

On the Influences of various Temperatures in Duration of Storage and various Moistures of Rice upon the Preservation of Germination Power of Hulled Rice.

By

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Introduction.

By the writers' earlier experiments^{4), 5)} it was confirmed, that the germination power of hulled rice in the air-tight storage or in the carbon dioxide storage was retained perfectly 4 years or even longer after harvest. In the writers' opinion, if the germination power is retained perfectly, it shows that the rice was preserved perfectly without changes in its quality during the time of storage. They pointed out therefore, the importance of air-tight storage to farmers as a means of reserve of rice.

The influences of various temperatures during storage and various moistures of rice upon the preservation of the germination power of hulled rice during air-tight storage require further study. The writers therefore, studied further about these problems and carried out three experiments. The details of which are reported in the present paper.

Chapter I. Experiment 1.

Materials and methods.

The writers have taken 2 kinds of hulled rice of "Omachi" and "Shinriki" of 1926 and divided each into 5 divisions with different moistures: 10%, 12%, 14%, 16%, 18%. The rice was stored 1) air-tight in the large zinc vessels and 2) in the same zinc vessels with carbon dioxide and placed in a granary. The temperature was not constant, but varied according to the season. The storage continued from January 1927 up to the present.

Results.

The writers have investigated the changes in the physical and chemical properties of rice due to storage, which should be reported later in another paper at the end of this experiment. Here is reported only the relation between the changes of germination power of rice and its moisture.

The germination power of rice was tested in February 1927, just in the beginning of the storage, then in February 1928, one year and three months after harvest and in March 1929, two years and four months after the harvest. The results of the germination experiment are given in Table I.

Table I.
Germinating capacity of hulled rice.

Material	Moisture of rice	Method of storage	Germinating capacity		
			February 1927	February 1928	March 1929
hulled rice of "Shinriki"	10	Air-tight storage	99.5%	99.5%	99.8%
		CO ₂ storage	//	99.8	99.8
	12	Air-tight storage	//	100.0	99.5
		CO ₂ storage	//	100.0	99.8
	14	Air-tight storage	//	25.3	0
		CO ₂ storage	//	13.3	0
	16	Air-tight storages	//	6.0	0
		CO ₂ storage	//	1.3	0
	18	Air-tight storage	//	6.0	0
		CO ₂ storage	//	0.8	0
hulled rice of "Omachi"	10	Air-tight storage	99.5	96.8	99.5
		CO ₂ storage	//	98.0	99.7
	12	Air-tight storage	//	99.5	99.8
		CO ₂ storage	//	99.5	99.5
	14	Air-tight storage	//	50.5	0
		CO ₂ storage	//	34.8	0
	16	Air-tight storage	//	35.3	0
		CO ₂ storage	//	31.8	0
	18	Air-tight storage	//	3.0	0
		CO ₂ storage	//	0.5	0

The above table shows, that rice of moisture 14%, 16% and 18%, either in the air-tight storage or in the carbon dioxide storage, lost its germination power greatly after one year, and completely after two years from the time of harvest. *The rice of moisture 10% and 12%, on the contrary, preserved its germination power perfectly, and it was just the same as that of the new rice.*

By the earlier experiment⁵⁾ the writers confirmed the data, if rice is dried very thoroughly till to ca. 11.5% moisture, its germination power is retained completely 4 years or even longer. It is clear, therefore, the rice with moisture of 10% and 12% in this experiment would retain its germination power much longer than two years.

In regard to the moisture of rice, 14% is rather excessive for the preservation of germination power, but 12% is very favorable. *13% must be a critical point for the preservation of germination power.*

As is well known, the preservation of germination power of seeds is much effected by temperature during storage. In the period of this experiment, the temperature changed according to the seasons, and in summer, rice was kept at high temperature. In the writers' opinion if the temperature in summer is not very high, the moisture of rice 14% would be favourable for preservation of germination power for one year or perhaps still longer.

About the rice with moisture of 10% and 12%, there was no marked difference between the air-tight storage or CO₂-storage, in regard to the germination power, or if any, the CO₂-storage was somewhat better than the air-tight storage. As to the rice with moisture of 14%, 16% and 18%, the CO₂-storage was, on the contrary, less effective than the air-tight storage. From this fact it seems better not to store rice in carbon-dioxide, when rice is not sufficiently dry.

As already mentioned, the germination power of rice indicate that the quality of rice was preserved very well. For the storage of rice, it is recommended, therefore to dry rice till less than 13% moisture and to keep it air-tight.

This experiment is not yet completed. Later the details will be reported.

Chapter II. Experiment 2.

Materials and methods.

Hulled rice of two kinds, "Omachi" and "Kibiho" of 1927 was divided into 4 divisions with different moistures and stored at various temperatures. The rice was sealed air-tight in glass vessels and stored from May 1st, 1928 to November 15th, 1928. The germination power was tested 13 times during storage. The moistures of the several divisions are as follows.

Table 2.
Moisture of rice.

Kinds of rice	Moisture of hulled rice in 4 divisions			
	%	%	%	%
"Omachi"	10.0	12.02	14.20	16.0
"Kibiho"	10.0	12.20	14.04	16.0

The constant temperatures used were 25°C, 30°C, 35°C, 40°C and as the control a part of rice was stored at the room temperature, which is like Table 3.

Table 3.
Room temperature.

Date	Temperature at 10 A. M.	Maximum temperature	Minimum temperature
1928	°C	°C	°C
19. May — 28. May	22.0	24.3	20.7
29. May — 8. June	22.0	24.0	20.3
9. June — 18. June	23.6	25.4	21.7
30. June — 6. July	24.5	27.0	23.3
7. July — 15. July	27.9	30.0	26.5
30. July — 6. Aug.	26.2	27.6	25.0
7. Aug. — 13. Aug.	26.3	28.3	24.4
14. " — 20. "	27.5	29.2	26.1
21. " — 26. "	25.3	28.5	24.0
27. Aug. — 2. Sept.	26.6	29.2	25.4
3. Sept. — 9. Sept.	26.7	29.2	25.7
10. " — 17. "	26.5	28.8	24.7
18. " — 24. "	24.4	27.5	23.5
3. Oct. — 12. Oct.	19.5	21.8	18.3
13. " — 20. "	19.7	22.4	14.0
28. Oct. — 3. Nov.	17.3	20.6	15.0
4. Nov. — 11. Nov.	16.1	19.5	14.4
12. " — 18. "	12.3	16.6	13.6

The maximum of room temperature is 30°C as Table 3 shows.

[illegible]

Table 5.
Germinating capacity of "Kibiho".

Temperature	Moisture of rice	Date put in germination test												
		15. May	1. June	15. June	2. July	15. July	1. Aug.	15. Aug.	1. Sept.	15. Sept.	1. Oct.	17. Oct.	1. Nov.	15. Nov.
Room temp.	% 10	% 100.0	% 99.5	% 100.0	% 100.0	% 100.0	% 98.0	% 98.0	% 97.0	% 99.0	% 98.0	% 99.0	% 100.0	% 100.0
// //	12	100.0	99.5	99.0	98.0	99.0	99.5	99.0	98.5	99.0	98.5	98.0	98.0	98.0
// //	14	98.0	93.0	93.0	94.0	96.0	89.0	87.0	70.0	68.5	38.0	33.0	29.0	27.0
// //	16	98.5	97.5	99.0	98.0	100.0	95.0	90.5	66.0	48.5	50.0	5.5	2.5	4.5
25°C	10	99.0	99.0	100.0	100.0	97.0	98.0	98.5	99.0	97.0	97.0	98.0	99.5	97.5
//	12	99.0	99.5	99.0	99.5	99.5	99.0	99.5	99.5	99.0	99.0	98.0	99.0	94.5
//	14	98.0	91.0	90.5	88.0	90.0	82.5	77.5	76.5	71.5	38.0	30.5	12.0	16.3
//	16	97.0	95.0	93.0	95.5	93.5	93.0	86.0	75.0	76.5	31.0	46.0	5.5	29.0
30°C	10	99.5	99.5	98.5	100.0	97.5	98.5	99.5	98.5	98.0	96.0	98.5	99.0	85.0
//	12	99.0	99.5	99.5	90.5	98.0	94.0	97.0	97.0	94.5	98.0	99.0	97.0	87.0
//	14	95.0	89.0	88.5	78.5	74.5	5.0	8.0	2.5	3.0	0	0	0	—
//	16	97.5	97.0	93.5	87.0	67.5	2.5	0.5	1.5	0	0	0	—	—
35°C	10	98.5	99.0	98.5	100.0	98.0	97.0	98.5	99.0	97.5	97.5	98.0	97.0	89.5
//	12	99.5	100.0	99.5	98.5	93.0	94.5	92.5	79.0	53.5	50.0	49.0	5.5	0
//	14	95.0	83.0	85.0	28.5	0	0	0	—	—	—	—	—	—
//	16	97.0	95.5	84.0	7.0	0.5	0	0	0	—	—	—	—	—
40°C	10	98.0	98.0	97.0	97.0	100.0	98.0	98.5	99.0	96.0	97.5	94.5	97.0	89.5
//	12	100.0	97.5	85.5	21.0	0	0	0	—	—	—	—	—	—
//	14	78.0	0	0	0	—	—	—	—	—	—	—	—	—
//	16	83.5	0	0	0	—	—	—	—	—	—	—	—	—

From the above 2 tables we can see the following facts about the influences of various constant temperatures upon the germination power of rice with the various moistures.

1) *Room temperature* :—

At the room temperature, when the hulled rice was dried to the moisture 10% or 12%, its germination power was preserved perfectly during storage through summer, from May 1st to November 15th. The germination power remained just the same as before the storage.

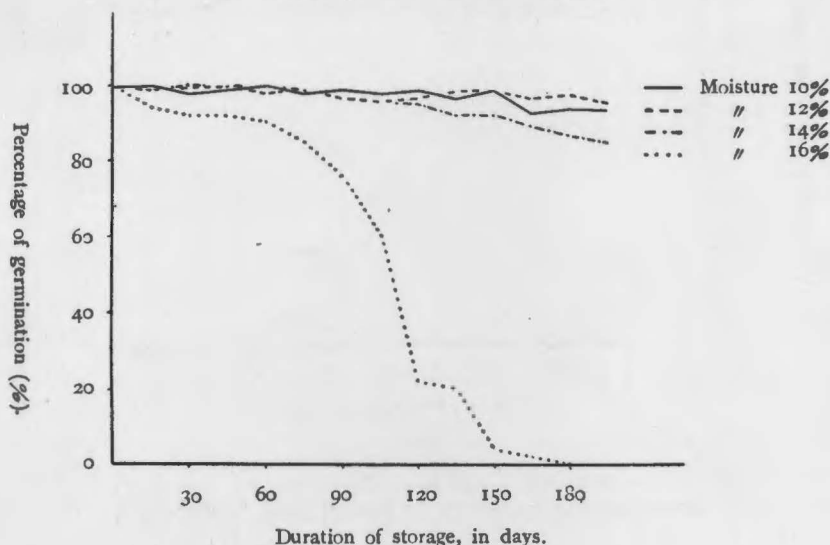
"Kibiho" rice with the moisture 14% lost much of its vitality, but in the case of "Omachi" the germination power was rather well retained.

The rice with moisture 16% lost its vitality entirely (Fig. 1).

Fig. 1.

Germinating capacity of hulled rice, "Omachi".

At room temperature, air-tight storage.



2) 25°C:—

At the temperature of 25°C, the rice with moisture 10% and 12% retained the germination power very well, just as in the room temperature, but the rice of moisture 14% and 16% lost very much of its vitality (Fig. 2).

(See Figure 2 on next page.)

3) 30°C:—

At the temperature of 30°C, the rice with moisture 10%—12% retained its germination power perfectly.

Of the rice with moisture of 14% and 16%, the preservation of the germination power was very bad, and in August and September its vitality was lost entirely (Fig. 3).

(See Figure 3 on next page.)

4) 35°C:—

At the temperature of 35°C, the rice with moisture 10% retained its germination power well and on November 15th its percentage of germination was still very large.

Fig. 2.
Germinating capacity of hulled rice, "Omachi".
At 25°C, air-tight storage.

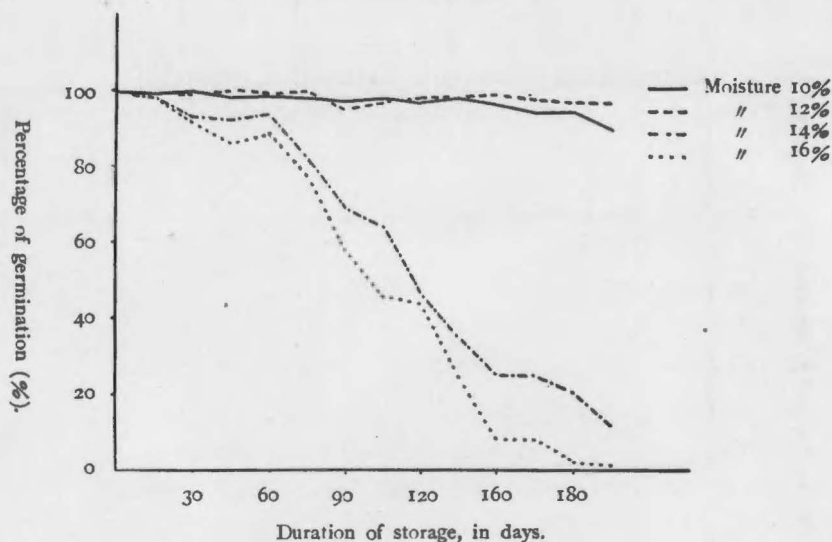
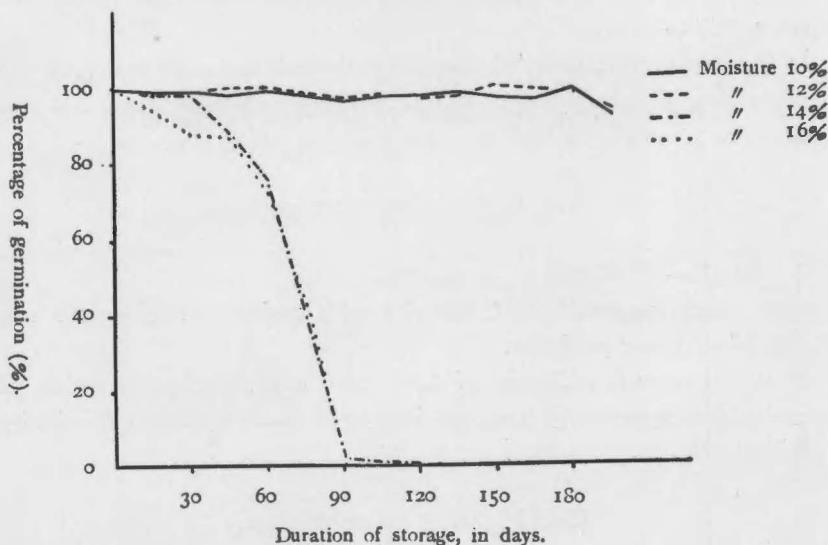


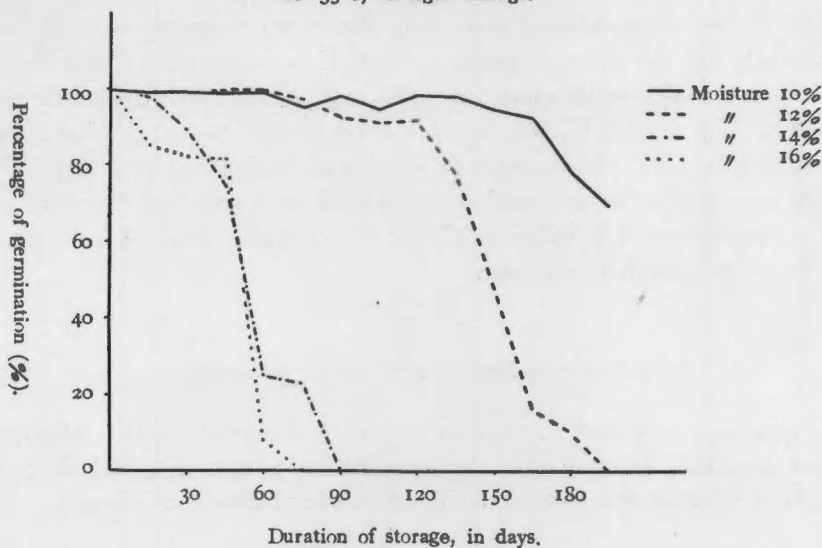
Fig. 3.
Germinating capacity of hulled rice, "Omachi".
At 30°C, air-tight storage.



Of the rice with moisture 12%, the preservation of germination power was rather bad.

The rice with moisture of 14% and 16% lost its germination power entirely in July (Fig. 4).

Fig. 4.
Germinating capacity of hulled rice, "Omachi".
At 35°C, air-tight storage.

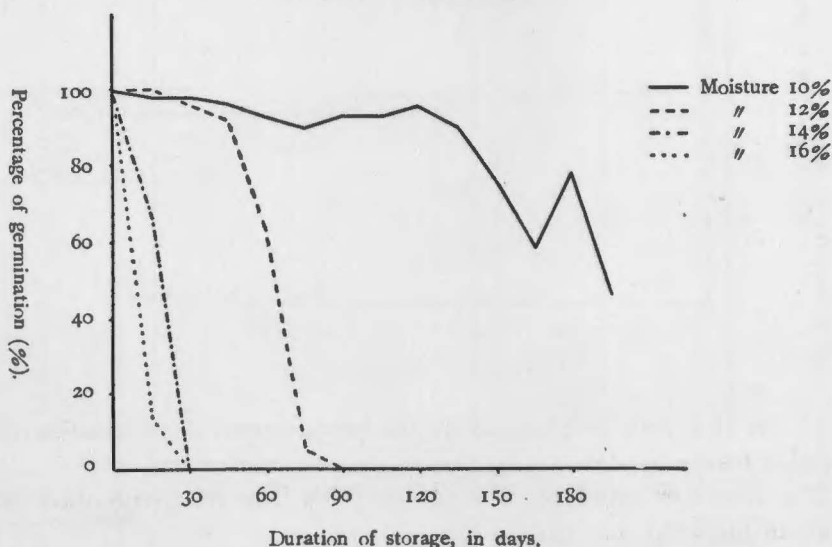


5) 40°C:—

At the temperature 40°C, the rice with moisture 10% retained its germination power well to November 15th.

The rice with moisture 12% or more lost its germination power entirely by June or July (Fig. 5).

Fig. 5.
Germinating capacity of hulled rice, "Omachi".
At 40°C, air-tight storage.



From the above facts it is recommended, *for the storage of rice at the room temperature or at lower temperature than 30°C, to dry the rice to the moisture 10% or 12%.* Then the germination power can be preserved perfectly. The storage at the temperature lower than the room temperature fails in this experiment, but the writers' opinion is that, if in summer rice can be stored cool, even the rice with moisture 14% may retain the germination power perfectly. If you want to store the rice *at the temperature of 35°C or 40°C, on the contrary to above, the rice must be dried to the moisture of 10% or less;* then the rice may retain the germination power 90% even one year after the harvest. At the temperature of 35°C or 40°C, the rice of the moisture of 12% or more soon loses the germination power.

B. Effects of moisture of rice on its germination power.

From Tables 4 and 5, we can see, at the same time the influences of various moistures of rice upon the germination power of hulled rice, stored air-tight at different temperatures. The following facts are confirmed.

1) 10% moisture :—

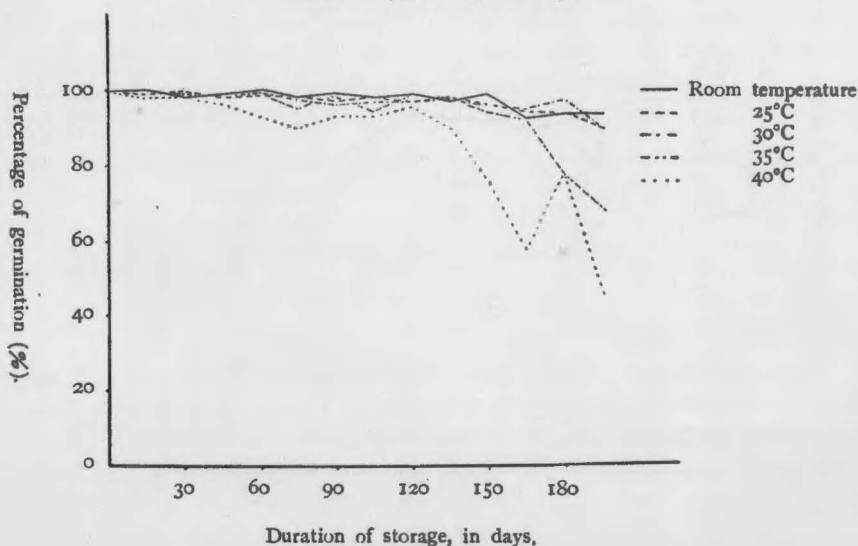
The rice with moisture 10% retained its germination power perfectly, when it was stored at the room temperature, 25°C or 30°C.

At 35°C or 40°C the preservation of germination power was also fairly well (Fig. 6).

Fig. 6.

Germinating capacity of hulled rice, "Omachi".

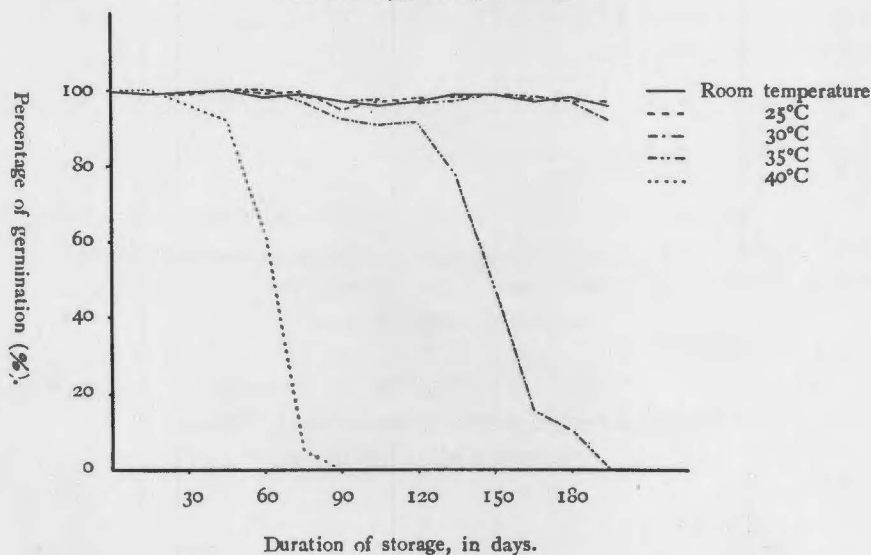
Moisture 10%, air-tight storage.



2) 12% moisture :—

When rice was dried to the moisture 12%, it retained at the room temperature, 25°C or 30°C the germination power perfectly well, at 35°C there was a decrease and at 40°C bad. At 40°C the vitality was lost in July and August entirely (Fig. 7).

Fig. 7.
Germinating capacity of hulled rice, "Omachi".
Moisture 12%, air-tight storage.



3) 14% moisture :—

When the moisture of rice was 14%, the preservation of germination power was even at 25°C rather bad, and at 30°C or 35°C very bad.

At 40°C the vitality was lost perfectly within one month only.

At the room temperature, however, "Omachi" retained the germination power fairly well, but in the case of "Kibiho" it was not so good (Fig. 8).

(See Figure 8 on next page.)

4) 16% moisture :—

When the moisture of rice was 16%, the germination power was retained well, at the room temperature and 25°C, until July or August, but after that much of the germination power was lost suddenly.

At 30°C or over 30°C the preservation of germination power was very difficult.

At 40°C the vitality was lost entirely within one month only (Fig. 9).

Fig. 8.
Germinating capacity of hulled rice, "Omachi".

Moisture 14%, air-tight storage.

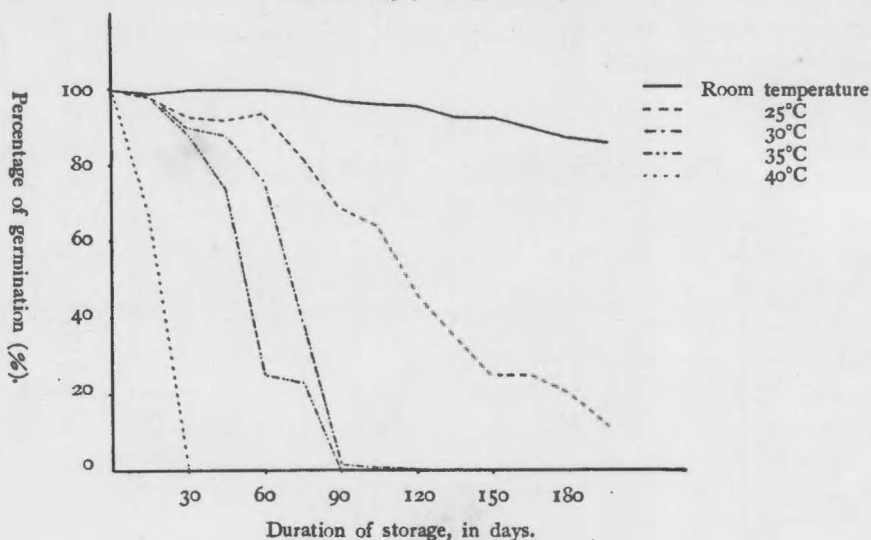
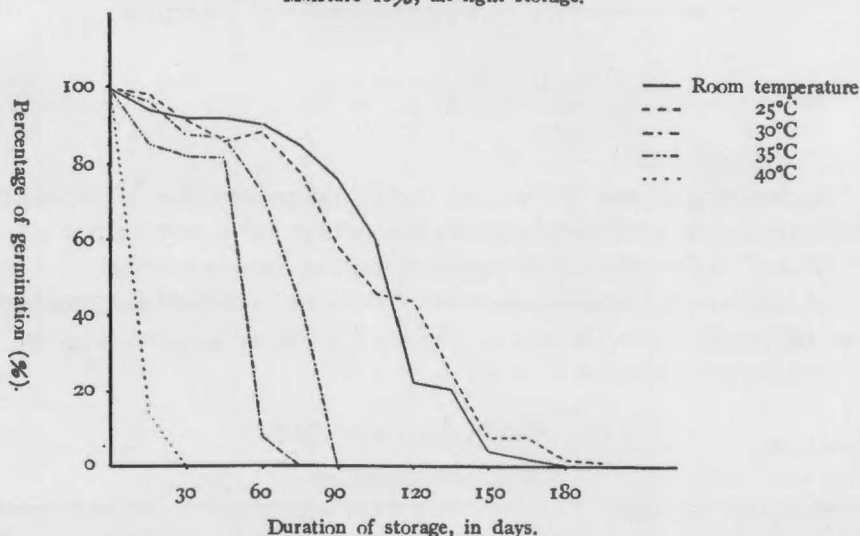


Fig. 9.
Germinating capacity of hulled rice, "Omachi".

Moisture 16%, air-tight storage.



From the above facts it should be understood, that if rice is dried to 12%, the germination power can be retained perfectly at 25°C or 30°C. If the moisture of rice is 14%, the germination power can be preserved fairly well, at the lower temperature than the room temperature. If the moisture of rice is 16%, the preservation of the germination power is very difficult.

Chapter III. Experiment 3.

Materials and methods.

In the preceeding chapter, it is reported about the effects of various temperatures during storage and the various moistures of rice on the preservation of germination power, when the rice is stored air-tight. In the present chapter the writers want 1) to compare the results of air-tight storage and ventilated storage, 2) to repeat the preceeding experiment and 3) to determine, what effect the time of beginning of the air-tight storage has.

As materials the hulled rice of "Omachi" and "Kibiho" of 1927 were used, which are quite the same as the materials used in the preceeding experiment. Each kind of rice was divided into 4 divisions, according to the different moistures. The moistures of rice are given in Table 6.

Table 6.
Moisture of samples.

Kinds of rice	Moisture of hulled rice in 4 divisions			
	%	%	%	%
"Omachi"	9.8	11.8	13.8	16.0
"Kibiho"	10.0	11.8	13.6	16.0

Note: In the following 9.8% will be mentioned by 10%, 11.8% by 12%, 13.6% and 13.8% by 14%, to make short.

Each sample of different moisture was divided again into 8 parts, and one set of 4 parts were sealed air-tight in glass-vessels and another set of 4 parts were stored in ventilated glass-vessels. Each of 4 parts of same moisture was placed at the various temperatures, i. e. at room temperature, 30°C, 35°C and 40°C.

The room temperature is as Table 7 shows.

Table 7.
Room temperature.

Date	Temperature at 10 A. M.	Maximum temperature	Minimum temperature
1928	°C	°C	°C
7. July — 15. July	27.9	30.0	26.5
30. July — 6. Aug.	26.2	27.6	25.0
7. Aug. — 13. Aug.	26.3	28.3	24.4

Date	Temperature at 10 A. M.	Maximum temperature	Minimum temperature
	°C	°C	°C
14. Aug. — 20. Aug.	27.5	29.2	26.1
21. " — 26. "	25.3	28.5	24.0
27. Aug. — 2. Sept.	26.6	29.2	25.4
3. Sept. — 9. Sept.	26.7	29.2	25.7
10. Sept. — 17. Sept.	26.5	28.8	24.7
18. " — 24. "	24.4	27.5	23.5
3. Oct. — 12. Oct.	19.5	21.8	18.3
13. " — 20. "	19.7	22.4	14.0
28. Oct. — 3. Nov.	17.3	20.6	15.0
4. Nov. — 11. Nov.	16.1	19.5	14.4
12. " — 18. "	12.3	16.6	13.6
19. " — 25. "	10.2	15.6	9.1
26. Nov. — 1. Dec.	10.8	17.2	8.8
2. Dec. — 9. Dec.	10.1	13.5	8.7
10. " — 16. "	10.6	14.3	8.9
17. " — 23. "	7.5	12.8	5.3
24. " — 31. "	8.6	12.8	6.3
1929 7. Jan. — 13. Jan.	7.1	14.0	5.0
14. " — 20. "	9.3	12.2	5.8
21. " — 27. "	5.9	10.7	3.8
28. Jan. — 3. Feb.	5.9	11.0	3.0
4. Feb. — 10. Feb.	7.8	11.9	4.7

The storage experiment continued from July 9, 1928 to February 9, 1929 and 14 times, in that period, the germination test was carried out.

Results.

A. Effects of various temperatures during storage on the germination power of rice.

The effects of various temperatures during storage on the germination power of hulled rice are as Table 8—11 show.

Germinating capacity of hulled rice stored air-tight, "Kibiho".

[illegible]

Germinating capacity of hulled rice stored in ventilation, "Kibiho".

[illegible]

Germinating capacity of hulled rice stored air-tight, "Omachi".

[illegible]

Germinating capacity of hulled rice stored in ventilation, "Omachi".

[illegible]

According to Table 8—11 the following effects of various temperatures as a condition of storage on the germination power of rice can be seen.

1) *Room temperature:—*

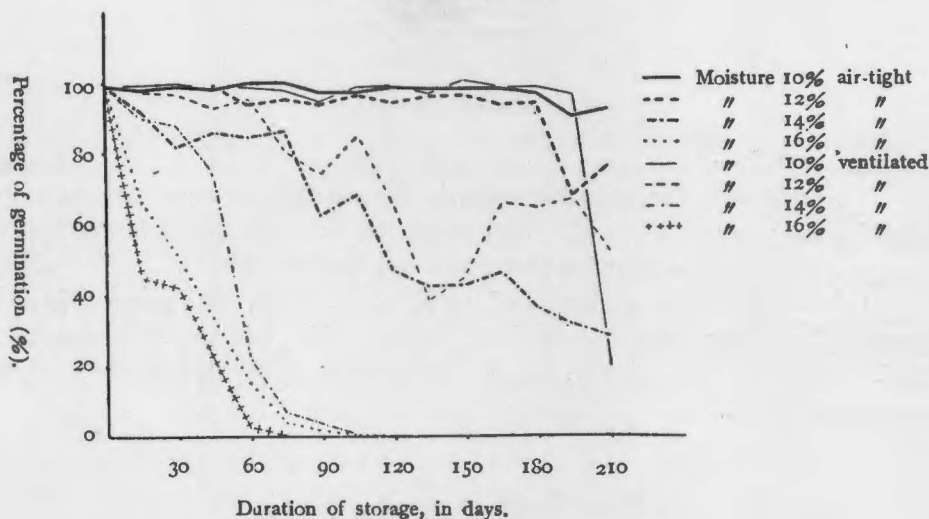
At the room temperature, the rice with 10% moisture retained its germination power perfectly, the rice in the air-tight storage was particularly well retained.

The rice with 12% moisture preserved the germination power well in the air-tight storage, but in the ventilated storage it was bad.

When the moisture of rice was 14% the germination power decreased gradually during the storage; in the ventilated storage, particularly the preservation of germination power was bad.

The rice with 16% moisture lost the germination power quickly, not only in the air-tight storage, but also in the ventilated storage. When it was stored in ventilation the preservation of vitality was especially bad (Fig. 10).

Fig. 10.
Germinating capacity of hulled rice, "Kibiho".
At room temperature.



2) 30°C :—

At the temperature 30°C , the germination power of rice was perfectly preserved, when the moisture of rice was 10% and the rice was stored air-tight. But it was worse, when the rice was stored in ventilation.

The rice with moisture 12% in the air-tight storage preserved the germination power well, but a little worse than the rice with moisture 10%. When it was ventilated, the result was bad.

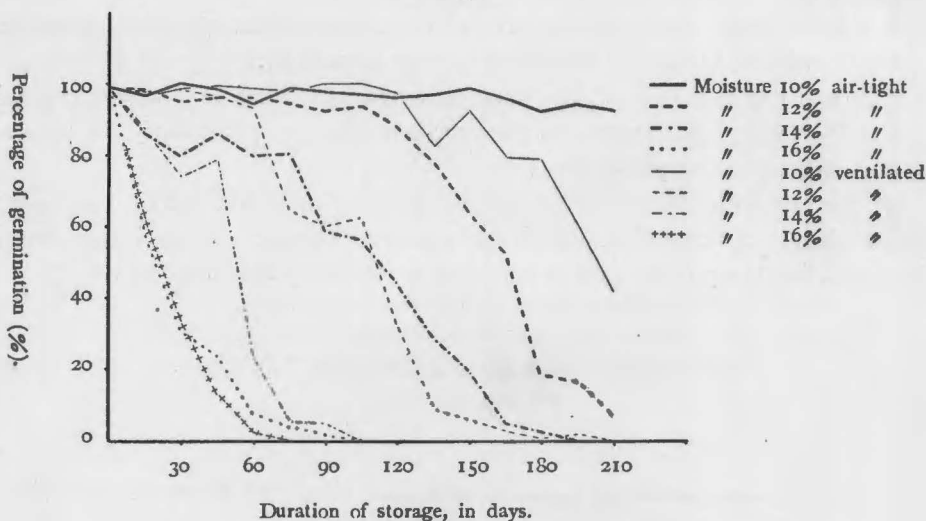
The rice with moisture 14% lost its germination power gradually. When ventilated, the result was much worse than by the air-tight storage.

The rice with moisture 16% lost its vitality quickly, when stored, not only air-tight, but also ventilated. When it was ventilated, the preservation of vitality was particularly bad (Fig. 11).

Fig. 11.

Germinating capacity of hulled rice, "Kibiho".

At 30°C.



3) 35°C:—

The rice with the moisture 10%, in the air-tight storage, preserved its germination power fairly well. But, when the rice was stored in ventilation the preservation of germination power was somewhat worse.

Of the rice with moisture of 12%, 14%, 16%, the preservation of germination power was always bad, by the rice with moisture 16% especially bad. When it was ventilated, the result was a little better than in the air-tight storage (Fig. 12).

(See Figure 12 on next page.)

4) 40°C:—

When the moisture of rice was 10%, the germination power of rice was preserved well for duration of 3—4 months, after which time, the vitality decreased suddenly. In the air-tight storage the preservation of vitality was worse than in the ventilated storage.

Of the rice with the moistures of 12%, 14% and 16%, the preservation of germination power was bad. When it was stored air-tight, its result was worse than the ventilated storage (Fig. 13).

Fig. 12.
Germinating capacity of hulled rice, "Kibiho".
At 35°C.

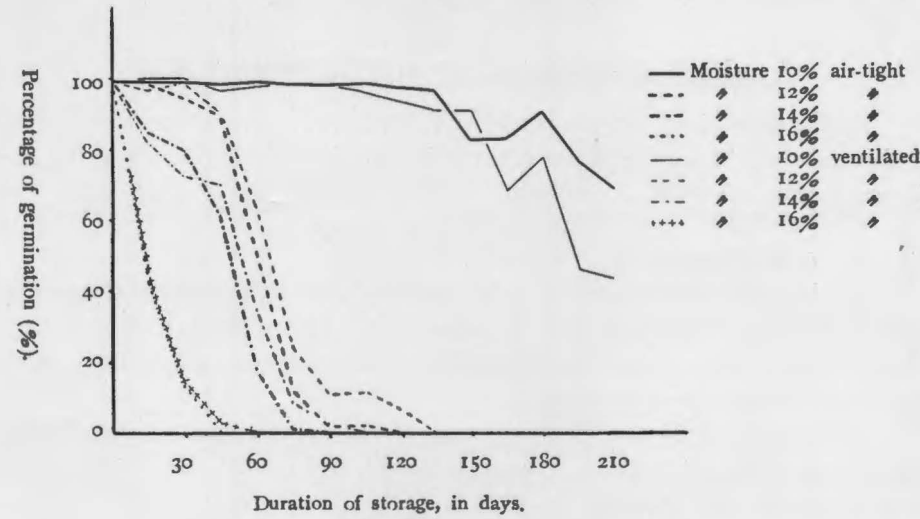
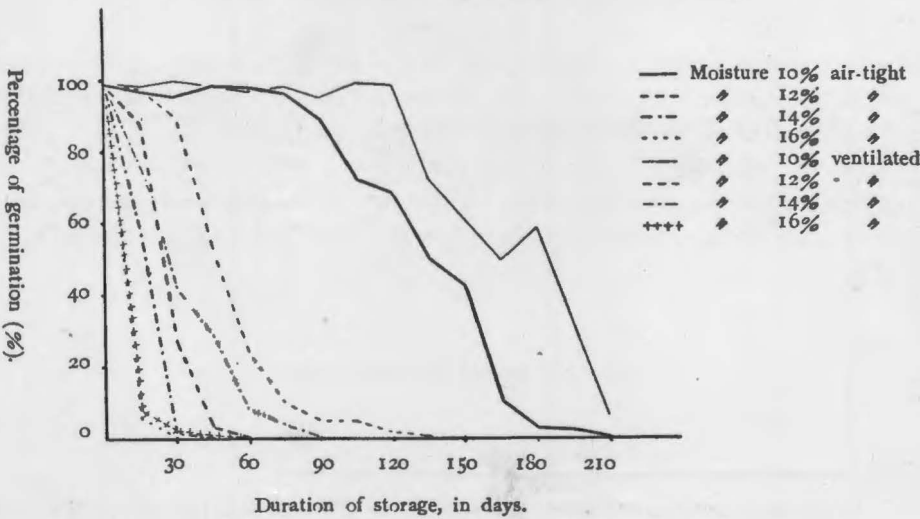


Fig. 13.
Germinating capacity of hulled rice, "Kibiho".
At 40°C.



From the above data the following conclusions were reached. If rice should be stored at the room temperature, it should be dried to moisture 12% and kept air-tight, then the germination power would be preserved perfectly. If rice should be preserved at 30°C, it should be dried to 10% moisture and stored air-tight. If rice should be stored at 35°C, it should be dried to 10% or less

moisture and stored air-tight. If rice should be stored at 40°C , it should be dried to less than 10% moisture and stored in ventilation. At 35°C and 40°C , the rice with moisture 12% preserves the germination power very badly.

B. Effects of moisture of rice on its germination power.

At the same time, we can see from Table 8—11, the influences of various moistures of rice upon the preservation of its germination power, when the rice is stored either air-tight or ventilated. The following facts are confirmed.

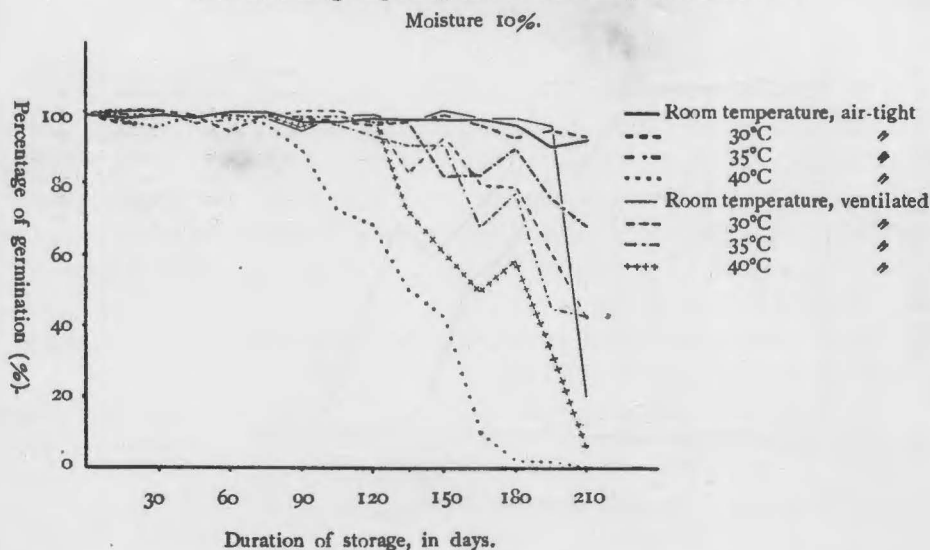
1) 10% moisture:—

As the room temperature or 30°C , and in the air-tight storage, the preservation of the germination power of hulled rice with moisture 10% was very good. Even when it was ventilated, the result was also good, but a little worse than by the air-tight storage.

At 35°C , and in the air-tight storage, the preservation of germination power was also good. When it was ventilated, the result was a little worse than by the air-tight storage.

At 40°C , the preservation of the germination power was fairly good, when it was ventilated, but worse when it was stored air-tight (Fig. 14).

Fig. 14.
Germinating capacity of hulled rice, "Kibiho".



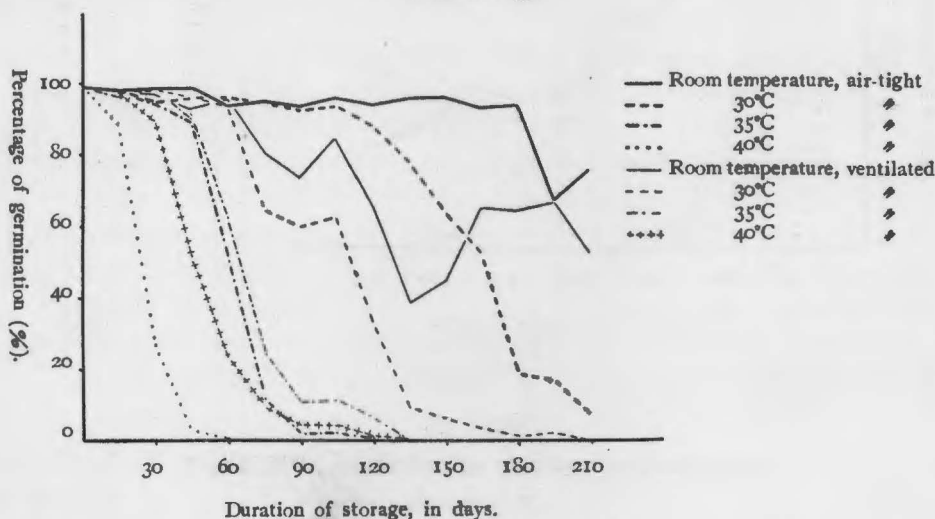
2) 12% moisture:—

At the room temperature and in the air-tight storage, the preservation of germination power of rice was very good. When it was ventilated the result was much worse.

At 30°C and in the air-tight storage, the preservation of the germination power was fairly good. When ventilated, however, it was bad.

At 35°C and 40°C, the preservation of the vitality of rice was bad, either in the air-tight storage or in the ventilated storage. In the air-tight storage the result was especially bad (Fig. 15).

Fig. 15.
Germinating capacity of hulled rice, "Kibiho".
Moisture 12%.



3) 14% moisture :—

By the moisture 14%, the preservation of vitality was generally rather bad. Among others, however, at the room temperature and in the air-tight storage the preservation of germination power was better. But when ventilated the result was much worse. The writers' opinion is that, if the rice is stored at a lower temperature than the room temperature, particularly in summer, its germination power should be preserved well.

At 30°C and in the air-tight storage, the preservation of the germination power was fairly good, but when ventilated the result was very bad.

At 35°C and 40°C, the preservation of vitality was very bad. Particularly, the result was very bad, when the rice was stored air-tight (Fig. 16).

(See Figure 16 on next page.)

4) 16% moisture :—

The preservation of the germination power was always bad. At the room temperature and 30°C, the preservation of vitality was better in the air-tight storage than in the ventilated storage, but at 35°C and 40°C it was the contrary (Fig. 17).

Fig. 16.
Germinating capacity of hulled rice, "Kibiho".
Moisture 14%.

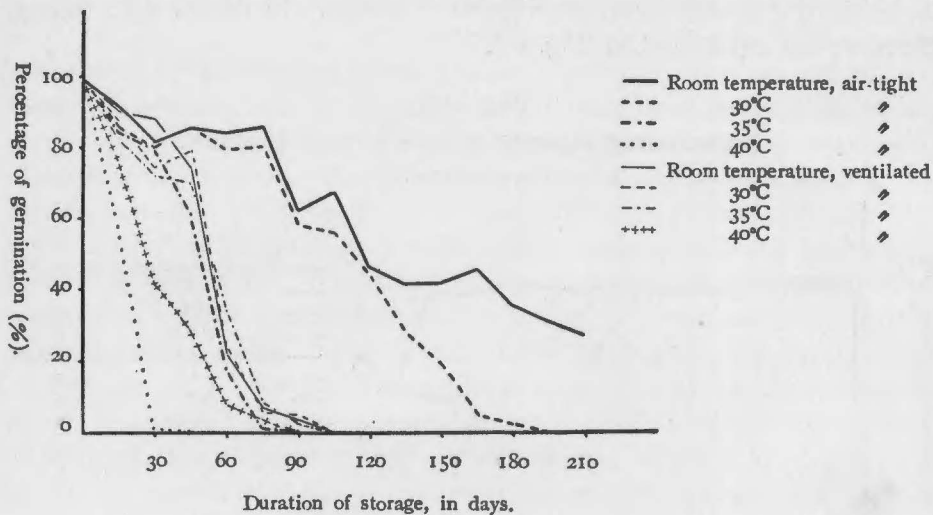
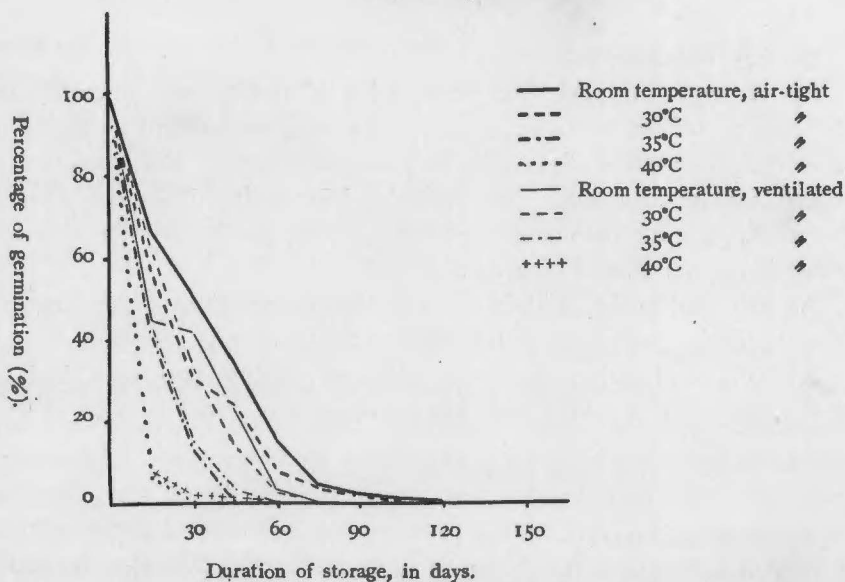


Fig. 17.
Germinating capacity of hulled rice, "Kibiho".
Moisture 16%.



Summarizing the data given above, the writers reach the following conclusion.

When the hulled rice is dried to the moisture 10%, and stored at the room temperature or 30°C air-tight, the preservation of the germination power is perfect. At 35°C the result is a little worse, but yet fairly good.

The rice with moisture 12% can retain its germination power very well, if it is stored at the room temperature and air-tight.

Of the rice with moisture 14%, the perfect preservation of germination power at the room temperature is rather difficult, but if it is stored at lower temperature, the result would be good.

If the rice contains 16% moisture, the preservation of the vitality is difficult.

There is another important fact to be added here. The materials of Experiment 2 and 3 were quite same. They were harvested in Autumn 1927. In Experiment 2, the storage experiment began on the 1st of May 1928, and at that time it was not hot. But in Experiment 3, the storage experiment began on the 9th of July 1928, when it was already very hot. Comparing the results of both experiments, there is a great difference, i. e. by Experiment 3 the preservation of the vitality was much worse than by Experiment 2. In the writers' opinion it is the effect of the time of beginning of the air-tight storage. The writers recommend, therefore, *to begin the storage of rice in the cold and dry season, but never in the hot and wet season.*

Chapter IV. Discussion.

It is a well known fact, that the moisture of rice and the temperature during storage effect the preservation of germination power of rice. According to the writers' opinion, if the vitality of rice is preserved perfectly as new rice, it shows, that changes of quality of rice scarcely ever happend. It is very important, therefore, to store rice in such a way as to conserve its vitality in safety. In the three experiments descrided above, the investigation was to make clear the relations between the moisture of rice, the temperature during storage, and the preservation of vitality of rice.

A. Moisture of rice.

When the hulled rice with moisture 10% is stored air-tight at the room temperature or at the lower temperature than 30°C, the rice can retain its germination power perfectly for a long time. By Experiment 2, moreover, the writers observed, that the rice with moisture 10%, stored from May 1st to November at 35°C and 40°C, retained the germination power very well. At 35°C or lower temperature, the air-tight storage is better than the ventilated storage, at 40°C, however, the air-tight storage is worse than the ventilated storage, as a condition of the preservation of germination power. For the storage of rice at 40°C, 10% of moisture is, however, rather too much, and rice

should be more dried to less moisture or it should be necessary to attach a drying apparatus to the vessels. Otherwise, it should be stored rather in ventilation so as to let its moisture escape.

Iso¹⁾ at Formosa, a subtropical island of Japan, saw, that rice seeds (unhulled rice) with moisture of less than 11% retained the germination power perfectly 18 months, while rice seeds with moisture of more than 11%, on the contrary, lost it entirely. The rice seeds with moisture 6.9% retained 98.5% germination power even after 32 months. SUZUTA⁹⁾ also at Formosa, stored rice seeds with CaCl_2 ; after 4 months the moisture became 6—7% and after 17 months 3—4%; after 2 years he saw, that the formosa rice seeds retained 99.4% germination power, japanese rice seeds 93.4%. Summarizing the above mentioned investigations of ISO, SUZUTA and writers' own, it is clear that, *if rice is thoroughly dried to less than 10%, it can retain for a long time its germination power perfectly at a temperature even as high as 35°, 40°C.*

SUZUTA¹⁰⁾ reported, that drying of rice seeds at 70°C for 24 hours, or at 30—70°C for 5 days, did not hurt their vitality at all. JONES²⁾ reported also, that an exposure of dry rice seeds for one hour at 158°F (70°C) did not affect germination. Therefore, it should be clearly understood, that unhulled rice can be dried, at 70°C or lower temperature, to moisture of less than 10%, without reduction of the vitality.

The hulled rice with moisture 12% or less can retain its vitality completely for several years, when it is stored air-tight at the room temperature. At 25°C and 30°C, it retains the vitality well too, when stored air-tight. At 35°C, the vitality decreases gradually and at 40°C it is lost entirely. At 35°C and 40°C it should be, therefore, necessary to attach a drying apparatus to the vessels, otherwise it should be stored rather in ventilation, but its result is not much effective for the preservation of the vitality.

According to the writers' opinion, in the temperate climate like the main land of Japan (= Hondo), hulled rice should be preserved in safety for several years, to keep its vitality, when the rice is dried to 12% moisture and stored air-tight.

When rice contains 14% moisture, the perfect preservation of its germination power for several years, is rather difficult. But, if it is possible to store rice cool, particularly in summer, and air-tight, it would be preserved well. At 25°C, the result of storage is rather bad, at 30°C or at higher temperature, the germination power decreases very much. If you want to store hulled rice with moisture 14%, at 35—40°C, to conserve its germination power, it is necessary to attach a drying apparatus to a vessel, in order to absorb, the moisture. At high temperature, the ventilated storage is better than the air-tight storage, but its effect is very slight.

When rice contains 16% moisture, it is not fit for storage at all. In either air-tight or ventilated storage, at room-temperature, or particularly at higher temperature, it is always difficult to preserve its vitality. At room temperature or at 30°C, the air-tight storage is better than the ventilated storage, at 35°C

and 40°C, on the contrary, the ventilated storage is better than the air-tight storage. TASAWA¹¹⁾ reported that, by rice with moisture 16—19% stored at 30°C, the preservation of germination power was bad, and particularly in the air-tight storage it was worse. We can say *that rice with moisture 16% or more, so called "soft rice", produced in the North-Eastern part of Japan, is out of question of storage at all.* This soft rice must be consumed before summer or dried thoroughly for storage, or it must be put in cold storage.

B. Temperature during storage.

In the preceeding paragraph of moisture, the effect of temperature during storage on the preservation of germination power was discussed together, but it is easier understood to repeat the discussion about temperature briefly again.

At room temperature of Okayama, or at lower temperature, i. e. at the temperate climate, hulled rice can retain its germination power a very long time, if it is dried to 12% and stored air-tight. At 25°C it is the same. *In practice, therefore, for the storage of rice for several years, rice should be dried to 12% or in some cases 13% moisture and kept air-tight.*

For the storage at 30°C or at lower temperature, rice must be dried to moisture 10—12% and kept air-tight.

At 35°C, the rice must be dried to a moisture of 10% or less, and stored air-tight.

At 40°C, the rice must be dried to a moisture of less than 10%, and a drying apparatus attached to each vessel. YAMAGAMI at Okayama has invented, according to the writers' suggestion, the air-tight zinc vessels for storage of rice and agricultural seeds, with a moisture absorbing apparatus, using CaCl_2 inside of vessels.

In a hot climate like Formosa, the Philippine islands, the Malay Peninsula, Java, India etc., where rice is the principal food of the people, it is recommended that rice be thoroughly dried to a moisture of less than 10% and to store air-tight in a vessel with a drying apparatus. If it is not possible to dry rice to a moisture of less than 10% and if is necessary to store it at 40°C, it is rather to be recommended that it be stored in ventilation so as to let its moisture escape.

C. Comparison of air-tightness and ventilation.

The effects of air-tightness or ventilation on the storage of rice is different, according as the moisture of rice and the temperature in the period. From the results of the experiments, we see the following facts about the comparison of both conditions.

From the point of temperature in the period :

1. At the room-temperature, air-tightness is better than ventilation as a condition of storage. When rice is dried to 10% or 12% moisture, the former is especially much better than the latter.

2. At 30°C it is the same as the above, and when rice dried to 10% moisture, air-tightness is especially better than ventilation.
3. At 35°C and in moisture of 10%, air-tightness is better than ventilation as a condition of storage, in moisture of 12—16%, the results of air-tight or ventilated storage are about the same, or the latter may be a little better, but the results of both are bad.
4. At 40°C, ventilation is always better than air-tightness as a condition of storage.

From the point of moisture of rice :

1. When moisture of rice is 10%, at the room-temperature or at the temperature to 35°C, air-tightness is better, at 40°C on the contrary, ventilation is better than the other as a condition of storage.
2. When moisture of rice is 12%, at the room temperature and at the temperature to 30°C, air-tightness is better, at 35°C, on the contrary, ventilation is somewhat better, at 40°C ventilation is better than the other, as a condition of storage.
3. When rice contains 14% moisture, at the room-temperature, and at the temperature to 30°C, air-tightness is better, at 35—40°C, on the contrary, ventilation is better than the other, as a condition of storage.
4. When rice contains 16% moisture, at the room temperature and 30°C, air-tightness is better, at 35—40°C, ventilation is better than the other, as a condition of storage.

In short, we can say, *if moisture of rice is small and temperature in the period is low, air-tightness is better than ventilation, if moisture of rice is great and temperature high on the contrary, ventilation is a little better than air-tightness, as a condition of storage of hulled rice.*

Summary.

Summarizing the data given above, the writers reach the following conclusions about the safest methods of storage of hulled rice.

1. At the lower temperature than 25°C, the rice should be dried to moisture 12% and stored air-tight.
2. At 30°C, rice should be dried to moisture 10—12% and stored air-tight.
3. At 35°C, rice should be dried to moisture 10% or less and stored air-tight.
4. At 40°C, rice should be dried to less than 10%, and stored air-tight, attaching a drying apparatus to the vessel.
5. When rice contains moisture of 10—12%, it should be stored at a lower temperature than 30°C and air-tight. Then the rice retains its germination power perfectly for a long time.

6. When rice contains moisture of 14%, it is difficult to perfectly conserve the germination power. But, when it is stored cool in summer, and air-tight, the vitality is preserved well.
7. When the moisture of rice is 16%, the preservation of its germination power for a long time is very difficult, particularly so at a higher temperature than 30°C. It must be stored in cold.
8. The results of the three experiments given above, show that in order to conserve the germination power of hulled rice, the conditions of storage must be so controlled, that the moisture of rice is kept to 10—12%, that the temperature is lower than 30°C and that it is to be stored air-tight.
9. The storage must be begun during the cold and dry season.

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