertile plants which were thrown sterile, bred true and the others segregated as in a former case. Namely, constant families appeared for the first time in the fourth generation of the sterile plant. The observed number of segregating families was 135 and that of constant ones 61, where we should expect 130.7 and 65.3 respectively. Though five families underlined in Table 2 contained a few sterile plants, they would be regarded as constant fertile families, for various degrees of sterility occur sometimes by mutation or by the causes not genetical.

In 1924, the offspring of about 5 fertile plants from each of 14 segregating families were reared, and the results were the same as in the previous year. Table 5 shows only the segregating families.

TABLE 5.

Showing the percentage of sterile plants in the offspring of fertile plants, in 1924.

Pedigree no.	No. of fertile plants	No. of sterile plants	Total no. of plants	Percent of sterile plants
S-3S-1F-3F	157	59	216	27.3
4F	155	49	204	24.0
5S-1F-3F	133	71	204	34.8
4F	145	44	186	23.3
5F	153	62	215	28.8
8S-1F-2F	143	50	193	25.9
3F	155	56	211	26.5
6F	168	49	217	22.6
18-1F-1F	123	50	173	28.9
2F	168	50	218	22.9
3F	160	60	220	27.3
4F	175	41	216	19.0
5F	155	38	193	19.7
19F-1F-2F	119	46	165	27.9
3F	103	52	155	33.5
5F	166	50	216	23.1
30F-1F-1F	80	27	107	25.2
2F	150	52	202	25.7
3F	166	60	226	26.5

TABLE 5. (Continued).

Pedigree no.	No. of fertile plants	No. of sterile plants	Total no. of plants	Percent of sterile plants
S-39F-1F-4F	91	30	121	24.8
5F	87	29	116	25.0
6F	114	42	156	26.9
36F-1F-1F	130	38	168	22.6
4F	128	54	182	29.7
5F	117	30	147	20.4
45F-2F-2F	178	52	230	22.6
5F	71	19	90	21.1
51F-1F-3F	126	31	157	19.7
4F	80	35	115	30.4
58F-1F-1F	148	55	203	27.1
2F	157	55	212	25.9
3F	141	33	174	19.0
5F	120	40	160	25.0
61F-1F-1F	80	50	130	38.5
2F	165	63	228	27.6
3F	173	52	225	23.1
4F	169	49	218	22.5
66F-3F-1F	166	70	236	29.7
4F	116	41	157	26.1
69F-1F-1F	169	54	223	24.2
3F	128	47	175	26.9
5F	63	18	81	22.2
83F-1F-1F	119	33	152	21.7
2F	147	33	180	18.3
3F	121	41	162	25.3
5F	169	51	220	23.2
Total	6247	2111	8358	25.26
Expect. (3 : 1)	6268.5	2089.5	8358	25.00
Dev./P. E.				0.805

In 1924, the number of segregating families was 46 and that of constant families was 25; theoretically, the former is 46.7 and the latter 24.3. The percentage of steriles in all the segregating families was 25.26.

In the same year, also offspring of 10 sterile plants from each of the segregating families as mentioned before, were reared and most families consisted of fertiles and steriles as will be seen in Table 6. Strange to notice, in most cases steriles were less than fertiles although they were produced by sterile plants. Moreover, the percentage of sterile plants ran from 0 to 50, showing a very wide range of variation, and that of sterile plants in total was 20.17 (Table 7). So any definite ratio of segregation could be hardly found.

TABLE 6.

Showing the percentage of sterile plants in the offspring of sterile plants, in 1924.

Pedigree no.	No. of fertile plants	No. of sterile plants	Total no. of plants	Percent of sterile plants
S-3S-1F-1S	21	2	23	8.7
2S	19	6	25	24.0
3S	15	3	18	16.7
4S	23	4	27	14.8
5S	24	2	26	7.7
6S	26	3	29	10.3
7S	20	3	23	13.0
8S	24	7	31	22.6
9S	15	10	25	40.0
10S	20	8	29	27.6
	SS1			
5S-1F-1S	22	4	26	15.4
2S	22	6	28	21.4
3S	17	5	22	22.7
4S	21	5	26	19.2
5S	17	7	24	29.2
6S	31	1	32	3.1
7S	25	8	26	3.8
8S	29	0	29	0
9S	21	5	26	19.2
10S	29	1	30	3.3
8S-1F-1S	14	13	27	48.1
2S	20	6	26	23.1
3S	16	12	28	42.9
4S	11	5	16	31.3
5S	15	9	24	37.5
6S	23	4	27	14.8
7S	16	3	19	15.8
8S	22	4	26	15.4
9S	20	5	25	20.0
18F-1F-1S	25	1	26	3.8
2S	19	6	25	24.0

TABLE 6. (Continued).

Pedigree no.	No. of fertile plants	No. of sterile plants	Total no. of plants	Percent of sterile plants
S-18F-1F-3S	23	6	29	20.7
4S	10	1	11	9.1
5S	20	6	26	23.1
6S	19	9	28	32.1
7S	20	5	25	20.0
8S	18	4	22	18.2
9S	25	5	30	16.7
10S	24	3	27	11.1
19F-1F-1S	23	6	29	20.7
2S	21	4	25	16.0
3S	24	6	30	20.0
4S	19	8	27	29.6
5S	21	8	29	27.6
6S	23	5	28	17.9
7S	30	1	31	3.2
8S	23	5	28	17.9
9S	24	7	31	22.6
10S	26	2	28	7.1
30F-1F-1S	25	5	30	16.7
2S	16	9	25	36.0
3S	20	8	28	28.6
4S	18	6	24	25.0
5S	23	6	29	20.7
6S	23	1	24	4.2
7S	25	5	30	16.7
8S	19	8	27	29.6
9S	22	6	28	24.4
36F-1F-1S	13	13	26	50.0
2S	23	6	29	20.7
3S	24	4	28	14.3
5S	21	5	26	19.2
6S	18	9	27	33.3
7S	17	9	26	34.6
8S	18	6	24	25.0
9S	20	8	28	28.6
10S	9	3	12	25.0
45F-2F-1S	22	5	27	18.5
2S	22	9	31	29.0
3S	20	4	24	16.7
4S	24	7	31	22.6
5S	21	6	27	22.2
6S	22	7	29	24.1

TABLE 6. (Continued).

Pedigree no.	No. of fertile plants	No. of sterile plants	Total no. of plants	Percent of sterile plants
S-45F-2F-7S	24	3	27	11.1
8S	22	7	29	24.1
9S	22	4	26	15.4
10S	24	6	30	20.0
51F-1F-1S	17	10	27	37.0
2S	26	2	28	7.1
3S	24	4	28	14.3
4S	24 SS1	6	31	19.4
6S	20	7	27	25.9
7S	25	2	27	7.4
8S	26	4	30	13.3
9S	22	4	26	15.4
10S	24	6	30	20.0
58F-1F-1S	20	7	27	25.9
2S	22	7	29	24.1
3S	19	7	26	26.9
4S	22	6	28	21.4
5S	19	7	26	26.9
6S	27	4	31	12.9
7S	20	8	28	28.6
9S	22	4	26	15.4
10S	21	6	27	22.2
61F-1F-1S	8	3	11	27.3
2S	24	4	28	14.3
3S	15	4	19	21.1
4S	20	10	30	33.3
5S	16	8	24	33.3
6S	13	4	17	23.5
7S	12	5	17	29.4
8S	18	3	21	14.3
9S	21	5	26	19.2
10S	22	1	23	4.3
66F-3F-1S	17	6	23	26.1
2S	21	7	28	25.0
3S	18	5	23	21.7
4S	21	3	24	12.5
5S	14	3	17	17.6
6S	26	4	30	13.3
7S	23	3	26	11.5
8S	28	2	30	6.7
9S	24	2	26	7.7

TABLE 6. (Continued).

Pedigree no.	No. ot fertile plants	No. of sterile plants	Total no. of plants	Percent of sterile plants
S-66F-3F-10S	23	7	30	23.3
69F-1F-1S	22	6	28	21.4
2S	22	3	25	12.0
3S	15	2	17	11.8
4S	23	7	30	23.3
5S	17	3	20	15.0
6S	26	4	30	13.3
7S	23	5	28	17.9
8S	25	6	31	19.4
9S	22	5	27	18.5
10S	25	4	29	13.8
83F-1F-1S	19	9	28	32.1
2S	18	11	29	37.9
3S	26	2	28	7.1
4S	23	7	30	23.3
5S	16	6	22	27.3
6S	22	9	31	29.0
7S	23	4	27	14.8
8S	21	8	29	27.6
9S	20 SS2	4	26	15.4
10S	26	4	30	13.3

TABLE 7.

Summing up the families in the preceeding table according to the family in 1923.

Pedigree no.	No. of fertile plants	No. of sterile plants	Total no. of plants	Percent of sterile plants
S-3S-1F	208	48	256	18.75
5S-1F	234	35	218	13.01
8S-1F	157	61	218	27.98
18F-1F	203	46	249	18.47
19F-1F	234	52	286	18.18
30F-1F	191	54	245	22.04
36F-1F	163	63	226	27.88
45F-2F	223	58	281	20.64
51F-1F	209	45	254	17.72
58F-1F	192	56	248	22.58
61F-1F	169	47	216	21.76
66F-3F	215	42	257	16.34
69F-1F	220	45	265	16.98
83F-1F	216	64	280	22.86
Total	2834	716	3550	20.17

2. Examination of the Percentage of Sterile Spikelets.

The numbers of sterile and fertile spikelets in some sterile plants of segregating families were counted and then the percentage of sterile spikelets was derived from them.

The percentage of sterile spikelets of 257 sterile plants from 26 segregating families in 1923 ranged from 35.4 to 93.9 (Table 8), and that of all of these spikelets was 80.88 (Table 9). As genetically fertile plants are apt to set more or less sterile spikelets according to the causes not genetical, the percentage of sterile spikelets of fertile plants in segregating families were also examined at the same time to compare with those of sterile plants.

The percentage of all the sterile spikelets of 134 fertile plants in the same 26 segregating families was 11.40 (Tables 10 and 11). In the same year, the percentage of sterile spikelets of 99 fertile plants in 10 constant fertile families were also examined, and that of sterile spikelets in total was 10.29 (Tables 12 and 13). Any conspicuous difference could not be seen between fertile plants in segregating and constant families.

Therefore, it will be seen readily that segregating families consist of steriles and fertiles, and the demarcation between them is very clear.

TABLE 8.

Showing the percentage of sterile spikelets of sterile plants in the segregating families in 1923.

Pedigree no.	No. of fertile spikelets	No. of sterile spikelets	Total no. of spikelets	Percent of sterile spikelets
S-3S-1F-1S	56	158	214	73.8
2S	50	202	252	80.2
3S	33	145	178	81.5
4S	87	297	384	77.9
5S	46	218	264	82.6
6S	94	397	491	80.9
7S	53	234	287	81.5
8S	69	284	353	80.5
9S	39	188	227	82.8
10S	72	276	348	79.3
4S-1F-1S	25	276	301	91.7
2S	43	291	334	87.1

TABLE 8. (Continued).

Pedigree no.	No. of fertile spikelets	No. of sterile spikelets	Total no. of spikelets	Percent of sterile spikelets
S-4S-1F-3S	86	294	380	77.4
4S	96	308	404	76.2
5S	77	219	296	74.0
6S	28	209	237	88.2
7S	92	252	344	73.3
8S	145	307	452	67.9
9S	118	561	679	82.6
10S	63	433	485	87.3
5S-1F-1S	35	241	276	87.3
2S	60	303	363	83.5
3S	74	302	376	80.3
4S	62	359	421	85.3
5S	103	313	416	75.2
6S	96	236	332	69.9
7S	65	230	295	78.0
8S	70	178	248	71.8
9S	75	368	443	83.1
10S	339	514	853	60.3
7S-1F-1S	63	180	243	74.1
2S	91	340	431	78.9
3S	41	293	334	87.7
4S	60	319	379	84.2
5S	41	219	260	84.2
6S	67	286	353	81.0
7S	73	212	275	77.1
8S	46	162	208	77.9
9S	82	425	507	83.8
10S	167	227	394	57.6
8S-1F-1S	131	376	507	74.2
2S	38	177	215	82.3
3S	105	358	463	77.3
4S	54	290	344	84.3
5S	76	189	265	71.3
6S	60	250	310	80.6
7S	52	293	345	84.9
8S	58	253	311	81.4
9S	110	418	528	79.2
13F-3F-1S	42	204	246	82.9
2S	30	421	451	93.3
3S	36	344	380	90.5
4S	84	364	448	81.3
5S	62	157	219	71.7

TABLE 8. (Continued).

Pedigree no.	No. of fertile spikelets	No. of sterile spikelets	Total no. of spikelets	Percent of sterile spikelets
S-13F-3F 6S	48	317	365	86.6
7S	48	253	301	84.1
8S	58	401	459	87.4
9S	56	244	300	81.3
17F-1F-1S	50	291	341	85.3
2S	26	116	142	81.7
3S	85	340	425	80.0
4S	78	314	392	80.1
5S	86	314	400	78.5
6S	75	235	310	75.8
7S	78	365	443	82.4
8S	40	280	320	87.5
9S	38	193	231	83.5
10S	88	275	363	75.8
18F-1F-1S	88	360	448	80.4
2S	83	143	226	63.3
3S	88	252	340	74.1
4S	33	227	260	87.3
5S	68	220	285	76.4
6S	37	218	255	85.5
7S	41	244	285	85.6
8S	102	271	273	72.7
9S	72	226	298	75.8
10S	63	303	366	82.8
19F-1F-1S	89	286	375	76.3
2S	88	168	256	65.6
3S	52	265	317	83.6
4S	91	253	344	73.5
5S	69	274	343	79.9
6S	96	345	441	78.2
7S	74	244	318	76.7
8S	88	287	375	76.5
9S	84	307	391	78.5
10S	61	354	415	85.3
29F-1F-1S	63	334	397	84.1
2S	46	170	216	78.7
3S	63	233	296	78.7
4S	38	256	294	87.1
5S	68	352	420	83.8
6S	91	301	392	76.8
7S	59	251	310	81.0
8S	75	335	410	81.7

TABLE 8. (Continued).

Pedigree no.	No. of fertile spikelets	No. of sterile spikelets	Total no. of spikelets	Percent of sterile spikelets
S-29F-1F-9S	110	351	461	76.1
10S	45	325	370	87.8
30F-1F-1S	41	238	279	85.3
2S	44	218	262	83.2
3S	80	232	312	74.4
4S	90	311	401	77.6
5S	85	328	413	79.4
6S	69	277	346	80.1
7S	73	258	331	77.9
8S	84	332	416	79.8
9S	46	253	299	84.6
32F-1F-1S	43	320	363	88.2
2S	71	310	381	81.4
3S	92	302	394	76.6
4S	80	306	386	79.3
5S	45	337	382	88.2
6S	83	360	443	81.3
7S	115	336	451	74.5
8S	56	198	254	78.0
9S	68	313	381	82.2
10S	71	322	393	81.9
36F-1F-1S	37	345	382	90.3
2S	48	363	411	88.3
3S	66	188	254	74.0
4S	116	385	401	76.8
5S	47	272	319	85.3
6S	52	435	487	89.3
7S	48	289	337	85.8
8S	35	227	262	86.6
9S	74	333	407	81.8
10S	16	215	231	93.1
45F-2F-1S	84	369	453	81.5
2S	61	330	391	84.4
3S	63	192	255	75.3
4S	52	187	239	78.2
5S	51	250	301	83.1
6S	56	93	149	62.4
7S	61	301	362	83.1
8S	58	281	339	82.9
9S	53	264	317	83.3
10S	54	224	277	80.5
46F-1F-1S	44	229	273	83.9

TABLE 8. (Continued).

Pedigree no.	No. of fertile spikelets	No. of sterile spikelets	Total no. of spikelets	Percent of sterile spikelets
S-46F-1F-2S	65	266	331	80.4
3S	112	289	401	72.1
4S	22	156	178	87.6
5S	84	240	324	74.1
6S	76	216	292	74.0
7S	70	290	360	80.6
8S	58	205	263	77.9
9S	97	255	352	72.4
10S	48	214	262	81.7
50F-1F-1S	54	230	284	81.0
2S	130	511	641	79.1
3S	105	381	486	78.4
4S	46	214	260	82.3
5S	90	360	450	80.0
6S	84	559	643	86.9
7S	70	312	382	81.7
8S	50	302	352	85.8
9S	43	298	341	87.4
10S	74	251	325	77.2
42F-2F-1S	55	520	575	90.4
2S	36	100	136	73.5
3S	40	151	191	79.1
4S	27	296	323	91.6
5S	46	232	278	83.5
6S	57	343	400	85.5
7S	42	363	405	89.6
8S	55	308	363	84.8
9S	28	353	381	92.7
10S	77	316	393	80.4
51F-1F-1S	39	602	641	93.9
2S	52	243	295	82.4
3S	102	361	463	78.0
4S	78	315	393	80.2
5S	117	390	507	76.9
6S	41	375	416	90.1
7S	55	304	359	84.9
8S	43	195	238	81.9
9S	75	184	259	71.0
10S	40	211	251	84.1
54F-1F-1S	33	148	181	81.8
2S	45	203	248	81.9
3S	63	205	268	76.5

TABLE 8. (Continued).

Pedigree no.	No. of fertile spikelets	No. of sterile spikelets	Total no. of spikelets	Percent of sterile spikelets
S-54F-1F-4S	85	314	399	78.7
5S	53	229	282	81.2
6S	54	249	303	82.2
7S	61	203	264	76.9
8S	78	353	431	81.9
9S	84	288	372	77.4
10S	39	210	249	84.3
58F-1F-1S	55	282	337	83.7
2S	112	390	502	77.7
3S	65	215	280	76.8
4S	67	223	290	76.9
5S	50	215	265	81.1
6S	93	242	335	72.2
7S	76	309	385	80.3
8S	30	139	169	82.2
9S	44	204	248	82.3
10S	49	219	268	81.7
60F-1F-1S	17	237	254	93.3
2S	81	327	408	80.1
3S	61	253	314	80.6
4S	47	200	247	81.0
5S	93	253	346	73.1
6S	62	228	290	78.6
7S	58	341	399	85.5
8S	48	256	304	84.2
9S	113	407	520	78.3
10S	52	240	292	82.2
61F-1F-1S	14	207	221	93.7
2S	50	218	268	81.3
3S	24	248	272	91.2
4S	33	283	316	89.6
5S	45	272	317	85.8
6S	33	259	292	88.7
7S	23	300	323	92.9
8S	30	245	275	89.1
9S	65	369	434	85.0
10S	82	202	284	71.1
66F-3F-1S	56	202	258	78.3
2S	86	414	500	82.5
3S	37	277	314	88.2
4S	96	351	447	78.5
5S	33	172	205	83.9

TABLE 8. (Continued).

Pedigree no.	No. of sterile spikelets	No. of sterile spikelets	Total no. of spikelets	Percent of sterile spikelets
S-66F-3F-6S	74	290	364	79.7
7S	81	265	346	76.6
8S	59	367	426	86.2
9S	96	481	577	83.4
10S	45	285	330	86.4
69F-1F-1S	83	270	353	76.5
2S	44	164	208	78.8
3S	32	241	273	88.3
4S	44	190	234	81.2
5S	31	276	307	89.9
6S	52	312	364	85.7
7S	154	252	406	62.1
8S	40	183	223	82.1
9S	81	332	413	80.4
10S	206	113	319	35.4
77F-3F-1S	42	226	268	84.3
2S	78	483	561	86.1
3S	173	157	330	47.6
4S	32	241	273	88.3
5S	30	218	248	87.9
6S	83	283	366	77.3
7S	52	362	414	87.4
8S	28	239	267	89.5
9S	79	503	582	86.4
10S	167	347	514	67.5
83F-1F-1S	90	368	458	80.3
2S	41	73	114	64.0
3S	92	282	374	75.4
4S	93	383	476	80.5
5S	35	252	287	87.8
6S	95	328	423	77.5
7S	74	499	573	87.1
8S	39	449	488	92.0
9S	82	311	393	79.1
10S	46	382	428	89.3
Mean	—	—	—	89.90±0.297
Stand. dev.	—	—	—	7.08±0.210

TABLE 9.

Summing up the plants in the preceeding table according to the family.

Pedigree no.	No. of fertile spikelets	No. of sterile spikelets	Total no. of spikelets	Percent of sterile spikelets
S-3S 1F	599	2399	2998	80.02
4S-1F	773	3149	3922	80.29
5S-1F	979	3044	4023	75.66
7S-1F	721	2663	3384	78.69
8S-1F	684	2604	3288	79.20
13F-3F	464	2705	3169	85.36
17F-1F	644	2723	3367	80.90
18F-1F	675	2464	3139	78.50
19F-1F	792	2783	3575	77.85
29F-1F	658	2908	3566	81.55
30F-1F	612	2447	3059	79.99
32F-1F	724	3104	3828	81.09
36F-1F	539	3052	3591	84.99
42F 2F	463	2982	3445	86.56
45F-2F	593	2490	3083	80.77
46F-1F	676	2360	3036	77.73
50F-1F	746	3418	4164	82.08
51F-1F	642	3180	3822	83.20
54F-1F	595	2402	2997	80.15
58F-1F	641	2438	3079	79.18
60F-1F	632	2742	3374	81.27
61F-1F	399	2603	3002	86.71
66F-3F	663	3104	3767	82.40
69F-1F	767	2333	3100	85.26
77F-3F	764	3059	3823	80.02
83F-1F	687	3327	4014	82.88
Total	17132	72483	89615	80.88

TABLE 10.

Showing the percentage of sterile spikelets of fertile plants in the segregating families in 1923.

Pedigree no.	Plant no.	No. of fertile spikelets	No. of sterile spikelets	Total no. of spikelets	Percent of sterile spikelets
S-3S-1F	1F	341	30	371	8.1
	2F	294	41	335	12.2
	3F	353	23	376	6.1
	4F	300	38	338	11.2
	5F	451	37	488	7.6
S-4S-1F	1F	337	37	374	9.9
	2F	442	66	508	13.0
	3F	358	20	378	5.3
	4F	354	53	407	13.0
	5F	359	29	388	7.5
S-5S-1F	1F	382	33	415	8.0
	2F	368	23	391	5.9
	3F	453	58	511	11.4
	4F	308	38	346	11.0
	5F	338	26	364	7.1
S-7S-1F	1F	367	62	429	14.5
	2F	396	27	425	6.4
	3F	307	34	341	10.0
	4F	450	33	483	6.8
	5F	346	51	397	12.8
S-8S-1F	1F	421	24	445	5.4
	2F	347	34	381	8.9
	3F	445	46	491	9.4
	4F	324	36	360	10.0
	5F	460	81	541	15.0
	6F	425	30	455	6.6
S-13F-3F	1F	334	100	434	23.0
	2F	423	106	529	20.0
	3F	225	38	263	14.4
	4F	325	103	428	24.1
	5F	376	54	430	12.6
	6F	272	33	305	10.8
S-17F-1F	1F	265	14	279	5.0
	2F	277	50	327	15.3
	3F	291	34	325	10.5
	4F	300	20	320	6.3
	5F	263	24	287	8.4
S-18F-1F	1F	257	39	296	13.2
	2F	339	24	363	6.6

TABLE 10. (Continued).

Pedigree no.	Plant no.	No. of fertile spikelets	No. of sterile spikelets	Total no. of spikelets	Percent of sterile spikelets
S-18F-1F	3F	311	38	349	10.9
	4F	516	141	657	21.5
	5F	274	70	344	20.3
S-19F-1F	1F	379	34	413	8.2
	2F	396	67	463	14.5
	3F	213	19	232	8.2
	4F	270	18	288	6.3
	5F	380	44	424	10.4
S-29F-1F	1F	297	35	332	10.5
	2F	330	38	368	10.3
	3F	472	58	530	11.0
	4F	309	43	352	12.2
	5F	206	20	226	8.8
S-30F-1F	1F	270	51	321	15.9
	2F	336	37	373	9.9
	3F	343	23	366	6.3
	4F	235	50	285	17.5
	5F	272	33	305	10.8
	6F	412	47	459	10.2
S-32F-1F	1F	410	77	487	15.8
	2F	219	27	246	11.0
	3F	409	37	446	8.3
	4F	280	63	343	18.4
	5F	330	55	385	14.3
S-36F-1F	1F	290	40	330	12.1
	2F	298	29	327	8.9
	3F	258	48	306	15.7
	4F	219	21	240	8.8
	5F	203	14	217	6.5
S-42F-2F	1F	300	55	355	15.5
	2F	311	33	344	10.0
	3F	336	87	423	20.6
	4F	400	70	470	14.9
	5F	326	51	377	13.5
	6F	446	42	488	8.6
S-45F-2F	1F	479	133	612	21.7
	2F	318	33	351	9.4
	3F	350	27	377	7.2
	4F	389	58	447	13.0
	5F	256	43	299	14.4
S-46F-1F	1F	372	46	418	11.0
	2F	294	33	327	10.1

TABLE 10. (Continued).

Pedigree no.	Plant no.	No. of fertile spikelets	No. of sterile spikelets	Total no. of spikelets	Percent of sterile spikelets
S-46F-1F	3F	226	27	253	10.7
	4F	387	38	425	8.9
	5F	329	43	372	11.6
S-50F-1F	1F	458	38	496	7.7
	2F	365	45	410	11.0
	3F	507	52	359	9.3
	4F	478	29	507	5.7
	5F	302	47	349	13.5
S-51F-1F	1F	393	40	433	9.2
	2F	586	130	716	18.1
	3F	299	52	351	14.8
	4F	356	20	376	5.3
	5F	320	69	389	17.7
S-54F-1F	1F	293	17	310	5.5
	2F	332	41	373	11.0
	3F	273	40	313	12.8
	4F	345	38	383	9.9
	5F	397	62	459	13.5
S-58F 1F	1F	607	134	741	18.1
	2F	475	40	515	7.8
	3F	380	49	429	11.4
	4F	412	68	480	14 2
	5F	320	17	337	5.0
S-60F-1F	1F	343	44	387	11.4
	2F	415	25	440	5.7
	3F	227	22	249	8.8
	4F	348	13	361	3.6
	5F	323	41	364	11.3
S-61F-1F	1F	367	28	395	7.1
	2F	340	36	376	9.6
	3F	372	63	435	14.5
	4F	376	39	415	9.4
	5F	346	44	390	11.3
S-66F-3F	1F	390	51	441	11.6
	2F	235	31	266	11.7
	3F	382	82	464	17.7
	4F	334	45	379	11.9
	5F	425	90	515	17.5
S 69F-1F	1F	473	40	513	7.8
	2F	439	28	467	6.0
	3F	323	23	346	6.6
	4F	230	13	243	5.3

TABLE 10. (Continued).

Pedigree no.	Plant no.	No. of fertile spikelets	No. of sterile spikelets	Total no. of spikelets	Percent of sterile spikelets
S-69F-1F	5F	262	46	308	14.9
S-77F-3F	1F	440	27	467	5.8
	2F	532	63	595	10.6
	3F	407	25	432	5.8
	4F	487	108	595	18.2
	5F	384	104	488	21.3
S-83F-1F	1F	304	26	330	7.9
	2F	335	21	356	5.9
	3F	225	45	270	16.7
	4F	305	21	326	6.4
	5F	377	29	406	7.1
Mean	—	—	—	—	11.23±0.262
Stand. dev.	—	—	—	—	4.51±0.185

TABLE 11.

Summing up the plants in the preceeding table according to the family.

Pedigree no.	No. of ferlile spikelets	No. of sterile spikelets	Total no, of spikelets	Percent of sterile spikelets
S-3S-1F	1739	169	1908	8.86
4S-1F	1850	205	2055	9.98
5S-1F	1849	178	2027	8.78
7S-1F	1866	207	2073	9.99
8S-1F	2422	251	2673	9.39
13F-3F	1955	434	2389	18.17
17F-1F	1396	142	1538	9.23
18F-1F	1697	312	2009	15.53
19F-1F	1638	182	1820	10.00
29F-1F	1614	194	1808	10.73
30F-1F	1868	241	2109	11.43
32F-1F	1648	259	1907	13.58
36F-1F	1268	152	1420	10.70
42F-8F	2119	338	2457	13.76
45F-2F	1792	294	2086	14.09
46F-1F	1608	187	1795	10.42

TABLE 11. (Continued).

Pedigree no.	No. of fertile spikelets	No. of sterile spikelets	Total no. of spikelets	Percent of spikelets
50F-1F	2108	211	2319	9.10
51F-1F	1954	311	2265	13.73
54F-1F	1640	198	1838	10.77
58F-1F	2194	308	2502	12.31
60F-1F	1656	145	1801	8.05
61F-1F	1801	210	2011	10.44
66F-3F	1766	299	2065	14.48
69F-1F	1727	150	1877	7.99
77F-3F	2250	327	2577	12.69
83F-1F	1546	142	1688	8.41
Total	46971	6046	53017	11.40

TABLE 12.

Showing the percentage of sterile spikelets of fertile plants in the constant fertile families in 1923.

Pedigree no.	Plant no.	No. of fertile spikelets	No. of sterile spikelets	Total no. of spikelets	Percent of sterile spikelets
S-4S-5F	1F	386	37	423	8.7
	2F	262	74	336	22.0
	3F	325	72	397	18.1
	4F	442	109	551	19.8
	5F	231	53	284	18.7
	6F	342	37	379	9.8
	7F	422	51	473	10.8
	8F	655	86	741	11.6
	9F	527	121	648	18.7
S-17F-6F	1F	355	15	370	4.1
	2F	340	20	360	5.6
	3F	349	13	362	3.6
	4F	505	37	542	6.8
	5F	283	18	301	6.0
	6F	287	25	312	8.0
	7F	301	14	315	4.4
	8F	403	30	433	6.9
	9F	440	49	489	10.0
	10F	282	22	304	7.2

TABLE 12. (Continued).

Pedigree no.	Plant no.	No. of fertile spikelets	No. of sterile spikelets	Total no. of spikelets	Percent of sterile spikelets
S-18F-9F	1F	402	50	452	11.1
	2F	360	36	396	9.1
	3F	280	27	307	8.8
	4F	300	32	332	9.6
	5F	336	27	363	7.4
	6F	326	60	386	15.5
	7F	261	29	290	10.0
	8F	450	59	509	11.6
	9F	350	58	408	14.2
	10F	375	26	401	6.5
S-29F-4F	1F	604	163	767	21.3
	2F	306	18	324	5.6
	3F	350	45	395	11.4
	4F	320	44	364	12.1
	5F	364	47	411	11.4
	6F	407	94	501	18.8
	7F	379	49	428	11.4
	8F	374	41	415	9.9
	9F	365	101	466	21.7
	10F	327	39	366	10.7
S-30F-2F	1F	287	16	303	5.3
	2F	333	58	391	14.8
	3F	320	24	344	7.0
	4F	253	17	270	6.3
	5F	243	33	276	12.0
	6F	352	31	383	8.1
	7F	470	45	515	8.7
	8F	299	30	329	9.1
	9F	267	28	295	9.5
	10F	309	26	335	7.8
S-42F-3F	1F	372	65	437	14.9
	2F	289	30	319	9.4
	3F	367	28	395	7.1
	4F	216	7	223	3.1
	5F	380	27	407	6.6
	6F	349	29	378	7.7
	7F	231	14	245	5.7
	8F	377	36	413	8.7
	9F	290	27	317	8.5
	10F	295	23	318	7.2
S-46F-2F	1F	335	47	382	12.3
	2F	344	27	371	7.3

TABLE 12. (Continued).

Pedigree no.	Plant no.	No. of fertile spikelets	No. of sterile spikelets	Total no. of spikelets	Percent of sterile spikelets
S-46F-2F	3F	280	18	298	6.0
	4F	226	23	249	9.2
	5F	281	42	323	13.0
	6F	238	10	248	4.0
	7F	343	39	382	10.2
	8F	282	27	309	8.7
	9F	292	22	314	7.0
	10F	294	33	327	10.1
S-58F-3F	1F	465	45	510	8.8
	2F	258	36	294	12.2
	3F	308	37	345	10.7
	4F	415	41	456	9.0
	5F	307	38	345	11.0
	6F	316	45	361	12.5
	7F	361	54	415	13.0
	8F	286	13	299	4.3
	9F	362	42	404	10.4
	10F	373	29	402	7.2
S-60F-4F	1F	238	25	263	9.5
	2F	231	20	251	8.0
	3F	412	35	447	7.8
	4F	305	45	350	12.9
	5F	301	37	338	10.9
	6F	269	54	323	16.7
	7F	193	24	217	11.1
	8F	345	39	384	10.2
	9F	200	22	222	9.9
	10F	301	27	328	8.2
S-66F-9F	1F	363	29	392	7.4
	2F	409	44	453	9.7
	3F	393	39	432	9.0
	4F	406	30	436	6.9
	5F	455	36	491	7.3
	6F	441	50	491	10.2
	7F	329	20	349	5.7
	8F	379	43	422	10.2
	9F	411	44	455	9.7
	10F	513	41	554	7.4
Mean	—	—	—	—	9.82±0.281
Stand. dev.	—	—	—	—	4.16±0.199

TABLE 13.

Summing up the plants in the preceeding table according to the family.

Pedigree no.	No. of fertile spikelets	No. of sterile spikelets	Total no. of spikelets	Percent of sterile spikelets
S-4S-5F	3592	640	4232	15.12
17F-6F	3545	243	3788	6.41
18F-9F	3440	404	3844	10.51
29F-4F	3796	641	4437	14.45
30F-2F	3133	308	3441	8.95
42F-3F	3166	286	3452	8.29
46F-2F	2915	288	3203	8.99
58F-3F	3451	380	3831	9.92
60F-4F	2795	328	3123	10.52
66F-9F	4099	376	4475	8.40
Total	33932	3894	37826	10.29

In 1924, the percentage of sterile spikelets of 60 sterile plants from 14 segregating families showed again pretty wide range of variation (Table 14), and that of sterile spikelets in total was 76.27 (Table 15), differing more or less from that of the previous year. This difference, however, was due mainly to the climatic difference of these two years. According to above mentioned two years' investigation it may be said that the percentage of sterile spikelets of sterile plants is about 80, though it is very variable.

TABLE 14.

Showing the percentage of sterile spikelets of sterile plants in the segregating families in 1924.

Pedigree no.	Plant no.	No. of fertile spikelets	No. of sterile spikelets	Total no. of spikelets	Percent of sterile spikelets
S-3S-1F-3F	1S	185	401	586	68.4
	2S	187	508	695	73.1
	3S	100	249	349	71.3
	4S	112	362	474	76.4
	5S	100	290	390	74.4
S-5S-1F-3F	1S	82	321	403	79.7
	2S	133	476	609	78.2
	3S	123	501	624	80.3
	4S	158	820	978	83.8
	5S	117	482	599	80.5
S-8S-1F-2F	1S	164	307	471	65.2
	2S	189	411	600	68.5
	3S	155	318	473	67.2
	4S	273	422	695	60.7
	5S	413	536	949	56.5
S-18F-1F-1F	1S	53	384	437	87.9
	2S	170	578	748	77.3
	3S	201	507	708	71.6
	4S	144	433	577	75.0
	5S	179	567	746	76.0
S-19F-1F-2F	1S	292	832	1124	74.0
	2S	152	649	801	81.0
	3S	136	650	786	82.7
	4S	210	584	794	73.6
	5S	134	472	606	77.9
S-30F-1F-1F	1S	253	843	1096	76.9
	2S	199	652	851	76.6
	3S	202	674	876	76.9
	4S	151	692	843	82.1
	5S	128	489	617	79.3
S-36F-1F-1F	1S	214	764	978	78.1
	2S	173	611	784	77.9
	3S	137	858	995	86.2
	4S	163	737	900	91.9
	5S	162	730	892	81.8
S-45F-2F-2F	1S	240	575	815	70.6
	2S	175	359	534	67.2
	3S	184	387	571	67.8
	4S	144	415	559	74.2

TABLE 14. (Continued).

Pedigree no.	Plant no.	No. of fertile spikelets	No. of sterile spikelets	Total no. of spikelets	Percent of sterile spikelets
S-45F-2F-2F	5S	131	452	583	77.5
S-51F-1F-3F	1S	163	732	895	81.8
	2S	200	860	1060	81.1
	3S	196	703	899	78.2
	4S	169	814	983	82.8
	5S	177	592	769	77.0
S-58F-1F-1F	1S	237	527	764	69.0
	2S	243	636	879	72.4
	3S	149	347	496	70.0
	4S	106	412	518	79.5
	5S	102	394	496	79.4
S-61F-1F-1F	1S	88	375	463	81.0
	2S	112	401	513	78.2
	3S	104	338	442	76.5
	4S	87	364	451	80.7
	5S	157	383	540	70.9
S-66F-1F-1F	1S	114	417	531	78.5
	2S	91	339	430	78.8
	3S	110	435	545	79.8
	4S	98	343	441	77.8
	5S	97	476	573	83.1
S-69F-1F-1F	1S	148	394	542	72.7
	2S	135	430	565	76.1
	3S	171	333	504	67.1
	4S	94	259	353	73.4
	5S	116	444	560	79.3
S-83F-1F-1F	1S	233	709	942	75.3
	2S	194	742	936	79.3
	3S	132	413	545	75.8
	4S	183	621	804	77.2
	5S	131	323	454	71.1
Mean	—	—	—	—	76.14±0.461
Stand. dev.	—	—	—	—	5.72±0.326

TABLE 15.

Summing up the plants in the preceeding table
according to the family.

Pedigree no.	No. of fertile spikelets	No. of sterile spikelets	Total no. of spikelets	Percent of sterile spikelets
S-3S-1F-3F	684	1810	2484	72.57
5S-1F-3F	613	2600	3213	80.92
8S-1F-2F	1194	1994	3188	62.55
18F-1F-1F	747	2469	3216	76.77
19F-1F-2F	924	3187	4111	76.31
30F-1F-1F	933	3350	4283	78.22
36F-1F-1F	849	3700	4549	81.37
45F-2F-2F	874	2188	3062	71.46
51F-1F-3F	905	3701	4606	80.35
58F-1F-1F	837	2316	3153	73.45
61F-1F-1F	548	1861	2409	77.25
66F-3F-1F	510	2010	2520	79.76
69F-1F-1F	664	1860	2524	73.69
83F-1F-1F	873	2808	3681	76.28
Total	11155	35854	47009	76.27

3. Observation on the Natural Cross.

If natural crossing occurs very often in the plants of the experiments, the manner of inheritance becomes obscure, and the analysis of hereditary factors will be very difficult in that case.

Therefore, it is important to ascertain in genetical studies whether there occurs natural crossing very often or not. Though rice is the self-fertilizing plant as a rule, natural crossing also occurs at times, and as proved by Akemine (1925 a), its frequency differs with varieties of rice.

The glume-tip colour of the variety, *Toyokuni* is green at the flowering time, but in autumn changes reddish brown ; and the variety is awnless. Therefore, the changed colour and awnlessness were turned to account as marks of self-fertilization for the sake of convenience.

Observations were made on each plant of 239 families in the autumn of 1923 to see whether it was the natural cross or not. As will be seen in Table 16, the majority of families (from S-3 S-1 F to S-8 S-9 F) descended from the sterile plants in 1921 segregated as to the characters of colour and awn while those (from S-13 F-1 F to S-83 F-10 F) descended from the fertile plants in the same year were generally quite uniform, and only 18 families out of 197 contained many plants with characteristics of other varieties. In 1924, natural crosses among the offspring of 138 sterile plants were examined. As shown in Table 17, the majority of families consisted of plants with various colours and various degrees of awn length.

From these investigations, we can see that the natural cross occurs more frequently on the sterile plant as compared with the fertile plant.

TABLE 16.

Showing the result of observation on natural crosses in 1923.

Pedigree no.	Color of the glume-tip			Length of the awn	
	Changed	Red or purple	Colorless	Long	Short
S-3S-1F	225				
2F	66	128	29		
3F	191				
4F	202	1			
5F	225				
6F	218			1	
S-4S-1F	25	144	51		1
2F	44	126	43		
3F	175				
4F	26	99	40		
5F	185	2		1	
6F	37	108	42		
7F	147				
8F	8	35	11		
9F	36	96	40		
10F	35	129	62		
S-5S-1F	35	131	64		
2F	45	123	54		
3F	31	135	62		
4F	229	1			
5F	9	46	15		
6F	140	1			
7F	103				
S-7S-1F	32	169	64		
2F	34	118	68		
3F	39	136	56		
4F	217				

TABLE 16. (Continued).

Pedigree no.	Color of the glume-tip			Length of the awn	
	Changed	Red or purple	Colorless	Long	Short
S-7S-5F	49	96	48		
6F	229				
7F	41	108	65		
8F	210				
9F	45	125	44		
10F	234	234			
S-8S-1F	11	33	11		
2F	153	14	56		
3F	143	32	52		
4F	92	34	45		
5F	228	1		1	
6F	110	67	48	1	
7F	76	12	36		
8F	134	34	40		
9F	211				
S-13F-1F		171			
2F	198	1			
3F	55	100	50		
4F		109	47		
5F		222			
6F	132	59			1
7F	58	89	59	1	
8F	66	95	34		
9F	53	111	51		
10F			207		1
S-17F-1F	230				
2F	209				
3F	224				
4F	232	1			
5F	224				
6F	155				
7F	207	1			
8F	214				
9F	219			1	
10F	217				
S-18F-1F	222	2			
2F	226				
3F	115				
4F	168				
5F	233				
6F	224	1			
7F	217	1			

TABLE 16. (Continued).

Pedigree no.	Color of the glume-tip			Length of the awn	
	Changed	Red or purple	Colorless	Long	Short
S-18F-8F	223				
9F	207	1			
10F	168				
S-19F-1F	220				
2F	108	2			
3F	229				
4F	226				
5F	224				1
6F	218				
7F	179	1		1	
8F	219				
9F	216	1			
10F	213	1			
S-29F-1F	222				
2F	207	2			
3F	221				
4F	200	1			
5F	218				
6F	219	1			
7F	203				
8F	225				
9F	226	3			
10F	164				
S-30F-1F	222	1			
2F	223			1	
3F	223				
4F	223	1			
5F	223				
6F	224				
7F	228				
8F	223				
9F	212	1			
10F	224	1			
S-32F-1F	208				
2F	230	1			
3F	219				
4F	220				
5F	227				
6F	210			1	
7F	219				
8F	215	3			
9F	225				

TABLE 16. (Continued).

Pedigree no.	Color of the glume-tip			Length of the awn	
	Changed	Red or purple	Colorless	Long	Short
S-32F-10F	220				
S-36F-1F	221				
2F	226	1			
3F	226				
4F	226	1		1	
5F	220				
6F	214				
7F	229	1			
8F	187				2
9F	189	2			
10F	217				
S-42F-1F	193	1			
2F	227			1	
3F	227	1			
4F	217				
5F	201				
6F	228	1			
7F	225				
8F	227				
9F	227				
10F	179				
S-45F-1F	226	1			
2F	218				
3F	225				
4F	219	2			
5F	222	1			
6F	205				
7F	222				
8F	225	1			
9F	90				
S-46F-1F	224	1			
2F	218				
3F	230			2	
4F	234	2			
5F	227				
6F	230				1
7F	222	1			
8F	21				
9F	226	1			
10F	224				
S-50F-1F	70	90	51		
2F	194				

TABLE 16. (Continued).

Pedigree no.	Color of the glume-tip			Length of the awn	
	Changed	Red or purple	Colorless	Long	Short
S-50F-3F	213				
4F	56	97	55		
5F	42	130			
6F	195				
7F	27	110	55		
8F	36	101	56		
9F	192	1			
10F	193	2			
S-51F-1F	201				
2F	194				
3F	207	1			1
4F	203				
S-54F-1F	208	1			
2F	202	1			
3F	202				
4F	210	2			
5F	202				
6F	207	1		1	
7F	209	1			
8F	205				
9F	206				
10F	200	1			
S-58F-1F	179				
2F	170	2			
3F	130			2	
4F	137	1			
5F	152				
6F	158	1			
7F	206				
8F	210	1			1
9F	146				
10F	205				
S-60F-1F	212	1			
2F	197				
3F	163	2		1	
4F	151				
5F	169	1			1
6F	210				
7F	204				
8F	184	1			
9F	209				
10F	196				

TABLE 16. (Continued).

Pedigree no.	Color of the glume-tip			Length of the awn	
	Changed	Red or purple	Colorless	Long	Short
S-61F-1F	209	1			1
2F	199				
3F	210	2			
4F	213				
5F	200	1			
6F	201				
7F	203	1			
8F	207				
9F	197	1			
10F	207	1			
S-66F-1F	148	1			
2F	164				
3F	179	1			
4F	185	2		1	
5F	190	1			1
6F	193				
7F	200				
8F	202	1			
9F	155	1		1	
10F	136				
S-69F-1F	196	2			
2F	209				
3F	208	1			
4F	195	1			
5F	207				
6F	215				2
7F	202	1			
8F	187				
9F	138				
10F	205	2			
S-77F-1F			97		
2F	96				
3F	159	25			
4F	4	13			
S-83F-1F	198			1	
2F	188			1	
3F	199	1			
4F	166				
5F	199			1	
6F	190	1			
7F	200				
8F	88				
9F	202	1			
10F	196	1			

TABLE 17.

Showing the result of observation on natural crosses in 1924.

Pedigree no.	Color of the glume-tip			Length of the awn	
	Changed	Red or purple	Colorless	Long	Short
S-3S-1F 1S	23				
2S	25			1	
3S	18				
4S	25	2		1	1
5S	24			1	1
6S	26	3		1	1
7S	18	5			1
8S	26	5		1	1
9S	20	5			1
10S	25	4			
S-5S-1F-1S	2	9	15	2	
2S	6	18	4		1
3S	7	15			
4S	22	4			
5S	15	9			1
6S	5	15	2	1	2
7S	4	22			2
8S	4	18	7		
9S	11	11	4	1	2
10S	2	18	10		1
S-8S-1F-1S		27		1	1
2S	10	7	9		1
3S	19	3	6	1	1
4S	6	7	3		1
5S		19	5		2
6S	6	21			2
7S	3	14	4		2
8S	7	12	10		3
9S	10	15		1	
S-18F-1F-1S	20	6			2
2S	23	2		1	
3S	22	7			3
4S	7	4			1
5S	22	4			
6S	24	4			1
7S	23	2			
8S	20	2			1
9S	30	5			1
10S	23	4		1	1
S-19F-1F-1S	21	8			2

TABLE 17. (Continued).

Pedigree no.	Color of the glume-tip			Length of the awn	
	Changed	Red or purple	Colorless	Long	Short
S-19F-1F-2S	22	3			1
3S	22	8		1	1
4S	23	4			
5S	27	2			1
6S	25	3			1
7S	19	12		1	3
8S	21	7			
9S	25	6		1	4
10S	20	8		1	
S-30F-1F-1S	24	6			2
2S	23	2			2
3S	22	6			
4S	21	3			1
5S	25	4			
6S	21	3			
7S	24	6			1
8S	22	5			
9S	23	5			
S-36F-1F-1S	24	2			
2S	22	7			3
3S	23	5			
5S	22	4			2
6S	22	5			
7S	24	2			1
8S	23	1		1	
9S	24	4		1	
10S	11	1			
S-45F-2F-1S	25	2			
2S	30	1			
3S	22	2			
4S	25	6		1	1
5S	25	2			
6S	26	3			1
7S	21	6			1
8S	22	7		1	
9S	25	1		1	
10S	25	5			2
S-51F-1F-1S	22	5		2	
2S	24	4			3
3S	22	6		1	2
4S	26	5		2	2
6S	24	3		1	2

TABLE 17. (Continued).

Pedigree no.	Color or the glume-tip			Length of the awn	
	Changed	Red or purple	Colorless	Long	Short
S-51F-1F-7S	19	8		3	
8S	27	3			
9S	24	3		1	2
10S	26	4			
S-58F-1F-1S	24	3			
2S	25	4		1	2
3S	21	5		1	
4S	26	2			2
5S	22	2			
6S	26	5			2
7S	26	2			2
9S	25	1			
10S	26	1			1
S-61F-1F-1S	11				
2S	26	2			1
3S	16	3			
4S	29	1			1
5S	23	1			
6S	18				
7S	14	3			1
8S	20	1			
9S	24	2			
10S	23				
S-66F-3F-1S	22	1			
2S	25	3			
3S	19	4			2
4S	22	2			
5S	16	1			
6S	28	2			1
7S	22	4			
8S	27	3			
9S	25	1			
10S	30				
S-69F-1F-1S	24	4			1
2S	21	4			
3S	13	4			
4S	20	3			
5S	17	3			
6S	27	3			
7S	27	1			
8S	27	4			
9S	27			1	

TABLE 17. (Continued).

Pedigree no.	Color of the glume-tip			Length of the awn	
	Changed	Red or purple	Colorless	Long	Short
S-69F-1F-10S	29				
S-83F-1F-1S	21	7		1	1
2S	22	7			1
3S	10	18		2	
4S	23	7			1
5S	13	9			2
6S	27	4			2
7S	20	7			2
8S	18	11			3
9S	17	9			2
10S	20	10			

4. The Results of the Cytological Investigation.

For a study of reduction division in the microspore mother cells and development of the pollen, young flowers of which glume-tips were cut to let the fixative effective for the inner part were fixed in the Flemming's weak solution for 24 hours.

To examine the apparatus of the ovule, the ovary was separated from the glume and fixed in the same solution. But sometimes the ovary treated with the Carnoy's fluid for 5 minutes was steeped in the Flemming's weak solution.

In every case, paraffin sections were cut from 8 to 10 micra thick and stained with Heidenhain's iron-alum haematoxylin.

There appear in the literature many descriptions of the process of abortion both in male and female reproductive organs.

Tischler (1906 a, b, 1908, 1910) found that in hybrids of *Ribes* spp. and in the sterile hybrid between *Mirabilis Jalapa* and *M. tubiflora* pollen abortion usually takes place following normal division. On the other hand, in *Potentilla tabernae montani* × *P. rubens*, *Syringa chinensis*, *Bryonia alba* × *B. dioica*, and in three varieties of banana having different chromosome numbers, irregular divisions are common, and always followed by much pollen abortion.

Rosenberg (1909) concluded in the investigation of *Drosera obovata* that because of the fact the microspore division was carried on the whole normally, the degeneration of the pollen grains was not result of the irregular distribution of chromosome during reduction division, but was due to the lack of cytoplasm. The abortion of the embryo-sacs, he again concluded, was not due to irregular divisions, as all of the divisions following reduction were normal, but was due to poor nutrition.

Nakao (1911) observed that very striking irregularities in reduction division of certain cereal hybrids were followed by complete abortion of the pollen after liberation. He concluded that abortion in this case was due to an insufficiency of cytoplasm previous to reduction division which resulted in abnormally early division and consequent irregularities.

Valleau (1918) pointed out that in the partially sterile variety of *Fragaria, Minnesota* 3 pollen development is carried on normally up to the liberation of the microspores from the tetrad. At this period all of the microspores appear normal and alike. Following liberation, variation in rate of growth, time of division of the microspore nucleus, and ability of the individual microspores to develop normally is shown. At all stages during this growth period microspores are found in various stages of abortion.

Dorsey (1915) stated that abortion of pollen grains is not to be noticed in the grape previous to the liberation of the microspores from the pollen mother cell. It is first noticeable during the early growth period of the free microspore and shows various degrees of arrested growth combined with loss of cytoplasm. He also found that the generative nucleus of the mature pollen in some varieties of the grape, and in some case, also the vegetative, degenerates; and that the germ pores are not formed in pollen born by the reflexed type of stamen. He (1919) pointed out also in the plum that typical pollen abortion does not become evident until after microspore liberation; and that in some pollen mother-cells of a cross between *Prunus Besseyi and P. armenica* at the tetrad stage, the conspicuous rings in the cytoplasm, which resemble small nuclei in some instances and indicate an unbalanced condition following the reduction division, appear; stating also that as many as thirteen of these rings are sometimes counted in a single tetrad. On the other hand, in the female reproductive organ, there may still be an even development of the two ovules, and two embryos may sometime develop to maturity in the same "pit". Such development, however, is not the typical condition. In most varieties, one ovule shows an arrested development before fertilization. If both ovules develop normal embryo-sacs, the one in which fertilization takes place first apparently gains ascendancy. If fertilization takes place in both ovules, which sometimes happens, suppression takes the form of embryo abortion.

Nagai (1926 b) observed that a certain number of caryopsis in the male sterile plant of rice develop parthenocarpically and reach a full size of the mature grain. These caryopsis are empty, lacking the embryo and endosperm, but filled with a clear liquid. In one of the families, such parthenocarpic ones reach 9.9 per cent of over 1900 spikelets examined. The pollen grains produced by the male sterile plant are entirely abortive but many of them retain the shape of the normal one, although the abortive pollen grains are generally shrivelled. However, the egg cells of the male sterile plant are functional, and they can be fertilized by the pollen of the normal plant.

As to the chromosome number of rice, Kuwada (1909, 1910) was the first observer, who counted 12 chromosomes as the haploid number in a variety. Nakatomi (1923) counting the chromosome number of a good many common varieties, and several varieties regarded as produced by mutation, found that all of them have the same number i.e. 12 as the haploid number. And Akemine (1925 b) also observed that some dwarf types produced by mutation have the same chromosome number.

It was found in 1924 that as considerable abortive pollen grains are produced in our sterile plant of rice, the anther can not burst, and there occurs no self-fertilization.

In our sterile the abnormal distribution of chromosomes can not be found during reduction division. Also pollen abortion does not occur immediately after liberation, but toward maturity pollen grains gradually degenerate. At the flowering time, most of them lose the contents completely and are collapsed as shown in Fig. 2, only a few normal grains appearing in an anther. The sterile plant has also 12 chromosomes as the haploid number.

On the other hand, the ovules of the sterile plant have the embryo sac of normal size and shape with the perfect apparatus. All of 41 flowers which were collected and fixed in 1925 at the flowering time were normal. Among the spikelets fixed on the third day after flowering many peculiar kernels were found, which enlarged normally, the endosperms developing well, but they lacked embryos (Fig. 3). Of 74 spikelets, 20 were such ones, 26 had embryos and 28 were empty. Namely, the percentage of such kernels was 27.0.

The kernel with endosperm only grew for a while, and although in the kernel fixed on the fifth day after flowering the said endosperm degenerated already forming a cavity there as will be seen in Fig. 5, the growth of the kernel still continued at that time; on the seventh day width growth almost came to an end notwithstanding it was very conspicuous in the normal kernel, rich starch depositing in the endosperm; and in the normal kernel, the glume was filled up with the kernel on the nineth day. Therefore, two kinds of the kernel were readily distinguished about that time from each other macroscopically. The measurement (in m.m.) of the largest kernel conducted each day gave the following result.

	5th day		7th day		9th day	
	length	width	length	width	length	width
Kernel with embryo	5.3	1.6	6.5	2.7	6.5	3.9
Kernel with no embryo	2.5	1.3	4.3	1.5	5.0	1.7

Such a kernel with no embryo is filled with clear liquid after degeneration of the endosperm, but dried up and shrivelled at the harvest. It can be formed without fertilization of the polar nuclei by the second male nucleus, because in a bagged sterile plant experimented in 1925, in spite of no self-pollination which was due to the lack of dehiscence of the anther sac, 87 flowers produced such kernels while 630 flowers degenerated completely, the percentage of such kernels being 12.1. Moreover, five sterile plants in the condition of open-pollination in the field were examined after the harvest in the same year, and the result was as follows:

Plant no.	No. of normal kernels	No. of empty spikelets	No. of embryo-deficient kernels	Percent of embryo-deficient kernels
1	176	493	229	25.5
2	139	631	190	19.8
3	147	584	111	13.2
4	132	714	103	10.9
5	214	568	339	30.2
Mean				19.92

The anther wall of the steriles undergoes the normal differentiation; its thickness is usual; impossibility of the dehiscence is due to the presence of considerable abortive pollen grains. Thus so far as the

2x tissue is concerned any abnormalities do not occur and degeneration begins with the 1x condition. Therefore, we can say this kind of sterility is due to gametic lethal.

5. The Results of Pollination with the Foreign Pollen.

In 1926, the flowers of three sterile plants which were in full-bloom at the same hour were marked and shed over artificially with abundant pollen grains of normal plants. On the nineth day after pollination, they were examined. Fifty-five spikelets out of 66 i.e. about 83 percent spikelets were fertile, while steriles in the field always set about 80 percent sterile spikelets, and it is very interesting that none of the peculiar kernels before mentioned could not be found there. As genetically fertile plants set always about 10 percent sterile spikelets, it is very clear that the female organs of steriles are perfect as proved already cytologically.

High sterility of the sterile plant in the field is therefore due to insufficiency of the pollen carried by the wind.

It is also ascertained by the result that formation of kernels with endosperm only does not concern with fertilization, but it takes place alone in the absence of pollen grains.

6. Summary.

1. A plant with about 80 percent sterile spikelets was found in 1920 in the multiplication plot of a strain of a rice variety, *Toyokuni*, and it split in the next year into 84 fertile plants and 8 sterile plants of the parent type. In 1922, not only the sterile plants but also the fertile plants segregated. The segregating ratio of plants in the offspring of sterile plants was not definite, but every fertile plant segregated into fertiles and steriles in the 3 : 1 ratio. Some of fertile plants which were collected from the segregating families segregated again and the others bred true for the first time in 1923. The proportion of segregating families and constant ones was 2 : 1. The same process of observation was repeated in 1924, and the same result was obtained.

2. Sterile plants threw always the small number of steriles, and its occurrence was always very variable. The percentage of sterile plants in 138 families in 1924 ranged from 0 to 50, and that of all of these sterile plants was 20.17.

3. The percentage of sterile spikelets of 257 sterile plants varied from 35.4 to 93.9, and that of all of these sterile spikelets was 80.88 in 1923. And the percentage of sterile spikelets totalled in 1924 was 76.27. This difference was due mainly to the climatic difference in these two years.

4. In the examination of natural crosses in 1923, they were conspicuously found in the families descended from sterile plants in a segregating family in 1921, while they were rarely found in the families descended from fertile plants. In 1924, it was found that the offspring of sterile plants contained numerous natural crosses.

5. In 1924, it was found that dehiscence of the anther of the sterile plant does not happen, so that pollen grains can not shed at the flowering time. Bagged sterile plants were able to produce none of fertile spikelets. The fertile spikelets of the sterile plant in the condition of open-pollination are the results of natural crossing. Most of pollen grains in the anther of sterile are abortive. Abortion does not occur before liberation of the tetrads. Differentiation and thickness of the anther wall is normal. Non-dehiscence of the anther seems to be due therefore to the presence of abundant abortive pollen grains. On the other hand, the embryo sac of the sterile plant has normal size and shape, and its apparatus is perfect.

6. The sterile plant has 12 chromosomes as the haploid number which are common in the rice varieties.

7. The sterile plant sets in the field many kernels which lack the embryo and the endosperm. Bagging experiments indicated that such kernels are produced without fertilization. The polar nuclei of some flowers of sterile divide by themselves again and again, form the endosperm in a few days after flowering; and the resulting endosperm degenerates afterwards. Length growth of the kernel continues still even after the complete degeneration of the endosperm, while width growth ceases early. The kernels are filled with clear liquid after degeneration of such endosperms, and shrivelled at the harvest.

8. The sterile plant was able to produce many fertile spikelets as does a fertile plant when pollinated artificially with pollen grains of normal plants, and there could be found none of kernels devoid of the embryo and endosperm. It shows clearly that the ovules are functional and the polar nuclei begin to divide by themselves only in the absence of pollen to fertilize.

II. On the Partially Sterile Plant.

1. Observation on the Mode of Inheritance.

In 1920, a partially sterile plant with about 40 percent sterile spikelets was found with the sterile plant in the same plot. It resembled semi-sterile plant very much; generally speaking, its sterile spikelets had the alternative position with fertile spikelets, and were uniformly distributed from the bottom to the top of panicles. Its other characteristics were the same as those of fertile plants in that plot. In 1921, this partially sterile plant threw 10 partial steriles of the parent type and 166 fertiles, showing about 12 percent partial steriles. The segregation of any other characteristics did not occur there.

All of the 10 partial steriles segregated into fertiles and partial steriles in 1922. Though there was more or less variation, the percentage of partial steriles in each family was about 12, and that of all of these partial steriles in 10 families 12.32 as shown in Table 18. As to the offspring of 166 fertiles, 116 families contained only fertile plants, and the others a few steriles or partial steriles besides fertiles as Table 19 shows.

But as such a few sterile plants usually result in the offspring of the fertile plant of rice by the external conditions or by mutation, those families should be regarded as fertiles.

It must be a peculiar mode of inheritance that in the offspring of a partial sterile, the greater part of which is fertile and breeds true while partial steriles segregate again.

TABLE 18.

Showing the percentage of partially sterile plants in the offspring of partial steriles, in 1922.

Pedigree no.	No. of fertile plants	No. of partially sterile plants	Total no. of plants	Percent of partially sterile plants
PS-1PS	141	23	164	14.0
2PS	137 S1	27	165	16.4
3PS	155	11	166	6.6
4PS	141	22	163	13.5
5PS	137	27	164	16.5

TABLE 18. (Continued).

Pedigree no.	No. of fertile plants	No. of partially sterile plants	Total no. of plants	Percent of partially sterile plants
PS-6PS	149 S1	11	161	6.8
7PS	145	20	165	12.1
8PS	142 S1	22	165	13.3
9PS	137	23	160	14.4
10PS	150	16	166	9.6
Total	1437	202	1639	12.32

TABLE 19.

Showing the offspring of fertile plants produced by partial steriles, in 1922.

Pedigree no.	No. of fertile plants	No. of partially sterile plants	Total no. of plants	Percent of partially sterile plants
PS-19F	166	1	167	0.6
24F	149	1	150	0.7
27F	152 S1		153	0
28F	159	2	161	1.2
35F	168	1	169	0.6
39F	157	1	158	0.6
52F	153	2	155	1.3
53F	157	3	160	1.9
68F	161	1	162	0.6
69F	164 S1		165	0
76F	156	1	157	0.6
79F	157	1	158	0.6
80F	132	1	133	0.8
81F	163	1	164	0.6
89F	161	1	162	0.6
90F	156	2	158	1.3
91F	158 S1		159	0
98F	161	1	162	0.6
99F	158	1	159	0.6
100F	159	1	160	0.6
103F	162	3	165	1.8

TABLE 19. (Continued).

Pedigree no.	No. of fertile plants	No. of partially sterile plants	Total no. of plants	Percent of partially sterile plants
PS-104F	168	3	171	1.8
106F	165	2	167	1.2
111F	153	1	154	0.6
112F	163	2	165	1.2
113F	157	2	159	1.3
115F	161	1	162	0.6
116F	158	1	159	0.6
118F	162	1	163	0.6
121F	155	1	156	0.6
123F	159	1	160	0.6
125F	163	1	164	0.6
126F	153	1	154	0.6
128F	160	1	161	0.6
133F	161	1	162	0.6
134F	161	1	162	0.6
138F	155	2	157	1.3
139F	159	2	161	1.2
142F	157 S1		158	0
143F	157	1	158	0.6
145F	163	1	164	0.6
161F	161	1	162	0.6
163F	158	1	159	0.6
164F	159 S1	2	162	1.2
165F	160	1	161	0.6
169F	161	1	162	0.6
170F	159	1	160	0.6
171F	161	1	162	0.6
174F	158	1	159	0.6
176F	156	1	157	0.6

All of the other 116 strains consisted of only fertile plants.

In 1923, the offspring of 10 partial steriles from each of 10 segregating families, with the exception of 3 families, ninety-seven families in all segregated all into partial steriles and fertiles as Table 20 shows, each showing about 12 percent partial steriles, and the percentage of all of these partial steriles in 97 families was 12.90 (Table 21). Concerning the exceptional 3 families, two of them which contained 0.6 percent and 2.4 percent partial steriles respectively were really constant fertile families. As will be shown afterwards, their parents proved sterility by the external conditions, and the percentage of their sterile spikelets differed very mnch from those of the true partial steriles ; one being 36.1, and the other 74.1. When partial steriles were collected for the parent stock in the field, they were also adopted by mistake because it was very difficult to distinguish such ones from true partial steriles by mere inspection without examining the percentage of sterile spikelets. The parent of the other family which contained 50 percent fertiles was semi-sterile, and it was probably produced by mutation in a segregating family in 1922.

The semi-sterile plant sets also about 50 percent sterile spikelets. It might, therefore, be impossible to distinguish it from the partially sterile plant by macroscopical observation or even by examining the percentage of sterile spikelets. A more detailed explanation for semi-sterility will be attempted later.

Owing to a small number of such plants resembling the true partially sterile plant, the percentage of the latter in the segregating family is as ever about 12 percent, although an adjustment of calculation of the percentage is tried.

Five fertile plants from each of 10 segregating families bred true to fertile that year. As will be seen in Table 22 in 11 out of 50 families a few sterile or partially sterile plants appeared. They would be regarded as the products of mutation or the external conditions, for it was so rare occurrence that only 14 out of 10248, i.e. 0.14 percent partial steriles were found there.

TABLE 20.

Showing the percentage of partially sterile plants in the offspring of partial sterile, in 1923.

Pedigree no.	No. of fertile plants	No. of partially sterile plants	Total no. of plants	Percent of partially sterile plants
PS-1PS-1PS	183	27	210	12.9
2PS	170	23	193	11.9
3PS	172	26	198	13.1
4PS	161	28	189	14.8
5PS	181	29	210	16.0
6PS	118	21	139	15.1
7PS	163	25	188	13.3

TABLE 20. (Continued).

Pedigree no.	No. of fertile plants	No. of partially sterile plants	Total no. of plants	Percent of partially sterile plants
PS-1PS-8PS	176 S1	34	210	16.1
9PS	153	1	154	0.6
10PS	124	28	152	18.4
2PS-1PS	131	27	158	17.1
2PS	170	16	186	8.6
3PS	124	10	134	7.5
4PS	172	27	199	13.6
5PS	191	18	209	8.6
6PS	154	18	172	10.5
7PS	190	31	221	14.0
8PS	148	31	179	17.3
9PS	192	30	222	13.5
10PS	148	25	173	14.5
3PS-1PS	146	25	171	14.6
2PS	123 S1	29	153	19.0
3PS	186	36	222	16.2
4PS	147	28	175	16.0
5PS	142	27	169	16.0
6PS	166	30	196	15.3
7PS	132	15	147	10.2
8PS	193	24	217	11.1
9PS	162	19	181	10.5
10PS	200	28	228	12.3
4PS-1PS	138	27	165	16.4
2PS	141	16	157	10.2
3PS	184 S1	30	215	14.0
4PS	155	36	191	18.8
5PS	79	79	158	50.0
6PS	120	11	131	8.4
7PS	130	21	151	13.9
8PS	91	17	108	15.7
9PS	134	24	158	15.2
10PS	136	31	167	18.6
5PS-1PS	201	17	218	7.8
2PS	87	14	101	13.9
3PS	154	24	178	13.5
4PS	174	20	194	10.3
5PS	183	34	217	15.7
6PS	150	21	171	12.3
7PS	185	33	218	15.1

TABLE 20. (Continued).

Pedigree no.	No. of fertile plants	No. of partially sterile plants	Total no. of plants	Percent of partially sterile plants
PS-5PS-8PS	152	22	174	12.6
9PS	185	20	205	9.8
10PS	189	20	209	9.6
6PS-1PS	150 S1	26	177	14.7
2PS	184	30	214	14.0
3PS	138	29	167	17.4
4PS	167	21	188	11.2
5PS	154	12	166	7.2
6PS	40	1	41	2.4
7PS	124	16	140	11.4
8PS	175 S1	27	203	13.3
9PS	172	27	199	13.6
10PS	179	45	224	20.1
7PS-1PS	190	34	224	15.2
2PS	134	25	159	15.7
3PS	136	19	155	12.3
4PS	132	9	141	6.4
5PS	165	21	186	11.3
6PS	135	24	159	15.1
7PS	130	14	144	9.7
8PS	197	25	222	11.3
9PS	200	26	226	11.5
10PS	194	33	227	14.5
8PS-1PS	149	27	176	15.3
2PS	141	19	160	11.9
3PS	68	9	77	11.5
4PS	118	8	126	6.3
5PS	142	16	158	10.1
6PS	201	26	227	11.5
7PS	174	19	193	9.8
8PS	152	15	167	9.0
9PS	122	12	134	9.0
10PS	138	21	159	13.2
9PS-1PS	123	21	144	14.6
2PS	156	24	180	13.3
3PS	172	26	198	13.1
4PS	125	21	146	14.4
5PS	149	21	170	12.4
6PS	161	30	191	15.7
7PS	129	9	138	6.5

TABLE 20. (Continued).

Pedigree no.	No. of fertile plants	No. of partially sterile plants	Total no. of plants	Percent of partially sterile plants
PS-9PS-8PS	196	29	225	12.9
9PS	127	25	152	16.4
10PS	178	29	207	14.0
10PS-1PS	144 S1	11	156	7.1
2PS	124	21	145	14.5
3PS	126	12	138	8.7
4PS	151	19	170	11.2
5PS	146	14	160	8.8
6PS	149 S1	20	170	11.8
7PS	113 S1	16	130	12.3
8PS	208	26	234	11.1
9PS	197	27	224	12.1
10PS	144	18	162	11.1

TAELE 21.

Summing up the families in the preceeding table according to the family in 1922.

Pedigree no.	No. of fertile plants	No. of partially sterile plants	Total no. of plants	Percent of partially sterile plants
PS-1PS	1449	241	1690	14.26
2PS	1620	233	1853	12.57
3PS	1598	261	1859	14.04
4PS	1230	213	1443	14.76
5PS	1660	225	1885	11.94
6PS	1445	233	1678	13.89
7PS	1613	230	1843	12.48
8PS	1405	172	1577	10.91
9PS	1516	235	1751	13.42
10PS	1505	184	1689	10.89
Total	15041	2227	17268	12.90

TABLE 22.

Showing the offspring of fertile plants in the segregating families in 1923.

Pedigree no.	No. of fertile plants	No. of partially sterile plants	Total no. of plants	Percent of partially sterile plants
PS-1PS-1F	205		205	0
2F	201		201	0
3F	224		224	0
4F	214	1	215	0.5
5F	218		218	0
2PS-1F	189		189	0
2F	199		199	0
3F	224	1	225	0.4
4F	223		223	0
5F	214		214	0
3PS-1F	186	2	188	1.1
2F	215	1	216	0.5
3F	206		206	0
4F	193		193	0
5F	177		177	0
4PS-1F	189		189	0
2F	101		101	0
3F	146	1	147	0.7
4F	215		215	0
5F	210 S1	2	213	0.9
5PS-1F	211		211	0
2F	220		220	0
3F	217		217	0
4F	172		172	0
5F	217	1	518	0.5
6PS-1F	226		226	0
2F	218		218	0
3F	226		226	0
4F	214	1	215	0.5
5F	224		224	0
7PS-1F	209		209	0
2F	183		183	0
3F	176		176	0
4F	205	1	206	0.5
5F	227		227	0
8PS-1F	216	2	218	0.9
2F	216		216	0

TABLE 22. (Continued).

Pedigree no.	No. of fertile plants	No. of partially sterile plants	Total no. of sterils plants	Percent of partially sterile plants
PS-8PS-3F	142		142	0
4F	210		210	0
5F	217		217	0
9PS-1F	224		224	0
2F	219		219	0
3F	211		211	0
4F	231		231	0
5F	222		224	0
	S2			
10PS-1F	218	1	219	0.5
2F	225		225	0
3F	159		159	0
4F	224		224	0
5F	203		203	0
Total	10234	14	10248	0.14

In 1924, the offspring of one hundred partial steriles, all of which descended from 10 partial steriles in 1921 contained all about 12 percent partial steriles as shown in Table 23 except one family underlined. The parent of the latter proved sterility by the external conditions, the percentage of its sterile spikelets being 22.8 as will be shown afterwards.

The percentage of partial steriles in the segregating family was slightly lower than that in the previous year, and that of all of these partial steriles in 99 segregating families did not reach 12 percent (Table 14).

There were in that year a good many plants, panicles of which were attacked by insects, and partial steriles could not be easily distinguished from fertiles in the field. Therefore some partial steriles might have been classified as fertiles.

TABLE 23.

Showing the percentage of partially sterile plants in the offspring of partial steriles, in 1924.

Pedigree no.	No. of fertile plants	No. of partially sterile plants	Total no. of plants	Percent of partially sterile plants
PS-1PS-1PS-1PS	58	4	62	6.5
2PS	66	12	78	15.4
3PS	69	9	78	11.5
4PS	52	6	58	10.3
5PS	55	10	65	15.4
6PS	73	14	87	16.1
7PS	117	9	126	7.1
8PS	119	18	137	13.1
9PS	86	12	98	12.2
10PS	93	9	102	8.8
2PS-1PS-1PS	120	14	134	10.4
2PS	125 S1	10	136	7.4
3PS	194	27	221	12.2
4PS	170	26	196	13.3
5PS	152	22	174	12.6
6PS	138	14	152	9.2
7PS	152	21	173	12.1
8PS	90	17	107	15.9
9PS	142	18	160	11.3
10PS	133	18	151	11.9
3PS-1PS-1PS	92	14	106	13.2
2PS	166	18	184	9.8
3PS	127	18	145	12.4
4PS	145	28	173	16.2
5PS	161	21	182	11.5
6PS	99	15	114	13.2
7PS	92	15	107	14.0
8PS	86	13	99	13.1
9PS	114	21	135	15.6
10PS	95	13	108	12.0
4PS-1PS-1PS	103	8	111	7.2
2PS	180	30	210	14.3
3PS	86	6	92	6.5
4PS	81	11	92	12.0
5PS	138	22	160	13.8
6PS	70	12	82	14.6
7PS	78	8	86	9.3
8PS	49	11	60	18.3

TABLE 23. (Continued).

Pedigree no.	No. of fertile plants	No. of partially sterile plants	Total no. of plants	Percent of partially sterile plants
PS-3PS-1PS-9PS	64	19	83	22.9
10PS	90	13	103	12.6
5PS-1PS-1PS	97	6	103	5.8
2PS	92	7	99	7.1
3PS	80	14	94	14.9
4PS	80	9	89	10.1
5PS	82	7	89	8.0
6PS	101	9	110	8.2
7PS	78	13	91	14.3
8PS	151	23	174	13.2
9PS	128	22	150	14.7
10PS	56	12	68	17.6
6PS-1PS-1PS	63	6	69	8.7
2PS	177	32	209	15.3
3PS	142	17	159	10.7
4PS	90	12	102	11.8
5PS	130	16	146	11.0
6PS	89	13	102	12.7
7PS	100	19	119	16.0
8PS	100	11	111	9.9
9PS	82	14	96	14.6
10PS	99	13	112	11.6
7PS-1PS-1PS	96	17	113	15.0
2PS	96	16	112	14.3
3PS	85	13	98	13.3
4PS	86	16	102	15.7
5PS	94	10	104	9.6
6PS	102	9	111	8.1
7PS	80	19	99	19.2
8PS	109	20	129	15.5
9PS	103	21	124	16.9
10PS	81 S1	9	91	9.9
8PS-1PS-1PS	103	10	113	8.8
2PS	90	10	100	10.0
3PS	101	7	108	6.5
4PS	97	14	111	12.6
5PS	102	8	110	7.3
6PS	59	17	76	22.4
7PS	132 S1	0	133	0
8PS	101	11	112	9.8

TABLE 23. (Continued).

Pedigree no.	No. of fertile plants	No. of partially sterile plants	Total no. of plants	Percent of partially sterile plants
PS-8PS-1PS-9PS	100	8	108	7.4
10PS	97	14	111	12.6
9PS-1PS-1PS	56	6	62	9.7
2PS	153	18	171	10.5
3PS	167	19	186	10.2
4PS	66	12	78	15.4
5PS	170	11	181	6.1
6PS	119	14	133	10.5
7PS	142	14	156	9.0
8PS	91	13	104	12.5
9PS	78	5	83	6.0
10PS	111	13	124	10.5
10PS-1PS-1PS	165	12	177	6.8
2PS	101	10	111	9.0
3PS	85	5	90	5.6
4PS	172	18	190	9.5
5PS	75	11	86	12.8
6PS	83 S1	14	98	14.3
7PS	111	17	128	13.3
8PS	98	15	113	13.3
9PS	97	11	108	10.2
10PS	127	6	133	4.5

TABLE 24.

Summing up the families in the preceeding table according to the family in 1923.

Pedigree no.	No. of fertile plants	No. of partially sterile plants	Total no. of plants	Percent of partially sterile plants
PS-1PS-1PS	788	103	891	11.56
2PS-1PS	1417	187	1604	11.66
3PS-1PS	1177	176	1353	13.01
4PS-1PS	939	140	1079	12.86
5PS-1PS	945	122	1067	11.43
6PS-1PS	1072	153	1225	12.49

TABLE 24. (Continued).

Pedigree no.	No. of fertile plants	No. of partially sterile plants	Total no. of plants	Percent of partially sterile plants
PS-7PS-1PS	933	150	1083	14.45
8PS-1PS	850	99	949	10.43
9PS-1PS	1153	125	1278	9.78
10PS-1PS	1115	119	1234	9.64
Total	10389	1374	11763	11.68

Generally speaking, when the segregation of a hybrid takes place with regard to two alternative characters one of them is dominant, and the other recessive; the number of dominant is larger than that of recessives; the dominant partly segregates, partly breeds true, and the recessive all breeds true. Nevertheless, in the offsring of the partially sterile plant, as the results of several years' investigations equally indicate, all of the fertiles which compose the larger part of the offspring breed true at once, while partial steriles which make the smaller number always throw about 7 fertiles to 1 partial sterile. Therefore, it will be seen readily that partial sterility is transmitted by the peculiar mechanism of inheritance.

2. Examination of the Percentage of Sterile Spikelets.

In 1922, the percentage of sterile spikelets of 10 partial steriles from each of 10 segregating families derived from 10 partial steriles in the previous year was examined. It was comparatively uniform, and that of sterile spikelets in total was 45.80 (Tables 25 and 26). Genetically fertile plants of rice set inevitably some sterile spikelets according to the external conditions, and also the semi-sterile plant of which fertile and sterile spikelets are genetically in a equal number sets always sterile spikelets, slightly over 50 percent. Therefore, the partially sterile plant though resembles closely semi-sterile plant in external appearance must be of a different kind from the latter.

Two families which bred true to fertile in 1923 were derived from two plants underlined in Table 25; the percentage of sterile spikelets of one of these was 36.1, and that of the other 74.1. Undoubtedly two plants set so many sterile spikelets owing to the external conditions. And one family differing considerably in a splitting manner from other families was derived also from the underlined plant which was semi-sterile, the percentage of its sterile spikelets being 54.2.

Once more, the percentage of sterile spikelets of 100 partial steriles which represented descendants of 10 partial steriles was examined in 1923. Showing pretty uniform numbers as Table 27 shows, it was generally under 50, and that of sterile spikelets totalled was 46.79 (Table 28). One family which consisted of only fertiles in 1924 was derived from a plant underlined in Table 27. The percentage of its sterile spikelets was 22.8, considerably smaller than that in others. The plant was sterile owing to the cause not genetical. In that year, the percentage of sterile spikelets of fertiles in the offspring of fertiles thrown by partial steriles was also examined, and that of sterile spikelets in total was 10,04 as will be seen in Table 29.

TABLE 25.

Showing the percentage of sterile spikelets of partial steriles in the segregating families in 1922.

Pedigree no.	Plant no.	No. of fertile spikelets	No. of sterile spikelets	Total no. of spikelets	Percent of sterile spikelets
PS-1PS	1PS	286	218	504	43.3
	2PS	349	285	634	45.0
	3PS	292	226	518	43.6
	4PS	223	209	432	48.4
	5PS	263	247	510	48.4
	6PS	218	145	363	39.9
	7PS	232	211	443	47.6
	8PS	349	288	637	45.2
	9PS	202	114	316	36.1
	10PS	199	169	368	45.9
PS-2PS	1PS	200	165	365	45.2
	2PS	230	231	461	50.1
	3PS	190	167	357	46.8
	4PS	250	242	492	49.2
	5PS	300	268	568	47.2
	6PS	241	194	435	44.6
	7PS	310	255	565	45.1
	8PS	222	182	404	45.0
	9PS	366	317	683	46.4
	10PS	217	212	429	49.4

TABLE 25. (Continued).

Pedigree no.	Plant no.	No. of fertile spikelets	No. of sterile spikelets	Total no. of spikelets	Percent of sterile spikelets
PS-3PS	1PS	228	196	424	46.2
	2PS	186	122	308	39.5
	3PS	367	298	665	44.8
	4PS	239	198	437	45.3
	5PS	242	178	420	42.4
	6PS	253	198	451	44.4
	7PS	193	169	362	46.7
	8PS	287	210	497	42.3
	9PS	240	185	425	43.5
	10PS	367	334	701	47.6
PS-4PS	1PS	201	155	356	43.5
	2PS	188	188	376	50.0
	3PS	282	246	528	46.6
	4PS	215	193	408	47.3
	5PS	186	220	406	54.2
	6PS	153	116	269	43.1
	7PS	177	152	329	46.0
	8PS	127	152	279	54.5
	9PS	236	204	440	46.4
	10PS	231	200	431	46.4
PS-5PS	1PS	361	265	626	42.3
	2PS	130	120	250	48.0
	3PS	240	227	467	44.3
	4PS	276	235	511	46.0
	5PS	335	270	605	44.6
	6PS	230	180	410	43.9
	7PS	331	264	595	44.4
	8PS	237	240	477	50.3
	9PS	263	217	480	45.2
	10PS	428	343	771	47.2
PS-6PS	1PS	254	202	456	44.3
	2PS	298	265	563	47.1
	3PS	248	181	429	42.2
	4PS	233	198	431	45.9
	5PS	202	166	368	45.1
	6PS	54	152	206	74.1
	7PS	166	160	326	49.0
	8PS	243	222	465	47.7
	9PS	252	235	487	48.3
	10PS	397	290	687	42.2
PS-7PS	1PS	322	283	605	46.8
	2PS	200	139	339	41.0

TABLE 25. (Continued).

Pedigree no.	Plant no.	No. of fertile spikelets	No. of sterile spikelets	Total no. of spikelets	Percent of sterile spikelets
PS-7PS	3PS	207	163	370	44.1
	4PS	213	181	394	45.9
	5PS	266	188	454	41.4
	6PS	218	178	396	44.9
	7PS	187	154	341	45.2
	8PS	272	200	472	42.4
	9PS	294	233	527	44.2
	10PS	429	361	790	45.7
PS-8PS	1PS	225	223	448	49.8
	2PS	196	172	368	46.7
	3PS	111	138	249	55.4
	4PS	194	168	362	46.4
	5PS	236	236	472	50.0
	6PS	318	270	588	45.9
	7PS	250	210	460	45.7
	8PS	257	221	478	46.2
	9PS	179	130	309	42.1
	10PS	225	199	424	46.9
PS-9PS	1PS	221	162	383	41.7
	2PS	231	186	417	44.6
	3PS	250	245	495	49.5
	4PS	196	140	336	41.7
	5PS	236	208	444	46.8
	6PS	230	214	444	48.2
	7PS	180	165	345	47.8
	8PS	316	257	573	44.9
	9PS	217	182	399	45.6
	10PS	254	190	444	42.8
PS-10PS	1PS	199	161	360	44.7
	2PS	179	133	312	42.3
	3PS	178	135	313	42.6
	4PS	194	175	369	47.4
	5PS	188	159	347	45.8
	6PS	216	170	386	44.0
	7PS	169	152	321	47.3
	8PS	351	351	702	50.0
	9PS	300	253	553	45.8
	10PS	197	202	399	50.6
Mean	—	—	—	—	45.69±0.220
Stand. dev.	—	—	—	—	3.22±0.155

TABLE 26.

Summing up the plants in the preceeding table according to the family.

Pedigree no.	No. of fertile spikelets	No. of sterile spikelets	Total no. of spikelets	Percent of sterile spikelets
PS-1PS	2411	1998	4409	45.32
2PS	2526	2233	4759	46.92
3PS	2602	2088	4690	44.52
4PS	1810	1606	3416	47.01
5PS	2831	2361	5192	45.47
6PS	2293	1919	4212	45.56
7PS	2608	2080	4688	44.37
8PS	2191	1967	4158	47.31
9PS	2331	1949	4280	45.47
10PS	2171	1891	4062	46.55
Total	23774	20092	43866	45.80

TABLE 27.

Showing the percentage of sterile spikelets of partial steriles *in the segregating families in 1923.*

Pedigree no.	Plant no.	No. of fertile spikelets	No. of sterile spikelets	Total no. of spikelets	Percent of sterile spikelets
PS-1PS-1PS	1PS	180	155	335	46.3
	2PS	189	160	349	45.8
	3PS	125	119	244	48.8
	4PS	108	92	200	46.0
	5PS	118	102	220	46.4
	6PS	148	151	299	50.5
	7PS	163	136	299	45.5
	8PS	202	172	374	46.0
	9PS	160	143	303	47.2
	10PS	143	105	248	42.3
2PS-1PS	1PS	191	159	350	45.4
	2PS	179	139	318	43.7
	3PS	269	259	528	49.1
	4PS	266	212	478	44.4
	5PS	250	206	456	45.2
	6PS	214	221	435	50.8

TABLE 27. (Continued).

Pedigree no.	Plant no.	No. of fertile spikelets	No. of sterile spikelets	Total no. of spikelets	Percent of sterile spikelets
2PS-1PS	7PS	220	211	431	49.0
	8PS	158	117	275	42.5
	9PS	217	203	420	48.3
	10PS	190	182	372	48.9
3PS-1PS	1PS	139	115	254	45.3
	2PS	233	94	327	28.7
	3PS	191	141	332	42.5
	4PS	240	248	488	50.8
	5PS	242	194	436	44.5
	6PS	154	115	269	42.8
	7PS	158	127	285	44.6
	8PS	125	106	231	45.9
	9PS	173	128	301	42.5
	10PS	186	181	367	49.3
4PS-1PS	1PS	162	125	287	43.6
	2PS	331	373	704	53.0
	3PS	162	188	350	53.7
	4PS	137	131	268	48.9
	5PS	273	178	451	39.5
	6PS	162	113	275	41.1
	7PS	133	162	295	54.9
	8PS	93	92	185	49.7
	9PS	114	70	184	38.0
	10PS	141	108	249	43.4
5PS-1PS	1PS	123	130	253	51.4
	2PS	146	156	302	51.7
	3PS	132	103	235	43.8
	4PS	117	95	212	44.8
	5PS	122	94	216	43.5
	6PS	171	189	360	52.5
	7PS	123	144	267	53.9
	8PS	237	229	466	49.1
	9PS	225	163	388	42.0
	10PS	143	105	248	42.3
6PS-1PS	1PS	122	129	251	51.4
	2PS	323	271	594	45.6
	3PS	245	199	444	44.8
	4PS	133	130	263	49.4
	5PS	201	216	417	51.7
	6PS	153	136	289	47.1
	7PS	174	150	324	46.3
	8PP	188	152	340	44.7

TABLE 27. (Continued).

Pedigree no.	Plant no.	No. of fertile spikelets	No. of sterile spikelets	Total no. of spikelets	Percent of sterile spikelets
PS-6PS-1PS	9PS	128	117	245	47.8
	10PS	214	268	482	55.6
7PS-1PS	1PS	139	140	279	50.2
	2PS	180	145	325	44.6
	3PS	153	143	296	48.3
	4PS	142	94	236	39.8
	5PS	172	157	329	47.7
	6PS	166	134	300	44.7
	7PS	140	124	264	47.0
	8PS	203	152	355	42.8
	9PS	231	202	433	46.7
	10PS	142	162	304	53.3
8PS-1PS	1PS	161	162	323	50.2
	2PS	119	125	244	51.2
	3PS	171	156	327	47.7
	4PS	130	100	230	43.5
	5PS	246	240	486	49.4
	6PS	99	70	169	41.4
	7PS	159	47	206	22.8
	8PS	331	296	627	47.2
	9PS	168	132	300	44.0
	10PS	215	185	400	46.3
9PS-1PS	1PS	125	142	267	53.2
	2PS	228	185	413	44.8
	3PS	223	200	423	47.3
	4PS	134	137	271	50.6
	5PS	241	209	450	46.4
	6PS	158	115	273	42.1
	7PS	190	178	368	48.4
	8PS	168	124	292	42.5
	9PS	115	120	235	51.1
	10PS	171	125	296	42.2
10PS-1PS	1PS	248	252	500	50.4
	2PS	146	134	280	47.9
	3PS	118	115	233	49.4
	4PS	324	281	605	46.4
	5PS	169	124	293	42.3
	6PS	126	90	216	41.7
	7PS	193	144	337	42.7
	8PS	179	160	339	47.2
	9PS	144	142	286	49.7
	10PS	175	120	295	40.7
Mean	—	—	—	—	46.49±0.300
Stand. dev.	—	—	—	—	4.43±0.212

TABLE 28.

Summing up the plants in the preceeding table according to the family.

Pedigree no.	No. of fertile spikelets	No. of sterile spikelets	Total no. of spikelets	Percent of spikelets
PS-1PS-1PS	1536	1335	2871	46.50
2PS-1PS	2154	1909	4063	46.98
3PS-1PS	1841	1449	3290	44.04
4PS-1PS	1708	1540	3248	47.41
5PS-1PS	1539	1408	2947	47.78
6PS-1PS	1881	1768	3649	48.45
7PS-1PS	1668	1453	3121	46.56
8PS-1PS	1640	1466	3106	47.20
9PS-1PS	1753	1535	3288	46.68
10PS-1PS	1822	1562	3384	46.16
Total	17542	15425	32967	46.79

TABLE 29.

Showing the percentage of sterile spikelets of fertiles in the constant fertile families in 1923.

Pedigree no.	Plant no.	No. of fertile spikelets	No. of sterile spikelets	Total no. of spikelets	Percent of sterile spikelets
PS-1PS-1F	1F	364	20	384	5.2
	2F	192	19	211	9.0
	3F	330	34	364	9.3
	4F	318	14	332	4.2
	5F	240	21	461	8.0
	6F	269	21	290	7.2
	7F	224	18	242	7.4
	8F	223	14	237	5.9
	9F	271	14	285	4.9
	10F	236	10	246	4.1
5PS-1F	1F	349	64	413	15.5
	2F	370	58	428	13.6
	3F	552	73	625	11.7
	4F	315	53	368	14.4
	5F	270	38	308	12.3
	6F	396	57	453	12.6

TABLE 29. (Continued).

Pedigree no.	Plant no.	No. of fertile spikelets	No. of sterile spikelets	Total no. of spikelets	Percent of sterile spikelets
PS-5PS-1F	7F	439	65	504	12.9
	8F	306	48	354	13.6
	9F	348	46	394	11.7
	10F	323	35	358	9.8
10PS-1F	1F	367	28	395	7.1
	2F	506	56	562	10.0
	3F	273	9	282	3.2
	4F	380	43	423	10.2
	5F	350	19	369	5.1
	6F	356	17	373	4.6
	7F	485	95	580	16.4
	8F	300	33	333	9.9
	9F	305	27	332	8.1
	10F	425	76	501	15.2
Total	—	10082	1125	11207	10.04
Mean	—	—	—	—	9.40±0.669
Stand. dev.	—	—	—	—	5.43±0.473

For a third time, the percentage of sterile spikelets of 50 partial steriles which represented also descendants of 10 partial steriles in 1921 was examined in 1924. For that year, variation of the percentage was also small (Table 30). The percentage of sterile spikelets in total was 43.72 (Table 31), somewhat less than those of the previous two years.

Several years' results of investigation show that partial steriles set usually from 40 to 50 percent sterile spikelets, some of which proved sterility by the cause not genetical, because genetically fertile plants also set some sterile spikelets. And it is reasonable under the same cultural conditions to suppose that the differences of percentages of sterile spikelets in different years are due mainly to the difference of climate.

TABLE 30.

Showing the percentage of sterile spikelets of partial steriles in the segregating families in 1924.

Pedigree no.	Plant no.	No. of fertile spikelets	No. of sterile spikelets	Total no. of spikelets	Percent of sterile spikelets
PS-1PS-1PS-2PS	1PS	786	505	1291	39.1
	2PS	586	450	1036	43.4
	3PS	480	382	862	44.3
	4PS	238	217	455	47.7
	5PS	474	355	829	42.8
2PS-1PS-1PS	1PS	165	111	276	40.2
	2PS	310	248	558	44.4
	3PS	418	341	759	44.9
	4PS	388	351	739	47.5
	5PS	448	358	806	44.4
3PS-1PS-1PS	1PS	422	337	759	44.4
	2PS	393	342	735	46.5
	3PS	559	408	967	42.2
	4PS	363	262	625	41.9
	5PS	407	319	726	43.9
4PS-1PS-1PS	1PS	355	293	648	45.2
	2PS	261	209	470	44.5
	3PS	396	344	740	46.5
	4PS	299	269	568	47.4
	5PS	337	275	612	44.9
5PS-1PS-1PS	1PS	300	248	548	45.3
	2PS	476	339	815	41.6
	3PS	356	282	638	44.2
	4PS	512	413	925	44.6
	5PS	239	197	436	45.2
6PS-1PS-1PS	1PS	521	389	910	42.7
	2PS	499	380	879	43.2
	3PS	296	241	537	44.9
	4PS	633	547	1180	46.4
	5PS	546	399	945	42.2
7PS-1PS-1PS	1PS	320	230	550	41.8
	2PS	308	252	560	45.0
	3PS	369	286	655	43.7
	4PS	695	492	1187	41.4
	5PS	388	276	664	41.6
8PS-1PS-1PS	1PS	633	418	1051	39.8
	2PS	529	368	897	41.9
	3PS	381	338	719	47.0
	4PS	266	226	492	45.9

TABLE 30. (Continued).

Pedigree no.	Plant no.	No. of fertile spikelets	No. of sterile spikelets	Total no of spikelets	Percent of sterile spikelets
PS-8PS-1PS-1PS	5PS	295	244	539	44.9
9PS-1PS-1PS	1PS	568	397	965	41.1
	2PS	401	203	704	43.0
	3PS	489	381	870	43.8
	4PS	426	356	782	45.5
	5PS	437	335	772	43.4
10PS-1PS-1PS	1PS	250	190	440	43.2
	2PS	423	342	765	44.7
	3PS	232	175	407	43.0
	4PS	311	277	588	47.1
	5PS	253	256	609	42.0
Mean	—	—	—	—	43.84±0.192
Stand. dev.	—	—	—	—	2.01±0.135

TABLE 31.

Summing up plants in the preceeding table according to the family.

Pedigree no.	No. of fertile spikelets	No. of sterile spikelets	Total no. of spikelets	Percent of sterile spikelets
PS-1PS-1PS-2PS	2564	1909	4473	42.68
2PS-1PS-1PS	1729	1409	3138	44.90
3PS-1PS-1PS	2144	1668	3812	43.76
4PS-1PS-1PS	1648	1390	3038	45.75
5PS-1PS-1PS	1883	1479	3362	43.99
6PS-1PS-1PS	2495	1956	4451	43.95
7PS-1PS-1PS	2080	1536	3616	42.48
8PS-1PS-1PS	2104	1594	3698	43.10
9PS-1PS-1PS	2321	1772	4093	43.29
10PS-1PS-1PS	1569	1240	2809	44.14
Total	20537	15953	36490	43.72

3. Observation on the Natural Cross.

Natural crosses among offspring of 100 partial steriles were examined in 1923. The result is shown in Table 32. According to it, the offspring of partial steriles did not contain many plants having different characters except one family which apparently was derived from a plant produced by natural crossing, and the percentage of natural crosses in families besides that family was 0.38. Natural crosses among 50 constant fertile families were also investigated in the same year, their percentage being 0.17 (Table 33). So we can say that there is almost no difference between partial sterile and fertile in regard to the frequency of natural crossing.

As natural crossing does not occur frequently in partial sterile, it will be seen that the manner of inheritance of partial sterility is not influenced by the natural cross to any extent, and that sterility in that case is not due to the deficiency of pollen grains as observed in the sterile plant.

TABLE 32.

Showing the result of observation of natural crosses in the segregating families in 1923.

Predigree no.	Color of the glume-tip			Length of the awn	
	Changed	Red or purple	Colorless	Long	Short
PS-1PS-1PS	209	1			
2PS	193				
3PS	197	1			
4PS	189				
5PS	210				
6PS	139				
7PS	188				
8PS	210	1			
9PS	154				
10PS	152				
2PS-1PS	156	2			
2PS	185	1			
3PS	134				
4PS	199			1	
5PS	209				
6PS	172				

TABLE 32. (Continued).

Pedigree no.	Color of the glume-tip			Length of the awn	
	Changed	Red or purple	Colorless	Long	Short
PS-1PS-7PS	221				
8PS	178	1			
9PS	222				
10PS	173				
3PS-1PS	170	1			
2PS	153				
3PS	222				
4PS	175				
5PS	168	1			
6PS	196				
7PS	146	1			
8PS	217				
9PS	181				
10PS	227				
4PS-1PS	164	1			
2PS	36	85	36		
3PS	213	2		1	
4PS	190	1			
5PS	158				1
6PS	130	1			
7PS	151				
8PS	108				
9PS	158				
10PS	166	1			
5PS-1PS	218			1	
2PS	101				
3PS	176	2			1
4PS	194				
5PS	217				
6PS	170	1			
7PS	218				
8PS	174				
9PS	204	1			
10PS	208	1			
6PS-1PS	177				
2PS	213	1			
3PS	166	1			
4PS	187	1			
5PS	166				
6PS	41				
7PS	140				
8PS	203				

TABLE 32. (Continued).

Pedigree no.	Color of the glume-tip			Length of the awn	
	Changed	Red or purple	Colorless	Long	Short
PS-6PS-9PS	198	1			
10PS	221	3			
7PS-1PS	223	1			
2PS	159				
3PS	155				
4PS	141				
5PS	186				
6PS	159				
7PS	144				
8PS	220	2			1
9PS	224	2			
10PS	226	1			
8PS-1PS	175	1		1	
2PS	160				
3PS	77			1	
4PS	125	1			
5PS	156	2			
6PS	226	1			
7PS	193				
8PS	165	2			
9PS	134				
10PS	158	1			
9PS-1PS	144			2	
2PS	180				
3PS	192	3			
4PS	144	2			
5PS	170				
6PS	191				
7PS	138				
8PS	225				
9PS	152				
10PS	205	2			
10PS-1PS	155	1			
2PS	145				
3PS	137	1			
4PS	170				
5PS	159	1			
6PS	168	2			
7PS	129	1			

TABLE 32. (Continued).

Pedigree no.	Color of the glume-tip			Length of the awn	
	Changed	Red or purple	Colorless	Long	Short
PS-10PS-8PS	234				
9PS	222	2			
10PS	161				
Total	17402	57		7	3
		67			
Percent		0.38			

TABLE 33.

Showing the result of observation of natural crosses in the constant fertile families in 1923.

Pedigree no.	Color of the glume-tip			Length of the awn	
	Changed	Red or purple	Colorless	Long	Short
PS-1PS-1F	204	1			
2F	201				
3F	224				
4F	215				
5F	218				
2PS-1F	189				
2F	198	1			
3F	223	2			
4F	222	1			
5F	213	1			
3PS-1F	188				
2F	216				
3F	206				
4F	193			1	
5F	177				
4PS-1F	189				
2F	189	2			
3F	146				2
4F	214	1			
5F	213				
5PS-1F	219	1			
2F	220				
3F	217				1
4F	172				

TABLE 33. (Continued).

Pedigree no.	Color of the glume-tip			Length of the awn	
	Changed	Red or purple	Colorless	Long	Short
PS-5PS-5F	218				
6PS-1F	226				
2F	218				
3F	226				
4F	215				
5F	224				
7PS-1F	209				
2F	183				
3F	176				
4F	206				
5F	227				
8PS-1F	217	1			
2F	216				
3F	142				
4F	209	1			
5F	217				
9PS-1F	224				
2F	219				
3F	211				
4F	231				
5P	224				
10PS-1F	218	1			
2F	224	1			
3F	159				
4F	222				
5F	203				
Total	10321	14		1	3
		18			
Percent		0.17			

4. The results of the Cytological Investigation.

In 1924, 20 flowers from each of 33 plants in the offspring of 7 partial steriles were fixed immediately before flowering, and 5 of these plants were found to be partially sterile in the autumn.

The embryo sacs and pollen grains of these partial steriles were found to be normal not differing from those of fertiles. The anthers of a partial sterile and a fertile in the segregating family are shown in Figs. 7 and 8 respectively. In 1925, likewise 20 young flowers from each of 15 plants thrown by partial sterile were fixed for the study of division of the pollen mother cell. Three of those plants were found to be partial sterile at the harvest, and they all segregated in 1926. In the three partial steriles, the meiosis and the tetrad formation were carried on normally, and any irregularity could not be found. The chromosome number was also 12 as the haploid number. Figs. 9 and 10 show chromosome distribution in a plant which was ascertained to segregate into 105 fertiles and 14 partial steriles in 1926. Fig. 11 shows the tetrads in a plant ascertained to segregate into 114 fertiles and 9 partial steriles also in 1926.

Although useless practically, partial steriles as the material for precise studies must be examined as to whether they are really genetical or not by breeding their offspring because they result at times by the external conditions as already stated repeatedly.

At the flowering time in 1925, pollen grains of 54 plants in the offspring of 10 partial steriles were scattered on glycerin which was dropped on the slide, and inspected carefully under the microscope. All plants had generally normal shaped grains with living protoplasmic contents, and any difference could not be found among them. In the autumn of that year, 3 of these plants were found to be partial sterile.

In 1926, 20 flowers from each of 40 plants in 5 families were fixed twice at the different stage of development, at bloom and on the third day after flowering. Four plants out of 40 were found to be partially sterile in the autumn. All ovaries of partial steriles at bloom were normal, but those on the third day after flowering consisted of two kinds; one was normal and the other carried no embryo.

In addition to these investigations, an attempt of artificial germination of pollen grains was undertaken in 1926 to ascertain whether the pollen of partial steriles is capable to send tube as usual or not. The artificial germination of rice pollen had been regarded as a very difficult task. At most only 7 percent of pollen grains were able to be germinated as in Sasaki's (1919) experiment. However, recently Gotoh (1926) improved the culture method of the pollen, when he found that in the hanging drop culture alkali which hinders the germination of pollen grains dissolves out readily into culture media from the soft cover glass.

Usually about 40 percent germination can be obtained in rice pollen on a culture media which contains 10 percent beet sugar and 1 percent agar by the improved method. Applying it to the pollen of our partial steriles and fertiles, the results as shown in Table 34 were obtained.

The pollen was collected from untimely late panicles of four plants, in which one could already distinguish partial sterile from fertile by means of thorough inspection of the glumes of early panicles of these plants. The four plants were discovered after much effort, examining carefully about 600 plants in the offspring of 5 partial steriles. No difference in the pollen germination could be, however, found in partial steriles and fertiles, the average germination percentage of partial steriles being 48.79 and that of fertile 38.4.

TABLE 34.

Showing the results of pollen germination test in 1926.

Plant no.	Slide no.	Microscopic field no.	Found no.		Percent	
			Germ.	Ungerm.	Germ.	Ungerm.
76(PS)	1	1	11	8	57.9	42.1
76(PS)	1	2	12	18	40.0	60.0
76(PS)	2	1	13	9	59.1	40.9
76(PS)	2	2	7	5	58.3	41.7
85(PS)	5	1	12	9	57.1	42.9
85(PS)	5	2	12	16	42.9	57.1
85(PS)	6	1	9	11	45.0	55.0
85(PS)	6	2	6	14	30.0	70.0
Mean	—	—	—	—	48.79	51.21
46(F)	3	1	10	29	25.6	74.4
46(F)	3	2	14	17	45.2	54.8
23(F)	4	1	5	13	27.8	72.2
23(F)	4	2	11	9	55.0	45.0
Mean	—	—	—	—	38.4	61.6

Thus we see that the female organs develop perfectly; and on the other hand, the reduction division of the pollen mother cells and the consequent tetrad formation are carried on normally. Moreover, pollen abortion and lower pollen germination can not be found by any means. The embryos, however, are not formed in the sterile flowers of the partially sterile plant.

5. The Results of the Artificial Cross.

Partially sterile plants have not morphologically any special characteristics which distinguish them from others in the flowering time. And as the offspring of partial steriles consist of a majority of fertiles and a small number of partial steriles i.e. in the approximate ratio of 7 : 1, crosses between fertile and partial sterile must be a difficult work. Moreover, the artificial cross in rice is harder than that in other species of *Graminiae*, and the percentage of fertilization by artificial crossing is not so high even through skilful technique. Therefore, it is not easy to get many seeds by crossing between fertile and partial sterile, and it is still harder to succeed in crosses between partial steriles.

Artificial crosses between offspring of partial sterile with each other were carried out in 1924 and 1925. The number of F1 plants obtained by these crosses were 16 in 1925 and 342 in 1926. In the former case, the 16 plants were hybrids strictly between the fertiles, and they were also fertile as shown in Table 35. But notwithstanding 69 plants out of 342 in the latter case were hybrids produced by the partial steriles by fertiles, the others being those between fertiles, all of them were fertile as will be seen in Table 36.

TABLE 35.

Showing the F_1 plants obtained in 1925.

Mother plant no. in 1924		Father plant no. in 1924	Number of F_1 plants obtained
16 (F)	×	50 (F)	7 (F)
59 (F)	×	42 (F)	4 (F)
18 (F)	×	47 (F)	3 (F)
4 (F)	×	34 (F)	1 (F)
1 (F)	×	9 (F)	1 (F)
Total			16 (F)

TABLE 36.

Showing the F_1 plants obtained in 1926.

Mother plant no. in 1925	Father plant no. in 1925	Number of F_1 plants obtained
55 (PS) ×	69 (F)	3 (F)
55 (PS) ×	91 (F)	1 (F)
60 (F) ×	99 (F)	4 (F)
61 (F) ×	18 (F)	12 (F)
63 (F) ×	18 (F)	7 (F)
63 (F) ×	57 (F)	13 (F)
64 (F) ×	18 (F)	15 (F)
64 (F) ×	68 (F)	15 (F)
64 (F) ×	94 (F)	8 (F)
64 (F) ×	95 (F)	10 (F)
64 (F) ×	98 (F)	7 (F)
64 (F) ×	100 (F)	20 (F)
70 (PS) ×	92 (F)	8 (F)
70 (PS) ×	94 (F)	7 (F)
70 (PS) ×	97 (F)	6 (F)
70 (PS) ×	98 (F)	6 (F)
84 (PS) ×	91 (F)	9 (F)
84 (PS) ×	92 (F)	10 (F)
84 (PS) ×	98 (F)	19 (F)
85 (F) ×	92 (F)	13 (F)
85 (F) ×	93 (F)	7 (F)
85 (F) ×	99 (F)	16 (F)
86 (F) ×	90 (F)	7 (F)
86 (F) ×	96 (F)	10 (F)
87 (F) ×	97 (F)	11 (F)
87 (F) ×	98 (F)	7 (F)
88 (F) ×	95 (F)	20 (F)
88 (F) ×	97 (F)	8 (F)
89 (F) ×	30 (F)	16 (F)
89 (F) ×	85 (F)	18 (F)
89 (F) ×	92 (F)	24 (F)
Total		342 (F)

Three mother partial steriles in the above table were ascertained to segregate in 1926; No. 55, 60 fertiles to 12 partial steriles; No. 70, 61 fertiles to 13 partial steriles; and No. 84, 70 fertiles to 17 partial steriles.

It is a remarkable fact that partial steriles are not obtained by the cross between fertiles, and also not produced even though they are pollinated by fertile plants notwithstanding they segregated always into fertiles and partial steriles.

6. The results of Germination Tests of the Seed.

It is well known both in the animal and plant kingdoms that embryos are often abortive owing to the zygotic lethal gene or some combinations of genes, and it leads in consequence to ungermination of seeds in plants. Therefore, it is necessary to ascertain in genetical studies of organisms which throw offspring in an unusual splitting ratio whether such a fact exists or not.

The seeds of 5 partial steriles and 5 fertiles from a certain segregating family which were harvested in September, 1925 were tested for germination in June 1926. One hundred seeds from each plant were arranged on sterilized sand in a dish and put in the germinating chamber, where the temperature was kept 30°C. Most of them ended germination in 5 days. As Table 37 shows, seeds from either partial sterile or fertile germinated well, and the percentages of germinated seeds were almost the same in both cases. Only slight excess of ungerminated seeds was shown in partial steriles. Namely, the mean percent of ungerminated seeds of partial steriles was 3.2 while that of fertiles was 0.8.

The germinating dishes were taken out from the chamber in a week after they were put in it. All seedlings of either fertile or partial sterile continued uniform growth in the germinating dishes until they were thrown away when they reached the length of 15 c.m.

TABLE 37.

Showing the results of germination tests of seeds of plants grown in 1925.

Partial sterile no.	No. of seeds		Fertile no.	No. of seeds	
	Germ.	Ungerm.		Germ.	Ungerm.
1	97	3	1	100	0
2	99	1	2	99	1
3	99	1	3	100	0
4	94	6	4	100	0
5	95	5	5	97	3
Mean	96.8	3.2	Mean	99.2	0.8

Once more, the germination tests of the seeds of 2 or 3 plants of fertiles and partial steriles respectively from each of segregating families harvested in September, 1926 were carried out a month and a half after by the same method as in the former case. It was probably due to the too much short period after the harvest that the number of ungerminated seeds was slightly greater and conspicuously more variable than in the former case. As shown in Table 38, the mean percent of ungerminated seeds was 5.1 in partial steriles while it was 2.8 in fertiles. Ungerminated seeds of partial sterile were in slight excess also in this case.

TABLE 38.

Showing the results of germination tests of seeds of plants grown in 1926.

Partial sterile no.	No. of seeds		Fertile no.	No. of seeds	
	Germ.	Ungerm.		Germ.	Ungerm.
1	97	3	1	91	9
2	97	3	2	98	2
3	96	4	3	98	2
4	97	3	4	97	3
5	96	4	5	96	4
6	85	15	6	100	0
7	91	9	7	99	1
8	96	4	8	97	3
9	99	1	9	99	1
10	95	5	10	97	3
Mean	94.9	5.1	Mean	97.2	2.8

The number of ungerminated seeds of partial sterile was very small in the above experiments, so that it is not to be assumed as due to some combinations of genes or the zygotic lethal gene. But slight as it was, the excess of ungerminated seeds of partial sterile over those of fertile indicates that there is a mark of difference in the vigour of embryos between fertile and partial sterile.

7. Summary.

1. A partially sterile plant was found with the sterile plant in the same plot in 1920, and to throw 166 fertiles and 10 partial steriles in 1921. All of these fertiles bred true, and every partial sterile threw about 7 fertiles to 1 partial sterile in 1922, the percentage of partial sterile in 10 segregating families being 12.32. The percentage of partial steriles in 97 families was 12.90 in 1923, and that in 99 families was 11.68 in 1924. It must be a peculiar mode of inheritance that in the offspring of partial sterile, all the fertiles which compose the larger part of that offspring breed true at once while all the partial steriles which make the smaller number segregate repeatedly in the same manner.

2. The percentage of sterile spikelets of partial sterile is fairly uniform. It ranges generally from 40 percent to 50 percent and varies more or less according to the climatic condition of the year. The percentages of sterile spikelets in total were 45.80 in 1922, 46.79 in 1923, and 43.72 in 1924.

3. Natural crosses among the offspring of 100 partial steriles and 50 fertiles thrown by partial steriles were examined, and their occurrence was ascertained to be seldom in the offspring of partial sterile as in that of fertile.

4. The ovules of partial steriles do not differ from those of normal plants in their development. The division of the pollen mother cell is carried on normally, and the abortion can not be found in any stage of the pollen development and maturity. And the pollen grains germinated as good as those of fertiles on the culture media. The chromosome number of partial steriles is 12 in a reduced number.

5. Two hundred and eighty nine F1 plants which were obtained by crossing between fertiles thrown by partial steriles were all fertile, and also 69 F1 plants obtained by partial steriles by fertiles were fertile without any exception.

6. The seeds of partial steriles germinated almost as good as those of fertiles, but the slight excess of ungerminated seeds of partial steriles indicates a mark of inferiority in the vigour of their embryos.

III. On the Semi-Sterile Plant.

1. Observation on the Mode of Inheritance.

Among the families segregating into fertiles and partial steriles, a family, the half of which consisted of semi-sterile plants was found in 1923 as already stated, but it was quite uniform in other characteristics besides the sterility. Its parent might be also a semi-sterile plant, mutant in the experimental plot of partial steriles, and collected as a parent stock by mistake because the semi-sterile plant so much resembles the partially sterile plant that it can be scarcely distinguished from the latter in the field even through careful observation. The semi-sterile plant sets usually slightly over 50 percent sterile spikelets. The sterile spikelets do not occupy definite areas in the panicle. They are uniformly distributed from the bottom to the top of panicles.

In 1923, 20 plants of fertiles and semi-steriles respectively were collected from the family, and in 1924 all the fertiles bred true while all the semi-steriles threw again 1 fertile to 1 semi-sterile as in the case of the semi-sterile plant found by Terao (1921) in the pedigree culture of a rice variety, Sekiyama. The variation in the percentage of semi-steriles among segregating families was comparatively small ranging from 36.5 percent to 62.7 percent, and the percentage of semi-steriles in a total of 20 families was 50.96 (Table 39).

The field observation in 1924 was sufficient to prove that the segregation of semi-sterile is in the 1 : 1 ratio, so that a further observation was though unnecessary. The ratio 1 : 1 does not, however, so frequently appear in biological field except concerning sexuality, and Belling (1914) and Terao (1921) have only obtained thus for the same ratio in the segregation of semi-sterile. But the two authors' interpretations differ from each other. An intense cytological study and cross experiments on a larger scale were therefore undertaken to know to which of the two interpretations our semi-sterility is to be applied, or whether a different mechanism of heredity may exist there or not.

TABLE 39.

Showing the percentage of semi-steriles in the segregating families in 1924.

Pedigree no.	No. of fertile plants	No. of semi-sterile plants	Total no. of plants	Percent of semi-sterile plants
PS-4PS-5PS-1SS	35	40	75	50.3
2SS	47	57	104	54.8
3SS	43	37	80	46.3
4SS	40	49	89	55.1
5SS	70	74	144	50.3
6SS	33	29	62	46.8
7SS	46	46	92	50.0
8SS	39	39	78	50.0
9SS	66	48	114	42.1
10SS	43	44	87	50.6
11SS	46	41	87	47.1
12SS	54	68	122	55.7
13SS	39	40	79	50.6
14PS	28	47	75	62.7
15SS	30	50	80	62.5
16SS	48	42	90	46.7
17SS	53	47	100	47.0
18SS	54	31	85	36.5
19SS	26	32	58	55.2
20SS	26	42	68	61.8
Total	869	903	1772	50.96
Expect. (1:1)	886	886	1772	50.00
Dev./P.E.				1.197

2. Examination of the Percentage of Sterile Spikelets.

The percentage of sterile spikelets of 20 semi-sterile plants in the offspring of a semi-sterile plant which set 54.2 percent sterile spikelets as shown in Table 25 was examined in 1923. As will be seen in Table 40, it was comparatively uniform ranging from 48.1 to 70.9. And the percentage of all of these sterile spikelets was 57.36. All the plants set over 50 percent sterile spikelets except one plant. Once more, the percentage of sterile spikelets of about 10 semi-sterile plant from each of 6 segregating families was examined in 1924. As Table 41 indicates, its variation among 60 plants was very small. The maximum was 65.7 and the minimum 47.0, the percentage of sterile spikelets in total being 54.09. Except two plants, all the plants set over 50 percent sterile spikelets. Fertile plants in the segregating family set more or less sterile spikelets. The percentage of all the sterile spikelets of 27 fertile plants collected in the same year from three segregating families was 7.62 as shown in Table 42.

TABLE 40.

Showing the percentage of sterile spikelets of semi-steriles in 1923.

Pedigree no.	Plant no.	No. of fertile spikelets	No. of sterile spikelets	Total no. of spikelets	Percent of sterile spikelets
PS-4PS-5PS	1SS	95	135	230	58.7
	2SS	173	204	377	54.1
	3SS	123	130	253	51.4
	4SS	131	195	326	59.8
	5SS	196	250	446	56.1
	6SS	97	145	242	59.9
	7SS	123	143	266	53.8
	8SS	132	143	275	52.0
	9SS	160	148	308	48.1
	10SS	134	187	321	58.3
	11SS	107	154	261	59.0
	12SS	155	205	360	56.9
	13SS	103	154	257	59.9
	14SS	123	147	270	54.4
	15SS	103	185	288	64.2
	16SS	140	187	327	57.2
	17SS	126	164	290	56.6
	18SS	99	164	263	62.4
	19SS	77	95	172	55.2
	20SS	82	200	282	70.9
Total		2479	3335	5814	57.36
Mean					57.00±0.749
Stand. dev.					4.97±0.530

TABLE 41.

Showing the percentage of sterile spikelets of semi-steriles in 1924.

Pedigree no.	Plant no.	No. of fertile spikelets	No. of sterile spikelets	Total no. of spikelets	Percent of sterile spikelets
PS-4PS-5PS-1SS	1SS	220	241	461	52.3
	2SS	269	308	577	53.4
	3SS	334	352	686	51.3
	4SS	307	342	649	52.7
	5SS	188	219	407	53.8
	6SS	471	567	1038	54.6
	7SS	480	561	1041	53.9
	8SS	374	438	812	53.9
	9SS	257	338	595	56.8
	10SS	262	305	567	53.8
PS-4PS-5PS-4SS	1SS	358	414	772	53.6
	2SS	300	332	632	52.5
	3SS	439	504	943	53.4
	4SS	369	504	873	57.7
	5SS	286	369	655	56.3
	6SS	296	318	614	51.8
	7SS	264	273	537	50.8
	8SS	145	171	316	54.1
	9SS	314	326	640	50.9
	10SS	238	268	506	53.0
	11SS	413	543	956	56.8
PS-4PS-5PS-8SS	1SS	373	387	760	50.9
	2SS	429	534	963	55.5
	3SS	252	321	573	56.0
	4SS	285	295	580	50.9
	5SS	265	295	560	52.7
	6SS	325	427	752	56.8
	7SS	390	418	808	51.7
	8SS	271	340	611	55.6
	9SS	318	411	729	56.4
PS-4PS-5PS-12SS	1SS	337	299	636	47.0
	2SS	321	404	725	55.7
	3SS	179	233	412	56.6
	4SS	182	219	401	54.6
	5SS	205	235	440	53.4
	6SS	374	374	748	50.0
	7SS	298	354	652	54.3
	8SS	313	360	673	53.5
	9SS	365	449	814	55.1

TABLE 41. (Continued).

Pedigree no.	Plant no.	No. of fertile spikelets	No. of sterile spikelets	Total no. of spikelets	Percent of sterile spikelets
PS-4PS-5PS-12SS	10SS	246	330	576	57.3
PS-4PS-5PS-16SS	1SS	476	598	1074	55.7
	2SS	263	278	541	51.4
	3SS	264	329	593	55.5
	4SS	411	486	897	54.2
	5SS	360	416	776	53.6
	6SS	379	441	820	53.8
	7SS	298	325	623	52.2
	8SS	433	430	863	49.8
	9SS	421	421	842	50.0
	10SS	274	319	593	53.8
PS-4PS-5PS-20SS	1SS	298	344	642	53.6
	2SS	277	517	794	65.1
	3SS	241	318	559	56.9
	4SS	388	471	859	54.8
	5SS	172	330	502	65.7
	6SS	203	217	420	51.7
	7SS	411	435	846	51.4
	8SS	179	238	417	57.1
	9SS	283	340	623	54.6
	10SS	208	226	434	52.1
Total		18551	21857	40408	54.09
Mean					53.91±0.287
Stand. dev.					3.30±0.203

TABLE 42.

Showing the percentage of sterile spikelets of fertiles in the offspring of semi-steriles, in 1924.

Pedigree no.	Plant no.	No. of fertile spikelets	No. of sterile spikelets	Total no. of spikelets	Percent of sterile spikelets
PS-4PS-5PS-1SS	1F	736	38	1074	4.9
	2F	708	73	781	9.3
	3F	654	56	710	7.9
	4F	393	33	426	7.7
	5F	414	20	434	4.6
	6F	778	70	848	8.3
	7F	356	37	393	9.4

TABLE 42. (Contuined).

Pedigree no.	Plant no.	No. of fertile spikelets	No. of sterile spikelets	Total no. of spikelets	Percent of sterile spikelets
PS-4PS-5PS-1SS	8F	841	51	892	5.7
	9F	514	51	565	9.0
	10F	695	76	771	9.9
PS-4PS-5PS-12SS	1F	741	51	792	6.4
	2F	747	58	805	7.2
	3F	594	45	639	7.1
	4F	749	43	792	5.4
	5F	567	75	642	11.7
	6F	655	66	721	9.2
	7F	599	42	641	6.6
	8F	632	26	658	4.0
	9F	908	82	990	8.3
	10F	667	30	697	4.3
PS-4PS-5PS-20SS	1F	511	46	557	8.3
	2F	484	50	534	9.4
	3F	785	83	868	9.6
	4F	810	51	861	5.9
	5F	512	59	571	10.3
	6F	349	29	378	7.7
	7F	743	72	815	8.8
Total		17142	1413	18555	7.62
Mean					7.54±0.270
Stand. dev.					2.08±0.191

The sterile spikelets of fertiles and some of those of semi-steriles result by the physiological conditions such as the want of the nourishment, insufficiency of water etc. And as will be stated later, half the flowers of the semi-sterile plant are genetically sterile and unable to develop following the bloom, so that the struggle for existence in the flowers of semi-steriles might be less severe than in those of fertiles. This seems to explain why the excess from 50 percent in the percentage of sterile spikelets of the semi-sterile plant does uot usually reach that of the fertile plant.

According to the above results, it will be seen that the semi-sterile plants set usually sterile spikelets slightly over 50 percent, and the variation in the percentage is comparatively small.

3. The Results of the Cytological Investigation.

The reduction division of pollen mother cells of the semi-sterile plant is carried on normally, and the irregular chromosome distribution is never observed as generally in the cases of the sterile and partially sterile plant.

Semi-sterile has 12 chromosomes as the haploid number. The tetrad formation is normal, and any pollen abortion does not occur immediately after liberation. It takes place, however, toward the period of pollen maturation. The paraffin sections of the flowers fixed immediately before flowering show pollen abortion in various grades (Fig. 12); some abortive pollen grains have the same size and shape as normal; some have the irregular shape and very often fold in two; some are very small but round; but others distintegrate very much leaving only their fragments. Most of them lose their contents and are transparent, but some of them have scattered cytoplasm stained faintly. Although as to the period when pollen abortion takes place there is not much difference between the semi-sterile and sterile plant, most of the abortive pollen of the latter can reach the normal pollen size.

The pollen abortion arises in every anther of the flowers of the semi-sterile plant, and the number of abortive pollen grains is about the same as that of the normal pollen.

On the other hand, microtome sections of 44 flowers of a semi-sterile plant which were fixed at the flowering time showed that just a half of them had perfect embryo sacs and none of the other 22 flowers had the embryo sac. The remains of the aborted megaspore scarcely could be seen. Belling (1914) stated that about half the ovules of semi-sterile plants obtained by the *Stizolobium* cross had either quite aborted embryo sacs, the nucellus being a uniformly cellular mass, in which, however, the remains of the aborted megaspore could usually be distinguished, or had only a small cavity instead of having the embryo sac.

But in our cases neither remains of the aborted megaspore nor cavity in the ovules could be seen. The place otherwise occupied by the embryo sac was filled by the slender cells as those which are usually seen around megaspores and embryo sacs (Fig. 13). And these cells could be hardly stained with haematoxylin, remaining colorless though luminous. So they could be easily distinguished from other cells of the nucellus. All of them lost their contents already when examined at the flowering time. It is, therefore, natural to suppose that when the megaspore is formed and degenerates, the slender cells which surround it divide again and again taking the place of the embryo sac. But following the increase of such cells, degeneration might arise there losing almost their contents as often seen in the cells at the periphery of the well developed embryo sac.

Notwithstanding the anther of the semi-sterile plant contains the abortive pollen in half the number, it bursts well and sheds good pollen grains while in the sterile plant, as cited already, the dehiscence of the anther does not occur probably owing to the presence of many abortive pollen grains. Thus semi-sterility is not due to the pollen abortion, but doubtless to the lack of the embryo sacs in half the flowers.

4. The Result of the Artificial Cross.

Because the partially sterile plant has not any morphological characteristics which distinguish it from the fertile plant at the flowering time, and its offspring contain the parent types in a small number, the cross between partial sterile and fertile is a hard work, and it is really more difficult to succeed in the cross between partial steriles. However, the number of semi-steriles in the offspring of the semi-sterile plant is the same as that of fertiles, so that various kinds of hybrid are obtained with ease even by crossing offspring of semi-sterile with each other at random. Moreover, as semi-steriles can be readily distinguished from fertiles by the microscopical investigation of pollen grains shed on glycerin which is dropped on the slide, the desired cross can be carried out without failure whenever the work is done after a thorough examination of the pollen of parents.

Thus in the offspring of some semi-steriles, the cross between semi-steriles, between fertiles, and the cross between semi-sterile and fertile were carried out with comparative ease in 1924. And the F1 plants as shown in Table 43 were raised in 1925.

TABLE 43.

Showing the F_1 plants obtained in 1925.

Mother plant no. in 1924		Father plant no. in 1914	Number of F_1 plants	
			Fertile	Semi-sterile
63 (SS)	×	71 (SS)		2
64 (SS)	×	65 (F)		2
65 (F)	×	62 (F)	1	
74 (F)	×	79 (SS)	1	3
75 (SS)	×	66 (F)	1	1
M-11-B (SS)	×	M-11-A (F)	1	
M-11-B (SS)	×	M-11-C (SS)	1	
M-11-C (SS)	×	M-11-B (SS)		1

It is noticeable that semi-steriles and fertiles are produced by either crosses between semi-steriles and fertiles thrown by semi-steriles, or crosses between semi-steriles.

All of the nine semi-steriles thus obtained by the above crosses segregated also into fertiles and semi-steriles in the ratio 1 : 1 as shown in Table 44.

TABLE 44.

Showing the results obtained in the F_2 generation in 1926.

Kind of the cross	Number of F_2 plants obtained	
	Fertile	Semi-sterile
63 (SS) × 71 (SS) No. 1	52	37
,, × ,, No. 2	62	53
64 (SS) × 65 (F) No. 1	68	44
,, × ,, No. 2	60	57
74 (F) × 79 (SS) No. 1	60	54
,, × ,, No. 2	52	60
,, × ,, No. 3	63	55
75 (SS) × 66 (F)	55	60
M-11-C (SS) × M-11-B (SS)	45	53
Total	517	473
Expected (1 : 1)	495	495
Dev./P.E.	2.075	

In 1925, the crosses between offspring of the semi-sterile plant were carried out once more, raising a goodly number of F_1 plants in the following year (Table 45).

TABLE 45.

Showing the F_1 plants obtained in 1926.

Mother plant no. in 1925		Father plant no. in 1925	Number of F_1 plants	
			Fertile	Semi-sterile
46 (SS)	×	78 (SS)	3	4
46 (SS)	×	82 (SS)		1
47 (SS)	×	78 (SS)	2	3
49 (F)	×	82 (SS)	12	3
50 (F)	×	48 (F)		13
50 (F)	×	80 (SS)	4	2
50 (F)	×	81 (F)	7	
51 (SS)	×	4 (F)	5	5
52 (SS)	×	9 (SS)	3	4
78 (SS)	×	79 (F)	3	3
79 (F)	×	49 (F)	7	
79 (F)	×	82 (SS)	3	3
81 (F)	×	8 (F)	11	
81 (F)	×	78 (F)	22	
83 (F)	×	78 (SS)	5	9

From the above results of the crosses, we can understand that by crossing between semi-steriles, and between semi-steriles and fertiles produced by semi-steriles, fertile and semi-sterile are always obtained; that the crosses between fertiles in the offspring of semi-steriles produce only fertiles in one case, and only semi-steriles in the other; and that semi-steriles thus produced throw again 1 semi-sterile to 1 fertile.

5. Summary.

1. A family splitting into 1 fertile to 1 semi-sterile was discovered in 1923 among families which threw fertiles and partial steriles in the approximate ratio of 7:1. It might have been derived from a mutant arisen in the offspring of the partially sterile plant. Twenty semi-steriles collected from that family segregated in the same manner as in the previous year, while twenty fertiles likewise collected bred true in

1924. Segregation in each family was quite uniform. The percentage of all the semi-steriles in 20 families was 50.96.

2. During these two years, the natural cross could hardly be seen, and the segregation of other characters could not be found there altogether.

3. The percentage of sterile spikelets of the semi-sterile plant was fairly uniform and usually over 50. The percentage of sterile spikelets of 20 semi-steriles was examined in 1923. It ranged from 48.1 to 70.9, and that of sterile spikelets in total was 57.36. Once more, the percentage of sterile spikelets of 50 semi-steriles was examined in 1924. It varied from 47.0 to 65.7, that of sterile spikelets totalled being 54.09. In the same year, the percentage of all of the sterile spikelets of 27 fertiles in the offspring of some steriles was 7.62.

4. Half the ovules of the semi-sterile plant lack embryo sacs though they have the normal size and shape, and the slender cells identical with the ones which are usually found at the periphery of megaspores and embryo sacs take the place of the embryo sac. It would be therefore supposed that the megaspore is formed once and degenerates soon afterwards. On the other hand, in the reduction division of the pollen mother cells, irregular distribution of chromosomes can not be found. And for a while following liberation of the tetrad, the pollen abortion does not arise, but it takes place toward the maturation period of the pollen. About the half pollen grains degenerate ultimately. Pollen grains in various degrees of degeneration are seen in every anther of the semi-sterile plant toward the flowering time.

5. The semi-sterile plant has the same chromosome number as the normal plant; the diploid number is 24 and the haploid 12.

6. In spite of the existence of abortive pollen grains in half the number, the anthers of the semi-sterile plant burst well and shed their healthy pollen grains while the dehiscence of the anther in the sterile plant does not occur probably owing to the presence of many abortive pollen grains. Thus semi-sterility is not due to insufficiency of healthy pollen, but to the lack of the embryo sacs in half the flowers.

7. As many semi-steriles as fertiles are obtained by the cross between semi-sterile and fertile thrown by semi-sterile and also by the cross between semi-steriles. Crosses between fertiles in the progeny of semi-sterile give, in one case, only fertiles; in the other, only semi-steriles. All of the semi-steriles thus obtained segregates also in the ratio 1:1.

8. The semi-sterile plant resembles the partially sterile plant in that it segregates always, and the resulting fertile breeds true. But as to the segregating ratio and the cause of sterility, there is marked difference between them.

INTERPRETATION.

Though the flowers of the sterile plants open normally, the anther does not burst and liberate pollen grains by itself; so there occurs no self-fertilization. But the ovules of the sterile plant are functional as proved by the cytological investigation and the cross experiment, so that the sterile plant sets usually some fertile spikelets in the field by foreign pollen grains in spite of the complete absence of fertile spikelets when bagged so as to prevent cross fertilization.

Considering these facts and examining the segregating manner of the progeny in several years, it will be readily understood that the sterile plant discovered in 1920 was a monohybrid recessive, and when it was fertilized by the pollen of the neighbouring heterozygous and homozygous plants which were fertile, it threw 8 steriles and 84 fertiles; that in 1922, the former produced both types in the irregular proportion while all of the latter segregated into fertiles and steriles in the 3:1 ratio, for they were heterozygous; thus in 1923, fertiles gave rise to constant fertile families in the one third proportion.

For several years, it was not observed that fertile spikelets on the panicles of the sterile plant were produced by the natural cross because the original sterile plant secured from the plot, where plants belonged to one strain were bred in a fairly extensive area, any conspicuous segregation of characters except sterility did not arise in its offspring even though there occurred natural crossing. However, as the offspring were then bred in the experimental plot, where several varieties were grown side by side, the progenies of the sterile plant fertilized time and again by the pollen of other varieties always contained the conspicuous number of products of natural crossing. And when materials for cytological investigation were collected in 1924 the lack of dehiscence of the anther was discovered. Moreover, the sterile plant panicles bagged in 1925 set none of fertile spikelets.

Thus it was ascertained at last that fertile spikelets on the sterile plant are entirely produced by natural crossing. The number of foreign pollen grains visiting the stigmas of the sterile plant on wind is not definite, and always insufficient to a remarkable degree to fertilize all of the ovules of the sterile plant. Therefore, the percentage of sterile spikelets of the sterile plant is very high showing about 80 percent, and conspicuously variable.

The sterile plant, having been fertilized by the pollen of neighbouring heterozygous and homozygous fertile plants, threw fertiles and steriles always in a irregular ratio, because two kinds of the pollen which visited the sterile plant had not a definite proportion naturally.

Although on the male side, abortion of the pollen is so considerable that the dehiscence of the anther does not occur, on the female side, the egg cell is normal and able to be fertilized by the foreign pollen as proved by artificial pollination. There exists a large difference botween the male and female sides as to the effect of the factor involved. Thus we might call the abortion in this case male sterility. However, the fact that some polar nuclei divide themselves again and again forming the endosperm, should be regarded as due to the influence of the factor on the female side though the abortive effect of it can not be found there.

It will be readily supposed that the mechanism of inheritance of partial sterile is fairly complex to a mere notice on the manner of its segregation, i.e. in the offspring of partial sterile, the greater part of which is fertile and breed true while partial steriles segregate again. And remarkable to see, no partial sterile was found not only among 273 F_1 plants obtained by the cross between fertiles thrown by partial sterile, but also among 69 F_1 plants which were produced by partial sterile by fertile. On the other hand, defects of the ovules, irregularity in the meiosis and the tetrad formation, and abortion of the mature pollen could not be found in the cytological investigation. Moreover, the pollen of partial sterile germinated as good as the normal pollen on the culture media. No embryo was formed in the sterile flowers.

Then the following interpretation will be put on these facts. As none of partial sterile can be obtained by the cross between fertiles which are seven times as much as partial steriles in the offspring of the partially sterile plant, partial sterile must be a monohybrid which may be represented by Ss. And as it can not be also obtained even though partial sterile is fertilized by fertile, the factor s must be carried only by the pollen. Thus on the female side, only S gametes are capable to fertilize, while all of s gametes are deprived of the faculty of fertilization, though there occurs no gametic abortion. On the male side, *S* gametes can fertilize *S* eggs, but the majority of *s* gametes lack the faculty of fertilization, though they can germinate normally, only a small part of *s* gametes being able to fertilize *S* eggs. The proportion of *S* pollen grains and *s* pollen grains which can fertilize is about 7:1.

Thus the number of fertile spikelets is expected to be the same as that of sterile spikelets, but the actual percentage of sterile spikelets was 45.80 in 1922, 46.79 in 1923, and 43.72 in 1924. Namely in each year, the number of fertile spikelets did not reach that of sterile spikelets by a small difference. This will be explicable on the assumption that *S* megaspores of the tetrad are more apt to survive than *s* megaspores.

The excess of ungerminated seeds of partial sterile is perhaps due to a lower viability of the seed of partial sterile than that of fertile on account of a slight effect of the lethal factor *s* when in heterozygous condition.

It can be seen clearly that semi-sterile is not also a Mendelian unit character from the fact that the semi-sterile plant segregates always into fertiles and semi-steriles in the 1:1 ratio, and that crosses between semi-sterile and fertile thrown by semi-sterile give always both of the types. It would thus be assumed that the semi-sterile plant is heterozygous for two or more factors, gametic abortion occuring there owing to the genetic constitution of the gamete.

Then the assumption of two factors will be first considered. The factorial constitution of the semi-sterile is *AaBb*, and four kinds of gametes viz. *AB*, *Ab*, *aB*, *ab* are formed from the semi-sterile plant. Both on the female and male side, *AB* and *ab* gametes are abortive. Then resulting zygotes are *AAbb*, 2*AaBb* and *aaBB*. Homozygous *AAbb* and *aaBB* are fertile, producing none of *AB* and *ab* gametes. Two *AaBb* which are identical with the parent type are of course semi-sterile. Therefore, in the offspring of semi-sterile, the number of fertiles is the same as that of semi-steriles.

The results of the crosses and the cytological observation can be explained well on the basis of this hypothesis. Cytological observation indicates, as expected, in the semi-sterile plant abortion of half the pollen grains and megaspores. Leaving the F_1 plants obtained in 1925 out of consideration as their numbers were very small, only those obtained in 1926 will be compared with the theoretical number.

Every semi-sterile plant gives *Ab* and *aB* gametes. On the other hand, fertiles thrown by semi-sterile consist of two classes *AAbb* and *aaBB*; one class gives only *Ab* gametes, and the other class only *aB* gametes. Then the cross between semi-sterile and fertile in either class should give 1 fertile to 1 semi-sterile. In this experiment, 32 fertiles and 25 semi-steriles were obtained. The cross between semi-steriles should give also 1 semi-sterile to 1 fertile. The fact showed 8 fertiles and 12 semi-steriles. If two cases of the above crosses are summed up, the proportion of fertiles and semi-steriles being 40:37, the actual number approaches fairly the theoretical number.

As to the cross between fertiles, by the cross between *AAbb* fertiles or between *aaBB* fertiles, only fertiles should be produced. However, only semi-steriles should be obtained by the cross between *AAbb* fertile and *aaBB* fertile. As the offspring of semi-sterile contain *AAbb* and *aaBB* in the same number, the fertile group and semi-sterile group should be produced in the proportion 1:1 by the crosses between fertiles. The result obtained by the crosses, however, was somewhat different, their proportion being 4:1. If the crosses were carried out between fertile plants in a greater number, the actual number might have come nearer the theoretical one.

All of the semi-sterile thus obtained should have the same factorial constitution *AaBb* and throw 1 fertile to 1 semi-sterile. As was expected, 9 F_1 semi-steriles obtained in 1925 segregated all into fertile and semi-sterile, and in the sum of 9 families, we obtained 517 fertiles to 473 semi-steriles, where we expect 495 for either type.

Thus it is clear that semi-sterile is a dihybrid, and half the female and male gametes are abortive because they bear two factors or lack both of them. The theoretical interpretation why the *AB* and *ab* gametes are abortive is that because some substance necessary for the development of gametes is produced by either *A* or *B*, the gametes which possess neither of them are naturally abortive, but the gametes bearing two factors are also abortive, as there is some substance overproduced.

DISCUSSION.

The articles on sterility are very numerous in the literature of genetics. We shall discuss the present problem comparing our notes with the literature related to the heredity of three types of sterility in rice, which is the subject of this research.

Terao (1917) was the first investigator who treated the problem of sterility inheritance in rice. He obtained in certain pedigree cultures of the rice plant two families containing besides ordinary fertile plants a number of sterile plants respectively. Some of these sterile plants yielded no seed, others bore a small number of normal seeds, and very few were mosaic forms with higher fertility. Sterility behaved as a simple recessive to fertility.

Lindstrom (1920) found that in the descendants of a certain maize cross three of the four selfed ears segregated into normal and abortive grains in the 3:1 ratio, and the fourth was an entirely normal, well developed ear. The abortive grains, in which no trace of an embryo was found, and no endosperm tissue developed, were merely shells made up of the pericarp tissue, and were scattered more or less evenly over the entire ear. And the abortive grains occurred in a family of plants that were showing segregation into green and chrolophyll-free seedlings. He considered that there might be some relation between a lethal factor destroying both embryo and endosperm and another lethal factor inhibiting the formation of normal chlorophyll.

Bateson and Gairdner (1921) observed that a peculiar dwarf form which appeared in ordinary flaxes spontaneously is harmaphrodite as the latter, but if fertilized by any fiber flax it gives in F_2 an ordinary recessive, characterised by male sterility, complete or less often partial. If fertilized by fiber flaxes, these recessives give only similar male steriles, whereas, if fertilized by pollen of the dwarf, they give all hermaphrodites in F_1, which in F_2 give 3 hermaphrodites to 1 sterile. He considered that in the fiber flaxes the element which determines hermaphroditism passes into the female side of the plant, leaving the pollen devoid of this factor.

Eyster (1921) found in maize that the male sterile plants were occurring in proportions approximately 25 percent in progenies from two closely related self-pollinated ear. Crosses and backcrosses proved this male sterility to behave as a simple Mendelian recessive to normal. No pollen is formed in the anther sacs, and they remain undeveloped. The sterile spikelets are almost empty and usually remain flattened against the rachis, giving a characteristic appearance to the whole tassel.

Nagai (1926 a) described the staminoidal sterile of rice. There sterility is due to staminoidy. The feather-shaped stigma is transformed into three extra anthers which are mostly abortive but occasionally produce healthy pollen grains. The F_1 plants produced by the crosses between fertile and staminoidal sterile were highly sterile, over 85 percent of the total spikelets being empty. The fertile grains from the highly sterile F_1 plants produced three classes of plants, i.e. fertiles, partial steriles like F_1, and complete steriles (staminoidal sterile) in 1:2:1 ratio. He (1926 b) observed the male sterile of rice such as mentioned already in the present paper. In that case, sterility is due to complete sterility of male gametes, the eggs being functional. The male sterile behaves as a monohybrid recessive to the normal fertile. He (1926 c) observed also paleaceous sterility in rice. The spikelets of the paleaceous sterile are abortive and a number of small, supernumerary green paleas are formed within the regular paleas. The anthers and ovules are seldom formed but generally abortive. Consequently the mutant is completely sterile in both sexes. It behaves as a simple recessive to fertile.

In the above cases, all of steriles, male-steriles and other steriles behave as a simple Mendelian recessive as in our sterile. Although abortion in our sterile is due to a kind of the gametic lethals, it is clearly caused by the somatic cell. Gametic abortion must occur if somatic cells supply insufficiently some substance essential to the formation of gametes or produce some substance which hinders the development of gametes.

Though frequently male sterility has been reported, it can not be said that the abortive factor in that case is always connected with only male gametes. Pollen grains are likely to be influenced more readily by the external conditions than embryo sacs embedded deep in the ovaries.

Studies of Sakamura (1920), Borgenstam (1922) and Belling (1925) in *Vicia*, *Syringa* and *Uvularia* respectively showed that the low temperature influences the reduction division of the pollen mother cell, whereby giant or dwarf abortive pollen grains are produced. Sakamura and Stow (1926) observed in *Solanum tuberosum* and *Gagea lutea* that the reduction division of the pollen mother cell of those plants is abnormal at the high temperature, giving rise to pollen sterility following the abnormal reduction division is not confined to the hybrid plants, but in some plants it will be also brought about by the climate or other external conditions.

These results indicate how strongly male reproductive organs are influenced by the external conditions. So it is probable that in the so-called male steriles, the external conditions acting upon some substance produced by somatic cells, pollen grains are considerably sterile while the abortive effect of the factor does not appear in embryo sacs.

Pollen abortion occurs also in our sterile, whereas the eggs are normal, and are able to be fertilized normally by the pollen of normal plants. The repeated division of some polar nuclei without fertilization is, however, regarded as irregularity in embryo sacs, which is caused by the recessive factor.

The pollen of our partial sterile germinates as good as that of fertile on the artificial media. Also in the cases of self-incompatibility and cross-incompatibility in some plants, the pollen grains germinate as those of the normal plant, but can not fertilize eggs.

Moore (1917) observed in *Tradescantia* that the tubes from self-pollination are wider than that from cross-pollination, and he supposed that the food supply is more favourable to the nourishment of a self-pollen tube than it is to a cross-pollen tube; and on account of the abundant food supply the pollen tubes do not lengthen, but grow wider since they were in a very favourable medium.

East and Park (1918) observed that pollen tubes of self-incompatible plants in *Nicotiana*, which are produced after self-pollination grow steadily and apparently normally, but do not reach the ovary before the flower decays as the growth is slow. Their length plotted against time is a straight line. On the other hand, pollen tubes produced after a compatible cross start their growth at about the same rate as the pollen tubes produced after selfing; but the growth becomes constantly more and more rapid. Length plotted against time produces a curve which resembles that of an autocatalytic reaction. Cross-sterile combinations resemble selfing in the rate of pollen-tube growth. And East (1926) assumed that when unequal factors come together on the occasion of pollination, growth of pollen tubes is promoted, because some readily diffusible substance produced by the cells of the stigma work its way through the membrane of the pollen tube, and becomes growth-promoting substance when it meets there some complemental stuff.

Crane (1925) stated that self-incompatibility in plums and cherries is probably due to a definite block to self-fertilization, and not to the slow pollen-tube growth as in Nicotiana studied by East. As to cross-incompatibility *Prunus* also differs from *Nicotiana*. Histological investigations show that it can not be entirely attributed to the slow pollen-tube growth. Styles which were pollinated with an incompatible variety were microscopically examined at frequent intervals from 24 hours up to 12 days after pollination. For convenience in the manipulations these styles were always cut approximately in halves previous to fixation, and in the subsequent examinations pollen tubes were not found in the lower half. He concluded that incompatibility is due to inhibition occurring shortly after the penetration of the pollen tubes, and not to slow growth.

All of the above cited investigations indicate that pollen tubes of the self-incompatible or cross-incompatible plant do not reach the ovary though pollen grains germinate. And self-incompatibility is due to the genetic constitution of the zygote and behaves as a Mendelian recessive, as proved by Compton (1921), East (1919) and Baur (1919) in *Reseda, Nicotiana* and *Antirrhinum* respectively.

Our partial sterile is, however, a hybrid which always segregates into partial sterile and fertile, so that it must be far different from the self-incompatible plant thus far reported. And irregularity in the reduction of the pollen mother cell does not occur. Any abortion can not be found both in the male and female reproductive organs. On the other hand, partial sterile is not produced by the cross between fertiles thrown by partial sterile, and also it can not be obtained even though partial sterile is fertilized by fertile.

Therefore, partial sterile is a monohybrid *Ss*. And *S* gives a faculty of fertilization to the gamete both on the male and female sides, but *s* which is an allelomorgh of *S* has different effects upon the male and female gametes, i.e. ovules bearing *s* are deprived of faculty of fertilization completely, though their appearance is normal, while pollen grains germinate normally, and some of them are capable to accomplish fertilization, because the effect of *s* is incomplete.

The seed of partial sterile is slightly inferior in germination to that of fertile. The embryo, the seedling, or the adult in plants is often seen to die by the genetical cause. Since Cuénot (1908) found that all homozygous yellow mice die, zygotic lethal has been studied by many biologists from the standpoint of genetics.

Vilmorin (1913) found new dwarf plants in the wheat varieties called *Reter's Brown Club Head* and *Shirno*. They split always into dwarfs and talls in the approximate ratio of 2:1 and did not breed true. On the other hand, talls produced only tall plants.

Little (1915, 1917) reported that in mice, homozygous black-eyed whites can not be obtained as homozygous yellows. He tried crossing between yellow and dark-eyed white to answer to the interesting question whether *Y* (yellow) and *W* (black-eyed white) factors are unable to exist in a single zygote.

yellow, *Yyww* × black-eyed white, *yyWw*
F_1 xygotes, (a) *YyWw*, yellow
(b) *Yyww*, yellow
(c) *yyWw*, non-yellow
(d) *yyww*, non-yellow

If the lethal action of *Y* and *W* is the same, the *YyWw* individuals should be non-viable, then the resulting ratio of yellow to non-yellow found in F_1 would be one to two, not one to one. The actual number of F_1 animals were yellow 76 and non-yellow 81. On a 1:1 ratio the Mendelian expectation would be 78.5:78.5. If a 1:2 ration was the correct explanation the numbers expected would be 52 yellow, 105 non-yellow, so it is certain that the action of *Y* and *W* is not identical.

Corrence (1918) described the *peraurea* type of *Urtica urens*. Its young plant almost lacks chlorophyll but contains xanthophyll and carotin. During growth more or less green colour increases. The *peraurea* type is a monohybrid and throws 2 *peraureas* to 1 homozygotic typical green. He considered that the embryo dies very early perhaps by the inhibiting factor or a lethal factor linked with *peraurea* factor when a double dose.

Muller (1918) confirmed after his detailed experiments that the factor for beaded wings in *Drosophila* is a lethal which kills all individuals homozygous for it. He explained the excess cf doubles in the offspring of double throwing stocks studied by Saunders (1911), assuming that the singles have a lower viability than the doubles perhaps on account of a slight effect of the pollen lethal factor which is in present in the chromosome carrying singleness when in heterozygous condition.

De Vries (1918) adopted an explanation identical with that of "balanced lethal factors" in order to account for the twin hybrids of his species crosses. He found that *Oe. grandiflora* is a permanent heterozygote for the factor "*ochracea*", and pointed out that this condition must be due to the existence of another, completely lethal factor, which segregates from it. He found, moreover, that in crosses of *Oe. grandiflora* with other species, the gametes containing the factor for "*ochracea*" give rise to one type of hybrid——*laeta*,——while the other gametes give rise to the twin hybrid——*velutina*. He pointed out also that in *Oe. Lamarckiana*, whose genetic behavior on crossing is similar to that of *grandiflora*, the "*ochracea*" type of gamete probably contains a completely lethal factor, as homozygous "*ochracea*" never appear.

Kirkham (1919) observed in the heterozygous yellow mice that eggs with the yellow factor undergo maturation and fertilization even when entered by yellow-bearing sperms, and abnormalities of homozygous yellows appear first in morula. The proportion of degenerate embryos from yellow is 29 percent, being very close to the Mendelian expectation.

Heribert-Nilsson (1920) reported that no *RR* homozygotes in *Oenothera Lamarckiana* are obtained; all red nerved plants are *Rr*. Any they do not segregate just in the ratio 2*Rr*: 1*rr*, but about 3:1. He tried to explain the matter assuming the incapacity of the *R*-pollen to fertilize the *R*-eggs, there is a repulsion between the gametes, or a kind of self-sterility in the genes not yet understood, notwithstanding all the *R*-eggs are fertilized by the *r*-pollen, which is always in excess. Thus the combination 2*Rr*, *rR*, and *rr* are obtained, that is 3:1 segregation. Besides this prohibition, he assumed "Zertation" to explain the great disturbance in the segregation in *Oe. Lamarckiana* which has the long style. The longer the style the greater the difference in the gamete representation in spite of the fact that the relative difference in the ratio of growth of the pollen tube is the same. He (1925) tried to self-fertilize red nerved *Lamarckiana* with various quantities of pollen grains. It segregated in the ratio 2*Rr*: 1*rr* either through few numbers or proportional numbers of pollen grains. Only through abundant pollen grains, it threw the 3:1 ratio. He concluded that the hypothesis of elimination is right, but the assumption of prohibition is not right because the segregation must show the 3:1 ratio when selfed by few grains on the basis of it. However, he recognized the assumption of "Zertation" right because when fertilized by rich pollen he obtained the 3:1 ratio,

Enomoto (1923) observed that special whites of *Portulaca grandiflora*, which differ from normal whites by having red stems are heterozygous giving a ratio of approximately 2 special whites to 1 normal on selfing. On selfing or back-crossing, the recessives are slightly in excess. Differential viability of seedlings is suggested as the explanation of the latter phenomena. High sterility of seeds in special whites is further evidence in support of the hypothesis that special whites are heterozygous for a factor which is lethal when present in a double dose.

Tanaka (1925) reported that "*No-lunula*", a type of the silk-worm does not breed true, throwing always the normal type. There is also differential viability between them, viz. "*No-lunula*" is slightly less viable than the normal type. In the calculation of segregation, not forgetting the above fact, the auther finds the exact ratio of 2 : 1.

From these results of various authers' experiments, we can see the organism homozygous for a lethal factor or some other factor will die. However, an excess of the ungerminated seeds of our partial sterile over those of fertile, which is about 3 percent, is too small as an indicator of any homozygous combination to be eliminated out of zygotic combinations thrown by partial sterile. This will be fairly explained on the assumption that the seeds of partial sterile is less viable than those of fertile on account of a slight effect of the lethal factor when in heterozygous condition as in the cases such as Enomoto's special white of *Portulaca*, Tanaka's "*No-lunula*" of the silk-worm, and double-throwing stocks if Muller's assumption is right.

On the subject of the inheritance of semi-sterility, only a few data are found.

Belling (1914) obtained the semi-sterile F_1 plants by crossing the Florida velvet bean (*Stizolobium deeringianum*) with the Lyon bean (*S. nivenum*), Yokohama bean (*S. hassjoo*) and the China bean (*S. nivenum var.*?). The flowers of these hybrids had uniformly one-half of their pollen grains quite empty and collapsed, and one-half of their ovules had no embryo sacs. These hybrids split in the second generation into fertiles and semi-steriles in the same numbers, and the former bred true while the latter segregated again in the same manner. He suggested the following hypothesis. If K is a gametic factor present in the velvet bean, but not in the other three parents, where it is replaced by the similar factor L, and the present of either K or L, but not both, is essential for the development of microspores into perfect pollen grains, and of functional megaspores into perfect embryo sacs. Then the F_1 zygotes will have $KkLl$. The microspores or megaspores with KL os kl will abort; those with KL because they have abnormally two factors instead of one; and those with kl because they lack an indispensable factor. So half of the microspores and megaspores are abortive, and the abortion of half megaspores causes semi-sterility. Then resulting zygotic combinations are $KKll$, $kkLL$ and $2KkLl$, Therefore, F_2 consists of fertiles and semi-steriles in the same number. He (1916) tried back-crosses to confirm his hypothesis. Two fertile lines, descended from semi-sterile F_2 and one fertile F_2 plant were back-crossed with the Florida velvet bean. And two plants had fertile progeny while one gave semi-sterile progeny.

Malinowski (1920) suggested a following hypothesis, which he considered explained better the results of Belling's experiments and those of his own more complex wheat crosses. Partial or complete sterility is formed by gathering of inharmonious factors in one zygote. The following is the most simple case of the experiments, in the cross between *AAbb* and *aaBB*, which are fertile, F_1 is partially sterile owing to inharmony of *A* and *B*, and in F_2, its 9 types contain both *A* and *B* in one zygote, all being partially sterile. The ratio of partially sterile plants to fertile plants is 9:7, which resembles the Belling's ratio of 1:1. In the hybrid, however, which has more than one pair of inharmonious factors the degree of sterility is higher or this hybrid is completely sterile according to a large number of these factors. For example, a hybrid between *AABBccdd* and *aabbCCDD* in which *A* does not harmonize with *C*, and *B* does not harmonize with *D*, has the higher degree of sterility than a zygote which contains one pair of inharmonious factors. And in its progeny, *AABBCCDD* shows the highest degree of sterility among *AaBbCcDd* or *AAbbCCdd* etc.; thus plants in various degrees of sterility are found. Micro-and megaspores of a partial sterile plant are abortive not owing to their genetic constitution; on the contrary there is the abnormal development in the same degree in all of their genetical types.

Terao (1921) found in certain pedigree strains of a rice variety, *Sekiyama*, a type of semi-sterile plants, in which about half spikelets are sterile. The semi-sterile plant split into fertiles and semi-steriles in the ratio 1:1, the former breeding true and the latter segregating in the same manner. His assumption is as follows: Semi-sterility is due to a sex-linked lethal factor *a* causing the death of the female gametes, but not affecting the male, and its allelomorph *A* behaves quite normally. The zygote *Aa* produces therefore both *A* and *a* male gametes, but only *A* female gametes, consequently the progeny consist of fertiles and semi-steriles in the same number.

Both Terao's semi-steriles and our semi-sterile were obtained in rice though in different varieties, and had the same mode of segregation. However, his explanation is not applicable to our case, for half the pollen grains of our semi-sterile are abortive, and not only fertiles but also semi-steriles are produced by the crosses between fertiles thrown by semi-sterile, and by semi-sterile by fertile, and whether his hypothesis acts true or not is not certain as Terao did not state the result of any cytological observations and hybridization experiments.

The results of our experiments, in which the ratio of segregation of semi-sterile was 1:1, the crosses between semi-sterile and fertile gave always semi-steriles and fertiles in the same number, and all of semi-steriles obtained by the crosses between the offspring of semi-sterile threw 1 semi-sterile to 1 fertile, can not be explained by the Malinowski's hypothesis.

Although the results of the back-crosses carried out by Belling to confirm his hypothesis can be explained also by the Malinowski's hypothesis, Belling's semi-sterile would be the same kind as our semi-sterile, because its segregating ratio seems to be 1:1 instead of 9:7. Belling's explanation that semi-sterile is heterozygous for two factors, and half of the gametes are abortive owing to their genetic constitution, is also well adapted to our case.

CONCLUSION.

The sterile, semi-sterile and partially sterile plants are mutants which arose in a strain of a rice variety; and they are externally different from each other only in the degree of sterility. In each of them, the meiosis is carried normally, and the chromosome number is 12 as a haploid number.

The sterile behaves as a monohybrid recessive to normal. It would be regarded as male sterile, because abortion occurs considerably in the pollen grains and consequently the anther can not burst itself though the egg cells are perfect and functional. Abortion of the pollen occurs after liberation of the tetrads, and although most pollen grains lose completely their contents by the flowering time, they reach the normal pollen size and then they burst. As all the egg cells are functional, sterile can set fertile spikelets as in a normal plant, if pollinated artificially with rich foreign pollen. However, the high sterility of the sterile in the field is caused by the deficiency of pollen supply.

The factor for sterile does not concern only microspores. Although its abortive effect does not appear on megaspores, it must be regarded as an influence of the factor on them that some polar nuclei divide by themselves again and again forming the endosperm which degenerates afterwards, without fertilization when not visited by the male nucleus. Gametic abortion occurs when there is harmful substance or the scarcity of nourishment produced by the somatic cells of sterile, and it is not due to genetic constitution of gametes. Therefore, abortion takes place in this case in pollen grains which are influenced more than embryo sacs by the external conditions which act upon the substance produced by the somatic cells.

The partial sterile segregates into fertiles and partial steriles in the approximate ratio of 7:1, and strange to notice, the fertiles which compose the larger part of the offspring breed true while the partial steriles which compose the smaller number segregate again in the same manner. In partial sterile, abortion of micro- and megaspores can not be found, and the pollen grains germinate as good as those of the normal plant. Partial sterile sets about 40 percent sterile spikelets, where no embryo is formed.

Partial sterile can not be obtained by crossing between fertiles thrown by partial sterile, and it is not also produced though partial sterile is fertilized by fertile. The seed of partial sterile is slightly inferior in germination to that of fertile.

Partial sterile is a monohybrid which may be represented by *Ss*. On the female side, only *S* gametes are capable to fertilize while all of *s* gametes are deprived of the faculty of fertilization though their appearance is normal. On the male side, *S* gametes can fertilize *S* eggs, and though the majority of *s* gametes are deficient of the faculty of fertilization notwithstanding they germinate normally, a small part of *s* gametes fertilize *S* eggs on account of the imperfection of the effect of the lethal factor in the gamete. The proportion of *S* pollen grains and *s* pollen grains which can fertilize is about 7:1.

The excess of ungerminated seeds of partial sterile over those of fertile is perhaps due to a lower viability according to a slight effect of the lethal factor when in heterozygous condition.

The semi-sterile throws fertiles and semi-steriles in the same number, and the former breed true while the latter segregate again in the same manner. The crosses between semi-steriles, and between semi-sterile and fertile thrown by semi-sterile give always semi-steriles and fertiles. And the crosses between fertiles thrown by semi-sterile give only fertiles in one case, and only semi-steriles in the other case.

Semi-sterile is heterozygous for two factors *A* and *B*. The micro- and megaspores which lack both factors are sterile, and those which possess both factors are also abortive. Therefore, half of the gametes of semi-sterile are abortive, and fertiles thrown by semi-sterile possess either *A* or *B*. After liberation of the tetrads, pollen abortion occurs in semi-sterile as in sterile. However, abortive pollen grains vary in size and shape, and most of them lose their contents by the flowering time.

In the abortive ovules, neither remains of the embryo sac nor cavity can be found there. The place otherwise occupied by the embryo sac is filled by the slender cells identical with those usually found at the periphery of megaspores or embryo sacs. So the megaspores degenerate perhaps before their development into embryo sacs.

The factor *A* like *B* produces substance necessary for the development of gametes, so that a gamete bearing neither of them naturally degenerates. However, a gamete bearing both of them also does not develop, owing to some surplus substance produced by them.

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EXPLANATION OF FIGURES.

Fig. 1. Panicles showing the three types of sterility. Left, partial sterile; middle, semi-sterile; right, sterile.

Fig. 2. Longitudinal section of the anther of sterile at the flowering time. Leitz, oc. 3, obj. 3.

Fig. 3. Longitudinal section of an embryo-deficient ovary of sterile on the 3rd day after flowering, showing the formation of an endosperm. Leitz, oc. 4, obj. 3.

Fig. 4. Longitudinal section of a normal ovary of sterile on the 3rd day after flowering. Leitz, oc. 4, obj. 3.

Fig. 5. Longitudinal section of an embryo-deficient ovary of sterile on the 5th day after flowering, showiug degeneration of an endosperm formed once. Leitz, oc. 4, obj. 3.

Fig. 6. Longitudinal section of a normal ovary of sterile on the 5th day after flowering. Leitz, oc. 4, obj. 3.

Fig. 7. Longitudinal section of the anther of partial sterile immediately before flowering. Leitz, oc. 3, obj. 3.

Fig. 8. Longitudinal section of the anther of a normal plant immediately before flowering. Leitz, oc. 3, obj, 3.

Fig. 9. Side view of reduction division of the pollen mother cells of partial sterile in the heterotypic metaphase. Leitz, oc. 4, obj. 1/12 oil imm.

Fig. 10. Polar view of reduction division of a pollen mother cell of partial sterile in the heterotypic metaphase. Leitz, oc. 4, obj. 1/12 oil imm.

Fig. 11. Pollen tetrads of partial sterile. Leitz, oc. 4, obj. 7.

Fig. 12. Longitudinal section of the anther of semi-steril immediately before flowering. Leitz, oc. 3, obj. 3.

Fig. 13. Longitudinal section of an embryosac-deficient ovule of semi-sterile immediately before flowering. Leitz, oc. 3, obj. 7.

Plate V.

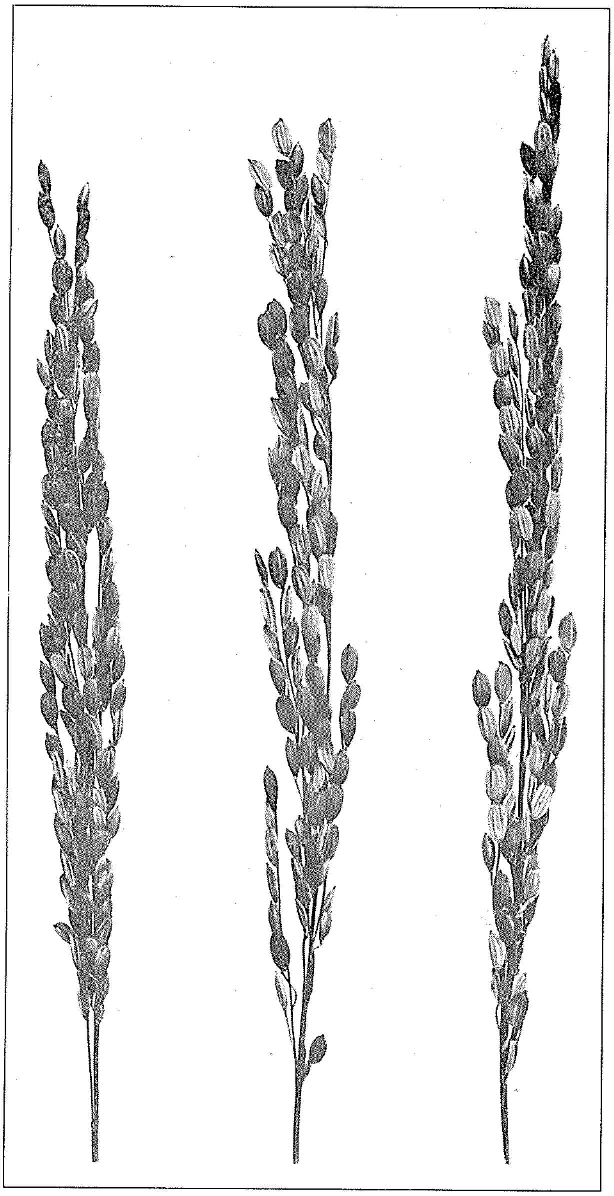

Fig. 1.

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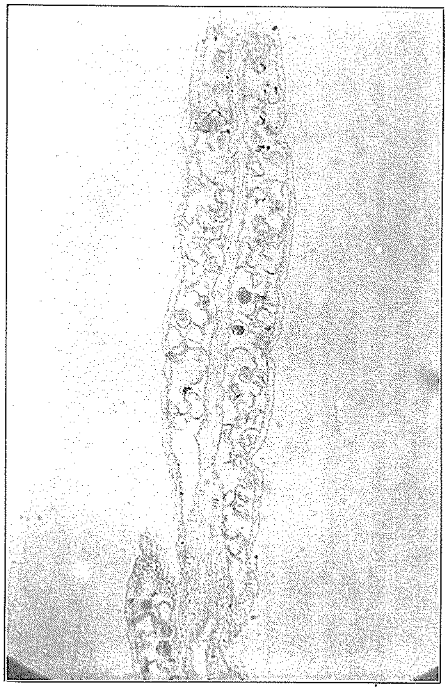

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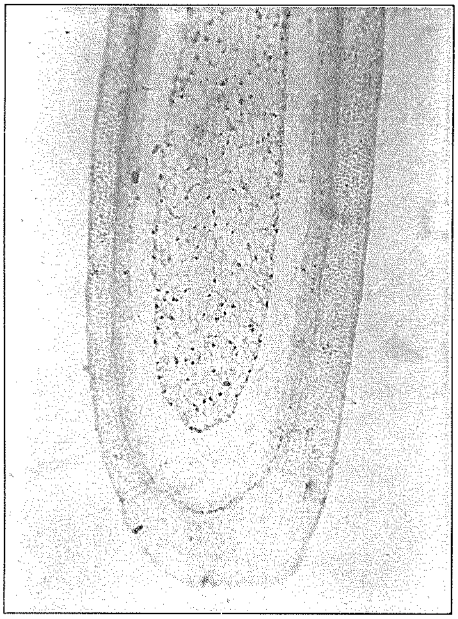

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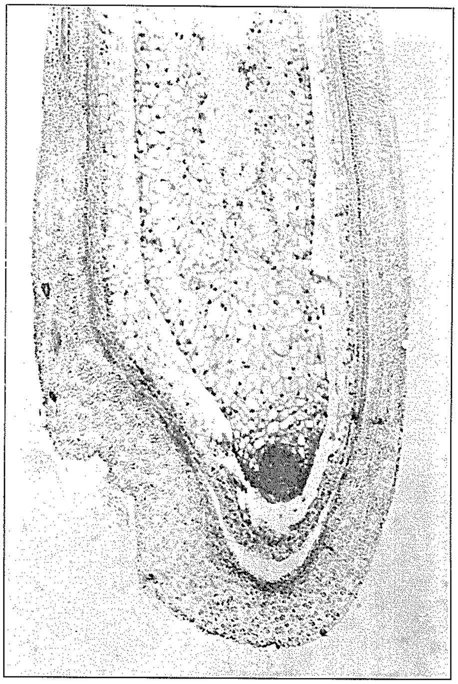

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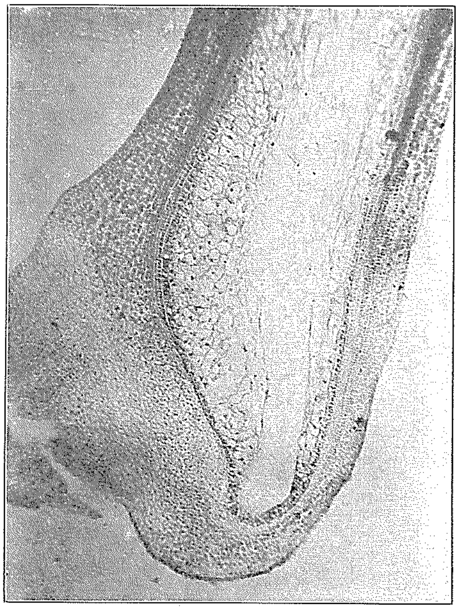
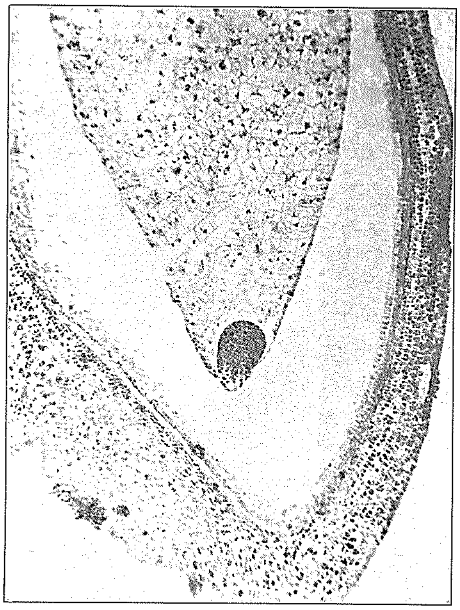


Fig. 5.

Junichi Ishikawa.



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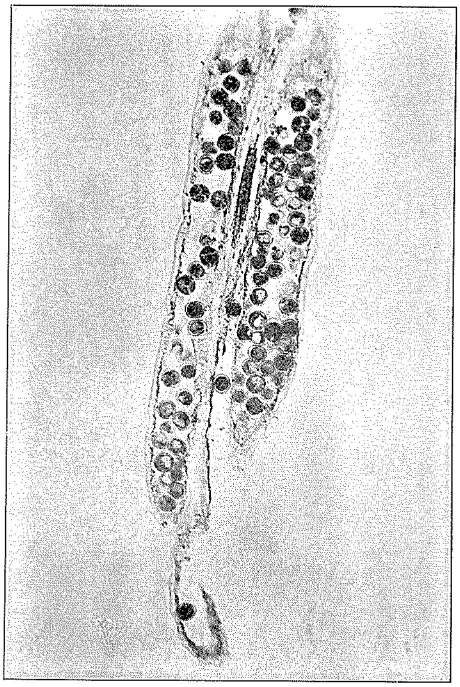

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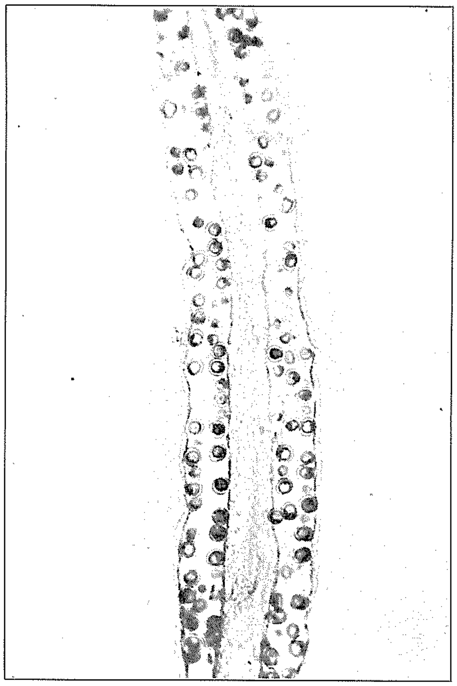

Fig. 8.

Fig. 9.

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Plate VIII.

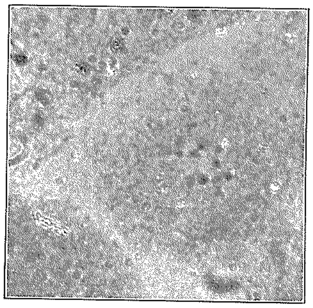

Fig. 10.

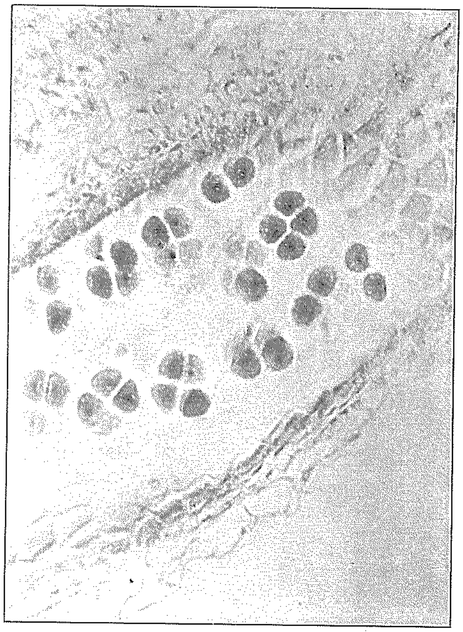

Fig. 11.

Fig. 12.

Fig. 13.

Junichi Ishikawa.