Summary and Conclusions
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The introduction of wheat cultivation in West Bengal is recent and within a very short time the acreage and production of wheat have shown great increase. The cultivators are, however, confronted with the serious problem of loss of seed germinability during storage under the ambient warm-humid conditions and much of the seed requirement is met by supplies from the north Indian wheat belts where the seed keeps well in the relatively dry climate. In West Bengal, wheat seeds harvested in March-April and then stored under ambient conditions in moisture-pervasive containers would show a rapid fall in germinability and by showing time in November-December, the viability may go down to half or even less. Thorough sun-drying after harvest, followed by storage in sealed containers, would greatly reduce the loss of viability. However, even in sealed storage, appreciable loss of seed vigour takes place. In such storage, if the seed is not dried to a relatively safe moisture content after harvest, its storability would be considerably reduced. Occasional rains before harvest is also detrimental to good storability of seeds and unless proper care is taken the seeds from the rain-soaked crop may show a significant loss of vigour and viability. During harvesting, threshing and storage of such seeds, fungal invasion and more insect attack would be resulting in aggravated physiological as well as
pathological seed deterioration.

Against the above background, the present investigation was taken up to develop a simple and inexpensive method of seed preservation which would enable our farmers to maintain the vigour, viability and productivity of stored wheat seeds. The compatibility of the hydration-dehydration treatment with fungicidal and insecticidal formulations, the effectiveness of dipping-drying treatments employing micronutrients and midstorage seed treatments for the alleviation of salinity stress were also studied. Apart from these practical objectives, experiments were taken up to elucidate the physiological and biochemical bases of the beneficial effects of hydration-dehydration seed treatments. The results of the different experiments in the laboratory and field, conducted over a period of about four years between February, 1978 and December, 1981 and the suggested interpretations of the findings are briefly summarized hereunder:

1. Wheat seeds harvested in March-April and stored in cloth bags under ambient conditions (average RH 74.5±2.7%, temperature 29.8±1.0°C during the storage period) started to show significant loss of vigour and viability after 4-5 months of storage. Seeds stored in unsealed containers absorb moisture from the air and undergo physiological deterioration and by the time of sowing, a considerable fall in vigour and viability of the stored seed occurs. Studies on the pattern of loss of germinability showed that the percentage of germination began to fall towards the end of the rainy season. Loss of vigour, as measured
by root and shoot growth was, however, noticeable much earlier, in about the middle of the monsoon months. Well-dried seeds, stored in cloth bags in the laboratory, showed a germination percentage of 50-60 or even less at the sowing time in November-December. All the cultivars of wheat showed a more or less similar pattern of decline in vigour and viability under ambient storage conditions.

2. The loss of vigour and viability could be controlled by hydration-dehydration treatment of stored seeds during the months of July to August. Hydration of stored seeds was accomplished in various ways: soaking, dipping and moisture equilibration with a saturated atmosphere. The findings of the hydration-dehydration treatments are given below:

i) In the soaking-drying treatment, stored seeds were soaked for 2 hours in double the volume of water followed by drying back to the original weight in a drying cabinet at 35±1°C or in the sun. The beneficial effects of soaking for 2 hours in two volumes of water was noted in all the cultivars.

ii) The physiological age of the seed at the time of treatment was a very important factor and only treatment of seed stored for several months was effective; treatment of harvest-fresh seed showed adverse effects on storability.

iii) In the dipping-drying treatment, stored seeds were dipped in water or dilute solutions for 2 minutes and then kept covered
for 2-3 hours followed by the usual drying back. Dipping-drying treatment was effective in relatively high-vigour seeds where soaking-drying showed no effect or very minor effect. A comparative study on the efficacy of single and multiple dipping-drying treatments showed that just one dipping-drying treatment in July-August would safely carry the seeds to the next sowing; more than one treatment would be unnecessary.

iv) Moisture equilibration with a saturated atmosphere was done by exposing the seed to a water-saturated atmosphere (100% RH and 26±1°C) for 16-120 hours followed by drying back. Among the different durations, 24-48 hours moisture equilibration (then drying) very effectively improved storability. In moisture equilibration-drying, the possibility of any soaking injury was virtually eliminated. But moisture equilibration-drying treatment is difficult to practise, more time-consuming and not advisable for low vigour seed in which prolonged equilibration with a water saturated atmosphere would cause some ageing of seeds.
v) Soaking-drying with water alone was very effective for the maintenance of vigour and viability. A number of chemicals such as sodium phosphate (dibasic, $10^{-4}M$) showed some improvement over water. But compared to the large water effect, the additional effects of chemicals were much smaller and inconsistent.

3. Field performance and productivity of the crop raised from the soaked dried and dipped-dried seeds were studied in three consecutive seasons. The findings are briefly outlined below.

(a) The field performance of the crop raised from the soaked-dried seeds was significantly better than that from the untreated control seeds. Hydration-dehydration treatment with water alone was very effective in improving the grain yield and other yield attributes. But sodium phosphate (dibasic, $10^{-4}M$) showed still better effects on most of the yield attributes and finally gave the highest yield.

Mid-storage hydration-dehydration treatment was much more effective than pre-sowing seed treatment. Significant effects were obtained when the treatments were given to 4-5-month-old seeds. Among the different hydration-dehydration treatments soaking-drying was more effective than dipping-drying in improving the grain yield.

(b) A single dipping-drying treatment was quite effective for improving field performance. A marginal improvement was noted.
on plant population in double dipping-drying treatment. More than
two dipping-drying treatments would not give any further beneficial
effect. From a practical viewpoint the single dipping-drying
treatment in the month of July-August would be a very effective way
of preservation of vigour, viability and yield potential.

4. The physico-chemical treatments gave beneficial effects in four
cultivars viz. Sonalika, Janak, UP 262 and WL 711, which have so far
been studied, implying thereby that the treatment effects are independent
of varietal differences. In all the aforesaid cultivars, the beneficial
effects of hydration-dehydration treatments were greatly reflected upon
storability as was evident from the results of laboratory germination
tests of the seeds subjected to accelerated and natural ageing conditions.
The usual manifestations were: higher germination, lower incidence of
abnormal seedlings, uniform growth and development of seedling and
increased root and shoot length. In field performance, studied over three
seasons, the four cultivars viz. Sonalika, Janak, UP 262 and WL 711 were
highly responsive to the hydration-dehydration treatments. Water treatment
alone was effective in improving yield but disodium phosphate (10^{-5}M)
showed additional effect over water. Among the different hydration-
dehydration treatments, soaking-drying gave better results than dipping-
drying. On an average the increase in yield over control ranged from
15-25% in the four cultivars.

5. The compatibility of several fungicidal and insecticidal preparations
(given mostly as dry-dressings) with the hydration-dehydration
treatments on the storability of seeds was studied. The major beneficial
effect was attributable to the hydration-dehydration treatments. There was little additional improvement with the protectants. The seed protectants, however, did not adversely influence the vigour and viability of control as well as hydrated-dehydrated wheat seeds.

In field performance, the beneficial effect was primarily attributable to hydration-dehydration treatments. Malathion (spraying-drying) and dithane M-45 (dry-dressing) in combination with the hydration-dehydration treatments showed some minor improvements in field performance but other protectants were ineffective. It may, however, be mentioned here that the protectants in general did not reduce the beneficial effects of the hydration-dehydration treatments. This would mean that under situations where storage fungi and stored grain pests would be a serious problem, they can be safely combined with the hydration-dehydration treatments.

6. Use of dilute solutions of micronutrients in the dipping-drying treatment did not give any additional advantage over water. Ferrous sulphate (10⁻³ M), zinc sulphate (10⁻³ M) and manganese sulphate (2 x 10⁻⁴ M) in dipping-drying treatments gave little additional effect on field performance and grain yield over hydration-dehydration treatment using water alone. Nevertheless, midstorage treatment with or without micronutrients was more effective than the corresponding pre-sowing (just before sowing)
treatments which would thus corroborate the findings of the previous experiments carried out in this laboratory.

7. The mid-storage soaking-drying treatments, using water, sodium chloride \((10^{-3} \text{M})\) and sodium phosphate (dibasic, \(10^{-4} \text{M}\)) solutions, overcame the stress situation caused by salinity (using different concentrations of sodium chloride) in laboratory germination tests conducted 9 months after treatment. Seeds treated with sodium phosphate (dibasic, \(10^{-4} \text{M}\)) showed slightly better performance than others. The difference between control and the hydration-dehydration treatments was maintained in concentrations of sodium chloride up to 0.2M. At high salt concentrations, the toxicity of the salt (osmotic effect and specific ion effects) was very high and control as well as treated seeds failed to germinate.

8. Physiological and biochemical studies have shown increased dehydrogenase activity, amylase activity, greater membrane integrity as demonstrated by lower electrical conductance of seed-steep water and reduced leaching of sugars and amino acids, and a significant reduction of lipid peroxidation in the treated seeds as compared to the untreated control.

9. The mode of action of the hydration-dehydration treatments is yet
to be clearly understood and interpreted. Based on the results of the present findings and on the basis of earlier studies conducted in this laboratory, several possibilities have been discussed. These are very briefly indicated hereunder:

i) Advancement of the germination process or pre-enlargement of the embryo would not explain the beneficial effect because fresh seed treatment was not effective.

ii) The pattern of absorption of moisture by treated and untreated seed was similar. Differential moisture absorption would not therefore account for the beneficial effects in the treated seeds.

iii) The beneficial effects of hydration-dehydration treatments cannot be attributed to antifungal action of the treatments as storability was also better in treated seed stored in an environment of 36% RH and 40°C in which storage fungi cannot thrive.

iv) The beneficial effects on storability cannot be attributed to leaching of toxic substances from the seed because moisture equilibration-drying treatment, in which the leaching factor is eliminated, greatly extended the storage life of seeds.

v) Repair of bioorganelles by the cellular repair system, would not possibly account for the beneficial effect of hydration-dehydration
treatments as there was little promotion of germinability immediately after treatment; the great improvement in germinability was noted only after storage indicating the prophylactic nature of the treatment.

vi) Control of free radical reactions may perhaps explain the effects of the treatments on the maintenance of viability. Studies in this laboratory by other workers have shown the great efficacy of hydration-dehydration treatments on the counteraction of age- and irradiation-induced seed deterioration and it has been suggested that the treatments extended seed viability by reducing free radical pathology and lipid peroxidation reactions. The beneficial effects of hydration-dehydration treatments may possibly be looked upon as the consequences of reduced physiological deterioration of the treated seeds in storage.

10. On the basis of the results of the present investigation, mid-storage hydration-dehydration treatments of stored wheat seed employing disodium phosphate ($10^{-4}$%) is suggested for the maintenance of seed viability in storage and improvement of field performance of the crop. It has also been indicated that where storage fungi and stored grain pests would be a serious problem, the seed protectants can be safely combined
with the hydration-dehydration treatments to reduce the physiological as well as pathological seed deterioration. If drying conditions are not good, instead of soaking-drying, the dipping-drying method of seed treatment should be practised.

Studies on field experiments on a wide scale in different localities are, however, necessary in order to make fruitful recommendations to the wheat growers for accepting the methodology. If the technological problems and difficulties encountered in the hydration-dehydration treatment of large seed stocks can be overcome, the present method of seed treatment may be of great advantage to our seed merchants and cultivators. It is worthwhile to mention here that the Directorate of Agriculture, Government of West Bengal have taken up the pilot experiments on seed preservation by soaking-drying and dipping-drying methods for recommendation to the farmers of the State. The results of their experiments during the last three years are indeed very encouraging.