# Studies on the Problem of Loss of Viability of Rice Seeds in Storage*

*By*

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**I. Introduction:** Oryza sativa, the species to which most of the cultivated rices belong, has great diversity of forms in India, varying with the seasonal and climatic conditions. Nevertheless, it is usual to find a particular variety adapting itself to different conditions of soil and climate. On this capacity of varietal adaptation, depends the success of "Introduction" as a method of crop improvement. In addition to the climatic factors that might facilitate the growth and development of an introduced variety, there are others that contribute directly or indirectly to its sustained popularity. Resistance to pests and diseases, consistency in response to intensive methods of cultivation, among others, have also to be taken into account in judging of a variety as suited to permanent cultivation in a locality. Still, the conditions may not be quite favourable to every phase of the life cycle from seed to seed of the variety introduced. A particular season or seasonal conditions might favour its growth and development to maturity but subsequent weather conditions and methods of storage might affect its rest phase as seed.

Strain CO. 3 isolated in Coimbatore and introduced into Malabar and South Kanara affords an interesting example. In these places CO. 3 is grown in August—September and harvested in December—January. In South Kanara the harvested grains are stored in straw-twist bundles called *Murra*, till the time of next sowing in August—September. The stored seeds thus pass through the wet weather period of South-West monsoon (June—July) which is marked by heavy rainfall and high humidity. At the time of sowing, the seeds stored in *Murra* are found to have lost viability to the extent of more than 50%, the percentage of germination going down to zero in some seasons. The same extent of deterioration is noted under conditions obtaining in Malabar also, if the seeds are stored in non-air-tight receptacles.

**II. Literature:** Srinivasan (1933) observed that *Garikasannavari*, the outstanding spring rice cultivated from February to May in the *Godavari* delta, lost viability if stored in basket bins and straw-twist bundles called *Mudicatta*. In order to avoid this the ryots sow the seeds as an intermediate crop from June to October (Autumn) as soon as it is harvested in May. It is a problem that affects the entire *Dalua* area of 200,000 acres in the delta. Parija (1940) observed this phenomenon in Orissa in the case of the *Dalua* or *Boro* (Spring) rices that are raised from

*Ramasastrulu Munagala Prize, 1952 — awarded for this paper.

January to April and occupying an area of nearly 30,000 acres. Here again, to avoid the storage problem the cultivators are forced to grow small seed plots in the main season for the *Dalua* crop immediately following.

The problem exists only in the case of winter and spring rices and it is presumed that the deterioration sets in as the stored seeds pass through a rainy period which brings about marked changes in atmospheric conditions. In South Kanara the introduced variety CO. 3 yields twice as much as the local variety it has partly replaced namely *Athikraya*, a red riced variety. It is preferred also for the reason that its kernel gives beaten rice of high quality and rice of good quality for the table.

This paper is an account of the studies undertaken on the various aspects of deterioration and the mode of inheritance of the character.

Literature on the storage of rice with reference to viability is meagre. All the studies related to its keeping quality in prolonged bulk storage and those of viability were only incidental. Srinivasan (1933) adopted nine methods of storage with the variety *Garikasannavari* and found that metallic receptacles alone maintained viability. Ramiah (1937) recorded that under conditions obtaining in Coimbatore where the stored seeds did not pass through a rainy spell, a great deal of variation existed among different varieties as regards viability in prolonged storage. He made the general observation that "it is the variety that germinates very quickly after harvest without a resting period, that loses its viability sooner". Saran (1945) adopted different methods of storage and noted viability after 27 months. He observed that seeds containing 10 to 12 percent moisture lost viability, the same seeds maintained viability when the moisture was brought down by desiccating agents or by drying.

**III. Experimental:** 1. On the differential maturity of the seeds: As the presence of immature and ill-developed seeds might bring about loss of viability the first set of experiments were undertaken to find out the extent of deterioration in such case. Winter strains PTB. 3, PTB. 4, PTB. 6 *(Athikraya)*, CO. 3, CO. 5, CO. 7, and GEB. 24, were harvested after 20, 25, 30, 35 and 60 days of flowering and stored in kerosene tins after the usual drying. Germination tests were conducted every month from June to October. (For the tests, samples were drawn from the receptacles and soaked for 24 hours in water before transferring to the germination trays. Tests were done in duplicate or replicates of four each and the figures given represent the average.)

From the results presented in Table I it will be seen that seeds of 20 and 25 days' maturity gave low percentages in all cases, both deteriorating and non-deteriorating types. This would show that

deterioration due to immaturity is of a nature different from that noticed in the case of mature seeds stored under aerobic storage in gunny or *Murra*.

2. Maturity and methods of storage: In another series PTB. 6 (Athikraya) and CO. 3, the local and introduced variety respectively, were harvested after 20, 25, 30 and 35 days of flowering. Each lot was stored in single gunny, double gunny, kerosene tin and *Murra*. The results are presented in Table II.

Here, within experimental limits, the degree of maturity had little effect on the loss of germinability. Single gunny, double gunny and *Murra* gave low percentage in the case of CO. 3, while PTB. 6 maintained satisfactory germination.

3. Place effect and methods of storage: In this experiment, varieties CO. 2, CO. 3, GEB. 24 and *Athikraya* grown in three different taluks of South Kanara were stored in tin and *Murra*. In *Murra* they were stored in two series one of which was kept on kitchen loft for smoking as practised by some of the ryots. Germinations were recorded from May to October.

Marked deterioration was noted in the case of *Murra*, a fall in germination by about 30% in July and more than 50% in August. Smoking improved germination to a very limited extent only. Seeds preserved in tin maintained viability throughout. CO. 2 and in certain cases GEB. 24 also deteriorated like CO. 3 while the viability of *Athikraya* was unimpaired. Variations in germinability were noticed between CO. 3 grown in different places. This would suggest that environmental factors acting on the crop had some influence on the extent of deterioration of the seeds.

4. (a) Aerobic and anaerobic methods of storage; CO. 3 harvested in South Kanara was stored under different methods listed below:—

1. Single gunny.
2. Double gunny.
3. Zinc bin.
4. Gunny lined inside with oil cloth.
5. Gunny lined inside with thick brown paper.
6. Kerosene tin.
7. *Murra*.

Percentages of germination given in Table I show that metallic receptacles preserved the seeds till October. Gunny lined with oil cloth gave 75% germination which would prove that the nearer the receptacles approached anaerobic condition, lesser was the loss of viability.

**TABLE I.**

**Aerobic and anaerobic methods of storage.**

Treatments :—

1. Single gunny.
2. Double gunny.
3. Zinc bin.
4. Gunny lined with oil cloth.
5. Gunny lined with thick brown paper.
6. Kerosene tin.
7. *Murra.*

| Treatments | Percentage germination in | | | | |
|---|---|---|---|---|---|
| | June | July | August | September | October |
| 1. | 98 | 78 | 36 | 27 | 3 |
| 2. | 97 | 77 | 39 | 13 | 5 |
| 3. | 93 | 96 | 98 | 98 | 100 |
| 4. | 99 | 100 | 86 | 75 | 75 |
| 5. | 98 | 82 | 36 | 13 | 8 |
| 6. | 98 | 96 | 95 | 93 | 96 |
| 7. | 99 | 68 | 21 | 15 | 12 |

(b) As confirmatory trials the following further methods of storage were adopted, the aim being to find out cheaper receptacles than metallic, for preserving the seeds. The descriptions of receptacles are given below :—

1. Kerosene tin.
2. Mud pot.
3. Mud pot made more impermeable by treatment over hearth.
4. Aska sugar gunny.
5. Wooden box.
6. Cement bin.
7. Metallic bin.
8. Murra.

Weekly germination tests were conducted from June to October. The results are presented in table II.

**TABLE II.**

**Aerobic and anaerobic methods of storage.**

Treatments :—

1. Kerosene tin.
2. Mud pot.
3. Mud pot made more impermeable by treatment over hearth.
4. Aska sugar gunny.
5. Wooden box.
6. Cement bin.
7. Metallic bin.
8. *Murra.*

| Treatments | Percentage germination in I, II, III, and IV weeks | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | June | | | | July | | | | August | | | | September | | | | October | | | |
| | *I | II | III | IV | I | II | III | IV | I | II | III | IV | I | II | III | IV | I | II | III | IV |
| 1 | * | 97 | 99 | 100 | 99 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 99 | 99 | 99 | 100 | 100 | 99 | 100 |
| 2 | | 98 | 99 | 100 | 98 | 99 | 97 | 94 | 95 | 89 | 92 | 80 | 82 | 67 | 48 | 47 | 37 | 33 | 19 | 23 |
| 3 | | 98 | 100 | 98 | 97 | 96 | 96 | 98 | 97 | 95 | 84 | 74 | 66 | 60 | 46 | 41 | 39 | 26 | 20 | 23 |
| 4 | | 97 | 98 | 99 | 99 | 91 | 90 | 98 | 79 | 60 | 65 | 53 | 55 | 52 | 30 | 16 | 11 | 15 | 15 | 10 |
| 5 | | 98 | 99 | 100 | 99 | 99 | 97 | 99 | 100 | 95 | 90 | 75 | 71 | 58 | 26 | 18 | 15 | 3 | 3 | 3 |
| 6 | | 98 | 100 | 100 | 99 | 100 | 99 | 100 | 99 | 99 | 100 | 99 | 100 | 99 | 100 | 99 | 100 | 99 | 98 | 98 |
| 7 | | 99 | 99 | 99 | 97 | 100 | 99 | 100 | 100 | 97 | 99 | 100 | 99 | 98 | 98 | 99 | 100 | 99 | 100 | 93 |
| 8 | | 96 | 98 | 99 | 99 | 97 | 96 | 95 | 93 | 71 | 75 | 44 | 42 | 39 | 24 | 18 | 18 | 16 | 7 | 7 |

* Tests commenced only from II week of June.

Metallic and cement bins alone preserved the seeds. Deterioration set in in August in the case of aerobic storage in Aska sugar gunny and *Murra*. It was considerably less in the case of mud pot (treated) and wooden box.

(c) Another experiment was therefore conducted in which wooden box and mud pot were given one and two coatings of tar and from the results (Table III) it is seen that with one are two coatings of tar, wooden box maintained viability of seeds till the second fortnight of October.

**TABLE III.**

**Modified methods of storage.**

Treatments :—

1. Kerosene tin.
2. Cement bin.
3. Wooden box with one coating of tar.
4. Wooden box with two coatings of tar.
5. Mud bin.
6. Mud bin with one coating of tar.
7. *Murra*.

| Treatments | Precentage germination in I and III weeks | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | June | | July | | August | | September | | October | |
| | I | III | 1 | III | I | III | I | III | I | III |
| 1 | 100 | 100 | 100 | 98 | 97 | 100 | 99 | 99 | 99 | 100 |
| 2 | 99 | 99 | 99 | 97 | 98 | 99 | 99 | 99 | 100 | 99 |
| 3 | 99 | 98 | 97 | 98 | 97 | 98 | 97 | 97 | 96 | 96 |
| 4 | 100 | 98 | 98 | 98 | 99 | 99 | 100 | 100 | 98 | 99 |
| 5 | 98 | 100 | 99 | 97 | 95 | 94 | 84 | 81 | 27 | 22 |
| 6 | 98 | 98 | 98 | 97 | 95 | 93 | 84 | 87 | 36 | 21 |
| 7 | 100 | 99 | 98 | 93 | 87 | 70 | 47 | 39 | 27 | 13 |

(d) With the encouraging results obtained above, an attempt was made to stimulate anaerobic conditions making *Murra* impermiable to air. After packing, it was coated with a thick coating (about one inch) of cowdung and red earth. Germination tested in October gave 85% in the case of *Murra* plastered with cowdung and red earth.

**TABLE IV.**

**Storage in *Murra*—modified.**

Treatments :—

1. Kerosene tin.
2. *Murra.*
3. *Murra* coated with cow dung.
4. *Murra* coated with cow dung and red earth.

| Treatments | Percentage germination in October |
|---|---|
| 1 | 99·5 |
| 2 | 12·8 |
| 3 | 77·5 |
| 4 | 85·0 |

5. Germination of paddy (rice in husk) and rice: In order to find out if inability of the embryo to break the husk was the cause of low germinability, the tests were extended to rice as well after husking. The germination of Co. 3 stored in tin and *Murra* was compared to that of two non-deteriorating types PTB. 19 (*Athikraya*) and PTB. 21. From the results given in table V it will be seen that husking did not improve germinability.

**TABLE V.**

**Comparative germination of rice and rice in husk.**

| Treatments | Percentage germination in October | |
|---|---|---|
| | Rice in husk | Rice |
| PTB. 19 | 98·5 | 91·0 |
| PTB. 21 | 98·0 | 95·0 |
| $CO_3$ in Tin | 95·0 | 92·5 |
| $CO_3$ in *Murra* | 18·0 | 12·0 |

6. Treatment of seeds with fungicides; In another trial Co. 3 seeds were treated with naphthalene and fungicide Agrosan. GN at the usual rates and stored in *Murra.* Result of germination test (Table VI) showed that they had no effect in checking loss of viability.

**TABLE VI.**

**Treatment of seeds and germinability.**

Treatments :—

1. $CO_3$ treated with Agrosan—G. N. and stored in *Murra.*
2. $CO_3$ .. Naphthalens .. ..
3. $CO_3$ without any treatment .. ..

| Treatments | July III week | August III week | September III week |
|---|---|---|---|
| 1 | 93·8 | 19·3 | 5·3 |
| 2 | 90 5 | 27·0 | 7·8 |
| 3 | 87·0 | 13·8 | 5·8 |

7. Correlation of loss of viability with post harvest germinability: As a result of his experiments with rice varieties in prolonged storage, Ramiah (1937) had showed that a close relationship existed between loss of viability and lack of dormancy of the grains. Studies were under taken to see if the association would hold good in this type of deterioration of Co. 3 in aerobic storge. Fourteen varieties including Co. 3 were selected for study. Germination was noted on a random sample drawn immediately after harvest and the balance of seeds in each of them were stored in *Murra* (10 to 15 lb. each). Germination was tested in the last week of August. The results are presented in table VII. The value of *r* is found to be as high as + 0·7968 showing that the loss of viability is positively correlated to post harvest germinability.

**TABLE VII.**

**Correlation studies on loss of viability and dormancy of seeds.**

| Varieties | Percentage germination immediately after harvest | Percentage germination after storage *Murra* |
|---|---|---|
| PTB. 3 | .. | 94 |
| PTB. 21 | 3 | 82 |
| *Karuva Kuttadan* | 26 | 60 |
| *Muthuchemba* | 2 | 91 |
| *Chempan* | 12 | 79 |
| *Chitteni* | .. | 89 |
| *Kodiyan* | 69 | 52 |
| *Vellakoli* | 96 | 33 |
| *Kasipichodi* | 11 | 45 |
| *Muthu Samba* | 17 | 62 |
| PTB. 15 | 31 | 66 |
| PTB. 6 | 4 | 99 |
| PTB. 16 | 46 | 54 |
| $CO_3$ | 92 | 49 |

Coefficient of correlation r = +0·7968

Significant at 1% level.

8. Inheritance studies: With a view to find out the mode of inheritance of the character of deterioration and the possibility of evolving a non-deteriorating type of Co. 3, artificial crossing was attempted between a positively deteriorating and non-deteriorating type namely, Co. 3 and PTD. 19 (Athikraya) (*Vide* table V). Half the quantity of the seeds obtained in the F1 was stored in thin cloth bags alongside the parents and and germination was tested in October. It may be noted here that the same extent of deterioration was observed when samples of Co. 3 were stored in cloth bags. The description of the parents and F1 and the percentages of germination are given in table VIII.

**TABLE VIII.**

**Description of parents and F. 1.**

| | CO. 3 | F1. | PTB. 19. |
|---|---|---|---|
| (a) Colour of lemma and palea | Straw | | Brown |
| (b) Rice | White | | Red |
| (c) Size of grain | Fine | | Medium Coarse |
| (d) Germination after storage | 18·4% | (a) Straw<br>(b) Red (darker)<br>(c) Intermediate | 96·5% |
| | 34·0% | (d) 84·5% | 99·0% |

The F1 hybrid gave 85% germination showing dominance (though not complete dominance), of the non-deteriorating character. The straw colour of the lemma and palea and red pericarp were also dominant. F2 generation comprised 732 progenies. They were studied for type of grain, colour of lemma and palea, colour of pericarp and viability. They could be grouped into the following main groups.

1. Co. 3 type of grain, white rice, straw lemma and palea.
2. ... ... red ... ... ...
3. ... ... white ... brown ...
4. ... ... red ... ... ...
5. PTD. 19 type ... white ... straw ...
6. ... ... red ... ... ..
7. ... ... white ... brown ...
8. ... ... red ... ... ...

One-sixth of progenies in each group were stored in cloth bags for determining loss of viabitity and another one-sixth were carried over to F3 generation. The range of variation in germinability in F2 and F3 generations are presented in table IX.

**TABLE IX.**

**Distribution of F2 and F3 generation.**

| | Percentage generation—F2. | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CO. 3 | 1–10 | 11–20 | 21–30 | 31–40 | 41–50 | 51–60 | 61–70 | 71–80 | 81–90 | 91–100 | PTB. 19 |
| 16·1% | 4 | 6 | 9 | 9 | 15 | 16 | 16 | 24 | 28 | 10 | 88·8 |
| | | | | | | F3 | | | | | |
| 14·0% | 9 | 10 | 9 | 11 | 16 | 21 | 15 | 19 | 14 | 4 | 75·1% |

As will be seen from the table the variation is continuous and the character may therefore be taken to be governed by multiple factors. The red colour of the pericarp itself is found to be of different intensities in different progenies with different ranges of germination showing the presence of many modifying minor genes. The average germination and range of variations in each group are presented in table X.

**TABLE X.**

**Average and range of germination.**

| Type | Germination | Straw W. rice | Straw R. rice | Brown W. rice | Brown R. rice |
|---|---|---|---|---|---|
| CO. 3 type | Average % | 22·7 | 55·4 | 30·0 | 68·9 |
| | Range | 1·0—51·1 | 22·0—89·4 | 20·0—53 0 | 44·2—92·9 |
| PTB. 19 | Average % | 47·1 | 71 2 | 55·0 | 84·3 |
| | Range | 15·0—83·0 | 23·0—96·4 | 22·0—87·9 | 59·0—94 8 |

The association of the non-deteriorating character in inheritance with the different morphological characters was determined by the Chi-square ($x^2$) test. From the results presented in table XI it will be found that the non-deteriorating character is highly associated with red pericarp and feebly with shape of grain and colour of lemma and palea.

**TABLE XI.**

**Chi-square tests.**

| Germination | Colour of rice | | | Colour of lemma and palea | | | Shape of grain | | |
|---|---|---|---|---|---|---|---|---|---|
| | Red | White | Total | Straw | Brown | Total | PTB. 19 type | CO. 3 type | Total |
| 1—20 | .. | 7 | 7 | 6 | 1 | 7 | 3 | 4 | 7 |
| 21—40 | 4 | 5 | 9 | 8 | 1 | 9 | 4 | 5 | 9 |
| 41—60 | 17 | 10 | 27 | 23 | 3 | 26 | 15 | 12 | 27 |
| 61—80 | 36 | 5 | 41 | 30 | 11 | 41 | 17 | 24 | 41 |
| 81—I00 | 37 | 3 | 40 | 24 | 17 | 41 | 26 | 14 | 40 |
| Total | 94 | 30 | 124 | 91 | 33 | 124 | 65 | 59 | 124 |
| Proportion: | 0·75807 | 0·24194 | | 0·73387 | 0·26613 | | 0·52419 | 0·47580 | |
| $x^2$ | 38·66 | | | 9·28 | | | 5·10 | | |

Value of $x^2$ for P 0·01=13·277

**IV. Discussion:** The experiments on different methods of storage as outlined in the foregoing pages were spread over a period of six years. In all seasons the loss of viability was found to set in after the month of July. One of the contributing causes for the deterioration might be the high atmospheric humidity prevailing during the months of June and July. Decrease in viability due to moisture in atmosphere was recorded in respect of wheat, oats and barley by Robertson *et al* (1939). Wide variations were noticed in the loss of germinability itself with reference to weather changes within the same place and with difference in place of cultivation. For instance, when germinability was reduced to less than 10% in the case of Co. 3 grown in Puthur and Mangalore that obtained from Moodabidri gave 50% germination in the same season. A range of one percent to 13% germination was noticed in the same place and for the same type of storage.

Immaturity of seeds might contribute to loss of viability in storage in all varieties but this type of deterioration was found to be different from that noticed in the case of Co. 3. Nevertheless, a fraction of the loss might be atributed to the presence of not-fully mature seeds as will be obtained if late developing tillers are caught in a spell of drought which is not uncommon during the ripening phase of winter rices on the West Coast.

The results clearly indicate that for storing varieties like Co. 3, the the containers have to be kept fairly air-tight if the seeds are to maintain cent percent viability; the nearer they approach aerobic condition, the greater is the loss of viability. Bearing this in mind, cultivators could devise measures to protect seeds against atmospheric humidity affecting the seeds in strong mud bins or wooden receptacles painted with two coatings of tar or the *Murra* itself plastered over with a thick coating of a mixture of cowdung and red earth would be more economical than metallic or cement bins and meet the situation to considerable extent. That the seeds absorb moisture under conditions of aerobic storage is certain. They become soft and do not crack under pressure. In such circumstances development of fungi is possible which might affect the embryo. However, dressing of seeds by fungicides like Agrosan. GN was not beneficial. Oxley (1948) working on wheat has suggested the possibility of a sub-epidermal mycelium as a cause of increased respiration of damp wheat and its deterioration. Whether such fungal growth is developed in rice seeds remains to be investigated.

The results set out in table VII would show that the loss of viability in aerobic storage between seasonal intervals is a varietal character. This is found to have a close correlation with the capacity of the grains to germinate immediately after harvest without a rest period. Ramiah's observation on rice in prolonged storage applies well in this type of deterioration also in which case, one of the solutions for the problem would be to induce dormancy by artificial means.

In the cross between CO.3 and PTB. 19 the F1 showed incomplete dominance while F2 generation showed wide range of variations, larger number of progenies ranging towards the non-deteriorating class than the other. The inheritance is essentially one of multi-factorial type modified minor genes. The character is associated with red pericarp and to some extent with colour of lemma and palea. One progeny of the CO.3 type and which is a double recessive for other characters, is in the F6 generation and is promising.

In tables VIII and IX are given the germination of parents in successive seasons of trial. The variations in both F2 and F3 generations show shifts towards either parents. In the season when F2 generation was grown the parents gave 16·1% and 88·8% but the progenies showed shifts on either side from 1% to 96%. Presumably this shift is

brought about by minor gene combinations. Since the parents also in certain seasons showed a range of 1·1% to 100%, the genetic shift in the F2 generation can be taken as an index of the potentiality of the parent types themselves. In this case for example, the effect brought about by minor genes in segregating progenies is of the same strength as that brought about by environmental factors on the parents.

V. **Summary**: 1. Loss of germinability was noticed when a variety like CO. 3 was stored during seasonal interval in receptacles which are not air-tight especially in straw-twist bundles called *Murra*.

2. Experiments conducted with different varieties and with different maturity showed that the deterioration was not due to immaturity of grains. Metallic and cement bins preserved the seeds.

3. Improvement in germination was noticed in the case of wooden box and mud bin when they were given one or two coatings of tar and in *Murra* when it was plastered over with a thick coating of a mixture of cowdung and red earth.

4. Experiments so far conducted did not indicate presence of superficial fungal infestation as a cause of deterioration since seeds treated with Agrosan. G. N. also lost viability.

5. The deteriorating character was found to be correlated with the capacity of the seeds to germinate after harvest without a rest period.

6. The inheritance of the character was found to be of the multifactorial type with continuous variations in the F2 generation. It was found to be strongly associated with red pericarp and to some extent with colour of lemma and palea.

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