Accession regeneration in genebanks: seed production environment and the potential longevity of seed accessions

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Summary

This article summarizes a programme of collaborative research between the Department of Agriculture, The University of Reading, and the Genetic Resources Center of the International Rice Research Institute. The research programme first identified the cause of poor seed quality in certain accessions of *japonica* rice. It then developed different seed production practices which not only avoided the problem in these accessions but also provided better seed quality in accessions of *indica* rice as well. The results of this programme may have implications for seed accession regeneration procedures elsewhere, and in crops other than rice.

Introduction

Seed accessions require regeneration either when the number of seeds is insufficient for continued conservation and utilization or when viability falls below a minimum value (the regeneration standard). Although there is a general belief that an accession should be regenerated in the environment from which it was collected, such individual attention to the requirements of each accession is not feasible in many large genebanks. In such cases, regeneration may be carried out either where resources (field site, equipment, labour, etc.) are under the direct control of the genebank, or where it can be contracted out most efficiently to meet the desired objective.

The genebank at the International Rice Research Institute (IRRI), Los Baños, Philippines, maintains a total of more than 80 000 accessions of both cultivated rice species and their wild relatives. For many years, it had been the practice of the genebank to regenerate rice seed accessions at Los Baños (14° 11' N, 121° 15' E, elevation 21 m a.s.l.) during both the wet-season months (July—October), and the dry-season months (November—May).

Over the years we had become concerned that the quality of the seeds of the *japonica* rice accessions in the IRRI genebank were poorer than those of the other ecogeographic races of rice. This led us to question whether the seed storage characteristics of *japonica* rices were intrinsically poorer than the *indica* rices, or whether they were a consequence of the seed production environment, given that the wet season at Los Baños is somewhat warmer than the conditions in which the *japonica* rices evolved.

Research in the UK

An investigation of the relations between seed longevity and seed storage moisture content confirmed that *japonica* accessions showed poorer longevity than *indica* accessions when seed lots of the same quality were stored in the same environment (Ellis *et al.* 1992). However, in addition to this intrinsic difference among the ecogeographic races of *Oryza sativa*, that research also confirmed the generally poor initial quality of the *japonica* accessions regenerated in the wet season at Los Baños.

We therefore approached the Overseas Development Administration (ODA) of the UK Foreign and Commonwealth Office for the support of investigations to develop experimental approaches with which to determine whether or not *japonica* rice seed quality was particularly sensitive to the seed production environment. The ODA funded an initial 12-month investigation at the Plant Environment and Seed Science Laboratories of The University of Reading.

In that research, changes in seed quality (assessed by potential longevity, i.e. the value of the seed lot constant K_i of the seed viability equation) in three contrasting cultivars of rice were monitored during seed development and maturation in two temperature regimes, *viz.* 28/20°C and 32/24°C (12/12h), provided by controlled environments (Ellis *et al.* 1993). The cooler temperature regime mimicked a warm temperate seed production environment (Tsukuba, Japan), and the warmer that pertaining at Los Baños during the wet season.

Mass maturity (defined as the end of the seed-filling phase) varied only between 18 and 20 days after 50% anthesis. In five of the six treatment combinations maximum potential longevity was not achieved until 12-19 days after mass maturity. In contrast, the maximum potential longevity of seeds of a *japonica* rice cultivar produced in the warmer regime was obtained soon after mass maturity. After mass maturity, the potential longevity of the *japonica* rice seed lots

produced in the warmer environment was much less than that for the cooler environments.

Maximum potential longevity was also consistently greater in the cooler than in the warmer regime for the two *indica* cultivars, although the difference in K_i was small (0.3—0.5). The deleterious effect of increase in temperature on seed quality development was not detected until after mass maturity. Maximum potential longevity in the cooler regime was greatest in the glutinous *indica* cultivar (K_i = 3.9) and least in the *japonica* cultivar (K_i = 3.1). It was concluded that the *japonica* cultivar is not as well adapted to warm seed production regimes as the *indica* cultivars. Hence, this research suggested that the seed production of *japonica* cultivars for long-term genetic conservation should be undertaken, whenever possible, in warm temperate environments.

These differences between seed production environments on the potential longevity of a *japonica* rice were confirmed in another investigation (Fig. 1). This further research also showed that the increases in potential longevity which were recorded were associated with the onset of the ability of the seeds to tolerate desiccation to very low moisture contents (Ellis and Hong 1994).

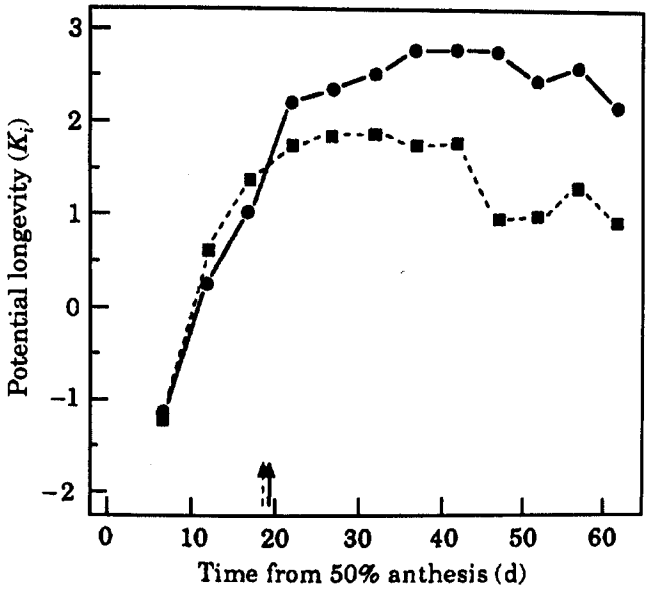

Fig. 1. Changes in the potential air-dry storage longevity (K_i) of seeds of a *japonica* rice during seed development and maturation in controlled environments of 28/20°C (●) or 32/24°C (■). Solid and broken arrows indicate the end of the seed-filling phase (mass maturity) in the cooler and warmer regimes, respectively (from Ellis and Hong 1994).

Tolerance of desiccation to low (4%) moisture contents improved until 22 and 14 days after mass maturity in the cooler and warmer regimes, respectively, when maturation drying had reduced seed moisture contents naturally to 24 and 32% moisture content, respectively. Further delays to seed harvest reduced desiccation tolerance, particularly in the warmer environments. Comparison among 15 samples of seeds harvested at different times in the two environments showed a strong correlation (r = 0.947, $P < 0.01$) between longevity (K_i) and desiccation tolerance (to 4% moisture content) (Fig. 2). It is possible, then, that the regulation of desiccation tolerance to low moisture contents and potential air-dry longevity during seed development and maturation may have a common cause.

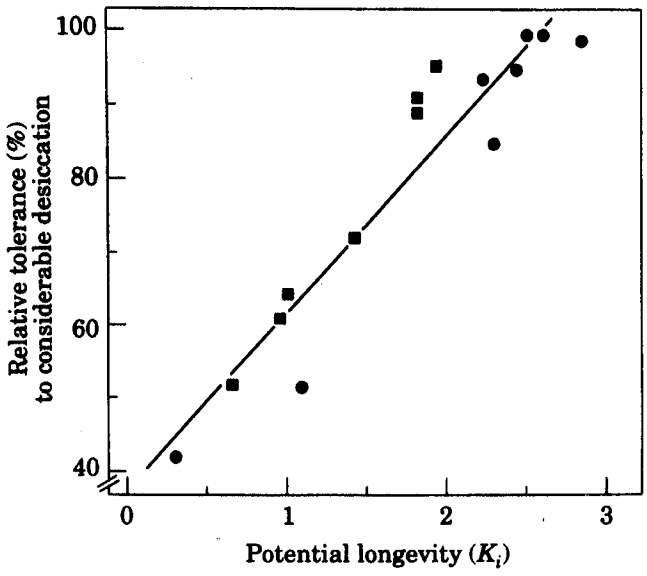

Fig. 2. Association between the relative tolerance to desiccation to 4% moisture content and potential storage longevity (determined at 15% moisture content) for seeds of a *japonica* rice harvested at different times during development and maturation from plants grown in controlled environments of 28/20°C (●) and 32/24°C (■) (from Ellis and Hong 1994).

Hence, this research in the UK demonstrated that one *japonica* rice cultivar was particularly sensitive to seed production environment and that both subsequent seed storage longevity and desiccation tolerance were much improved in the cooler seed-production environment. The research also showed that, provided seeds were produced in suitable environments, maximum seed quality was obtained if seeds were harvested at the developmental stage described as harvest maturity (when seed moisture content has declined naturally to below about 20%).

Research in the Philippines

The research then switched to the Philippines, using a wider range of cultivars. On the basis of the results of the research at Reading, the experiments at Los Baños were all conducted during the dry-season months. A comparison of *japonica* rices in the field and growth chamber was also made. The research has confirmed several points.

1. The cooler dry season provides a better seed production environment than the warmer wet season for all rice accessions; better in this case means greater subsequent seed storage longevity.

2. The seed production environment at Los Baños during the dry-season months is not harsh for *japonica* cultivars.

3. Estimates of potential longevity in *japonica* cultivars were high and close to those of the *indica* cultivars. However, lowland *japonica* cultivars, large-seeded accessions, and *Oryza glaberrima* cultivars do have shorter storage longevity than *indica* rices, but from a practical conservation standpoint this is not a problem.

4. Advancing the planting date of *japonica* cultivars so that flowering and grain-filling coincide with the cooler and drier segment of the dry season at Los Baños, and harvesting between 28 and 35 days after flowering, significantly improve potential longevity in these rice accessions.

Impact

As a consequence of this collaborative programme of research, the IRRI genebank now regenerates rice accessions only during the dry-season months at Los Baños. Moreover, in view of the particular sensitivity of the *japonica* rice accessions to warm temperatures during seed development and maturation and the fact that the seasonal trend in temperature toward the end of the dry season is upward, the *japonica* rice accessions are sown first (and as early as possible) during the dry season. This ensures that the grain-filling period coincides with the coolest nights in January.

We have shown that the environment at Los Baños is conducive for the regeneration of rice accessions originating from a wide geographical area. Furthermore, armed with this enhanced knowledge about the interaction between the effects of seed production environment and genotype in rice on seed quality, we have been able to set higher initial viability standards than in the past for *indica* as well as *japonica* rices.

Thus the quality of germplasm regenerated at this single site in Los Baños has improved. While it is not possible to provide optimum regeneration conditions genotype by genotype, we have identified those factors that have the greatest pre-harvest effect on subsequent storage longevity. Coupled with changes in seed-drying procedures, under which recently harvested seeds equilibrate to 15% RH at 15°C over several weeks, we now have in place a set of procedures aimed at maximizing seed quality and thus extending storage potential.

Insofar as the IRRI genebank is concerned, then, this collaborative research between The University of Reading and IRRI has had considerable impact on its practices. We believe that the research may also be of interest to certain other organizations. First, to those maintaining (and so regenerating) rice accessions in genebanks elsewhere, and second, to those genebanks maintaining seed accessions of other species.

References

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Résumé

Régénération des obtentions dans les banques de gènes: l'environnement de la production des semences et la longévité potentielle des obtentions de semences

Cet article résume un programme de recherche mené en collaboration par le Département de l'agriculture, l'Université de Reading et le Centre de ressources génétiques de l'Institut international de recherche sur le riz. Le programme de recherche a d'abord identifié la cause de la qualité médiocre des semences dans certaines obtentions de riz *japonica*. Ensuite, il a mis au point différentes méthodes de production de semences qui, outre qu'elles ont évité le problème dans ces obtentions, ont fourni une meilleure qualité de semences dans les obtentions de riz *indica*. Les résultats de ce programme pourraient avoir une incidence sur les méthodes de régénération des obtentions de semences ailleurs et pour des plantes cultivées autres que le riz.

Resumen

La regeneración de accesiones en los bancos de genes: influencia del medio ambiente en la producción y la longevidad potencial de las accesiones de semilla

En el presente artículo se resume un programa de investigación realizado por el Departamento de Agricultura en colaboración con la Universidad de Reading y el Centro de Recursos Genéticos del Instituto Internacional de Investigaciones sobre el Arroz. Se identifica en primer lugar la causa de la escasa calidad de las semillas de ciertas accesiones de arroz *japonica*. A continuación se examinan diferentes técnicas de producción que no solamente evitan el problema en estas accesiones sino que también proveen semilla de mejor calidad en accesiones de arroz *indica*. Los resultados de este programa pueden ser aplicables a los procedimientos de regeneración de accesiones de semillas empleados en otros lugares, así como en cultivos distintos del arroz.