Seed production environment and storage longevity of japonica rices *(Oryza sativa* L.)

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Abstract

Changes in seed dry weight, moisture content and germinability of three japonica cultivars of rice during development and maturation in the dry season (November–May) field multiplication at Los Baños, Philippines were compared with those in a cooler controlled environment (24°/18°C). Under field conditions, maximum dry weight accumulation, which indicates mass maturity, was attained 18–21 days after flowering in all cultivars. In the cooler environment however, mass maturity was achieved 21 days after flowering in Fujisaka 5 and Minehikare, and 28 days in Shuang cheng nuo. The moisture content of the seeds at mass maturity varied between 28 and 35% among cultivars in the two environments. Although the ability of seeds to germinate differed in early harvests (7 and 14 days) among cultivars and across two environments, germination of the mature seeds was similar in all. There were no significant differences in potential longevity of the seeds harvested at 28, 35 and 42 days after flowering within each cultivar, which was determined by the germination of seeds that had been hermetically stored with 15% moisture content at 35°C. Differences among cultivars within each seed production environment were also not significant. However, potential longevity of the seeds harvested from the cooler environment was higher than those from the field ($P<0.05$), which confirmed that japonica cultivars which evolved under temperate regions are sensitive to warmer seed production environments. However, the magnitude of differences in potential seed longevity between the two environments was not high. This indicates that the seed production environment during the dry season at Los Baños is not harsh for japonica cultivars.

Keywords: *Oryza sativa* L., japonica rices, seed production environment, potential longevity.

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Introduction

The optimum conditions for seed ripening vary for the japonica and indica cultivars of rice (Sato, 1973; Yoshida and Hara, 1977). When produced under warmer conditions (32/24°C, 12/12 h), the potential longevity of seeds of japonica cultivars which had evolved under temperate environments was shown to be significantly less than that from a cooler environment (28/20°C, 12/12 h) (Ellis *et al*., 1993). These findings have significant implications for the management of some 5300 japonica rice accessions kept in the International Rice Genebank at the International Rice Research Institute (IRRI), Los Baños, Philippines, where the climate is tropical — characterized by high temperatures, and frequent and prolonged precipitation. However, the above studies were conducted in the UK under controlled conditions and limited to only one japonica cultivar. Further research on a wide range of japonica accessions was suggested to confirm these implications. Moreover, the warmer temperature regime (32/24°C) investigated in the UK experiment mimicked the seed production environment during the wet season (July–October) at Los Baños. But Los Baños experiences relatively cooler and drier weather between November and May (dry season) which was shown to be favourable for seed production of japonica rices (Kameswara Rao and Jackson, 1996). The initial quality and subsequent longevity of the seeds were high and nearly similar to those of the cooler seed production regime (28/20°C) of the UK experiment. It is however not known whether potential longevity of the japonica cultivars improves further in an even cooler seed production environment than that previously investigated. This information is necessary to refine appropriate strategies for efficient management of the japonica rice germplasm, in view of the suggestion that they might be better regenerated at a warm temperate location other than IRRI (see Ellis *et al*,. 1993).

The main objective of this study was to compare the potential longevity of seeds produced under simulated temperate conditions (average temperature of 21°C) with the dry season field multiplication at Los Baños, and determine whether or not regeneration of japonica cultivars at an alternative temperate location is warranted.

Materials and methods

Three japonica cultivars, Fujisaka 5, Minehikare and Shuang cheng nuo, were used in this experiment. They were grown along with 14 other rice cultivars on the IRRI upland farm Block UV 4, during the dry season (November–May) of 1992–93. Details of plant culture and sampling procedures have been given elsewhere (Kameswara Rao and Jackson, 1996).

The plants were grown in pots for the controlled environment experiment. To obtain a large number of panicles that would flower simultaneously in pot culture, 20 pregerminated seeds were sown in a circular pattern in 4-l plastic pots filled with Maahas clay soil, fertilized with 1 g of complete fertilizer (NPK), following Yoshida and Hara (1977). The plants were raised in a screen house until 3 days after 75% flowering and then transferred to an artificially lighted (1 200 μ mol $m^{-2} s^{-1}$, 12 h) Thermolyne growth cabinet, maintained at 24°/18°C (12/12 h) and 60–70% RH. Panicles were sampled at weekly intervals from 7 to 42 days after flowering and changes in dry weight, moisture content, and germinability were recorded. For initial harvests, 10–15 panicles were sampled at random. However for the 28-, 35- and 42-day maturity, panicles of all plants, from four randomly selected pots in each block were harvested. Dry weight of 100 or 200 seeds as two replicates each of 50 or 100 seeds was recorded. Seed moisture content was determined by the constant high temperature oven method (ISTA, 1985a, b) using 2 × 100 seed samples. Germination tests were conducted on 100 seeds (2 × 50 seeds) in Petri dishes containing two filter papers moistened with 7 ml of distilled water. An alternating temperature regime of 30°/20°C (18/6 h) was used for germination tests as recommended by Ellis *et al.* (1985).

Table 1. Changes in mean dry weight, moisture content and germinability of seeds during development and maturation in three japonica cultivars grown under field and controlled environments (24°/18°C, 12h/12h)

Days after anthesis	Dry weight (mg/seed)		Moisture content (%)		Germination (%)	
	Field	24°/18°C	Field	24°/18°C	Field	24°/18°C
			Fujisaka 5			
7	7.9	7.9	62.1	64.1	18.0	0.0
14	13.5	18.4	49.0	43.9	77.0	64.0
21	20.0	25.9	34.5	30.3	97.0	98.0
28	23.5	28.4	28.0	25.3	99.0	98.0
35	22.8	28.8	16.1	21.6	99.0	98.0
42	22.8	28.6	12.9	17.4	99.0	96.0
			Minehikare			
7	8.3	8.7	58.8	62.0	8.0	2.0
14	15.5	16.3	40.4	44.8	92.5	70.0
21	25.4	25.9	28.5	30.3	98.5	93.0
28	24.9	25.0	24.8	25.1	99.0	98.0
35	23.0	25.5	20.7	20.3	99.0	100.0
42	23.0	25.8	18.8	17.9	97.0	98.0
			Shuang cheng nuo			
7	8.1	7.9	62.5	63.3	1.0	9.0
14	18.2	12.0	46.3	54.0	76.0	45.0
21	22.4	17.6	35.3	42.0	94.0	90.0
28	23.1	22.0	30.6	28.4	97.0	100.0
35	21.1	22.1	26.9	21.5	99.0	99.0
42	19.4	22.1	23.3	18.1	98.0	99.0
Mean	19.0	20.5	34.4	35.0	80.4	75.4
LSD (0.05)*	0.18		0.85		6.39	

*To compare means between the two environments within harvest time and cultivar

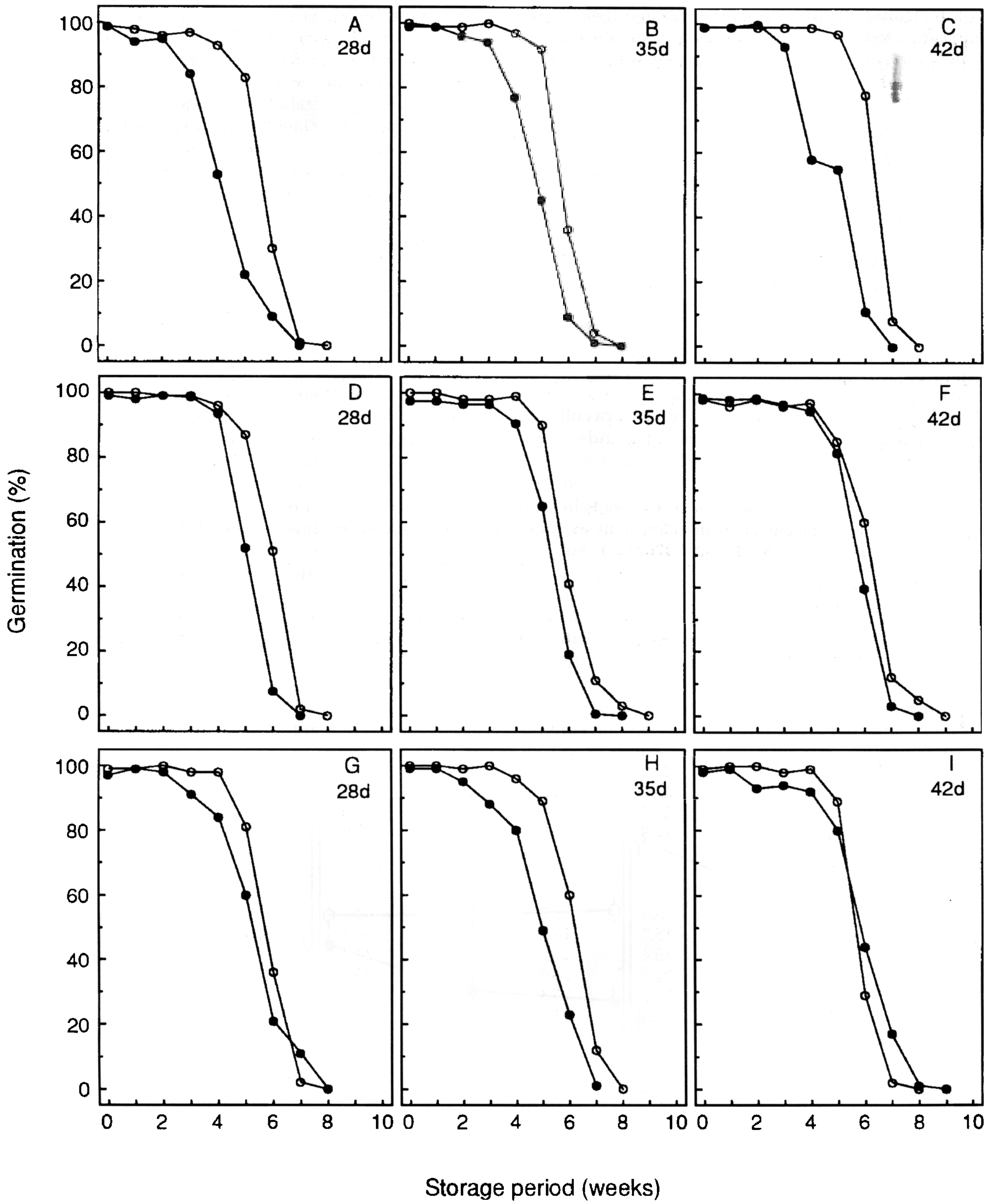

Figure 1. Seed survival curves (% normal germination plotted against time in storage) in three japonica cultivars, Fujisaka 5 (**A–C**), Minehikare (**D–F**), and Shuang cheng nuo (**G-I**), grown in the field (●) during the dry season (November–May) 1992–93, or in cooler controlled environment (24°/18°C) growth cabinets (○). Within each cultivar, seeds were harvested at 28, 35 and 42 days after flowering and stored at 35°C with 15 ± 0.2% moisture content.

The remaining seed was dried to 10–12% moisture content in a ventilated oven at 30°C. The seeds were then threshed gently by hand, cleaned, and stored in sealed laminated aluminium foil packets at 1–2°C until studies on longevity began. The first counts of normal germination were taken on the seventh day. The structures (hulls) covering any ungerminated but firm seeds were removed and germination tests were continued for another 7 days before taking the final counts.

Potential longevity of the seed lots harvested at 28, 35 and 42 days after anthesis was assessed by storing the seeds at 35°C with 15 ± 0.2% moisture content. Samples were taken out every week and germination was tested as described above.

Results and discussion

Initial flowering occurred in the three japonica cultivars 6–9 days earlier in pot cultures than under field conditions. The data on changes in dry weight, moisture content, and germinability of seeds from the field and controlled environments were analysed as a split-split design with seed production environment as main effect, cultivars as sub-effect, and maturity as sub-sub effect (Table 1).

There were significant differences in the accumulation of dry weight among cultivars within each seed production environment. While no differences in the dry weights of seeds harvested at all stages of maturity were found between the two environments, except 35 and 42 days after flowering in Minehikare, differences were significant for all harvest dates except 7 days in Fujisaka 5 and for 7-, 28- and 35-day harvests in Shuang cheng nuo ($P<0.05$). The mean dry weight of the seeds harvested from the cooler environment was significantly higher than that from the field (Table 1). Mass maturity, which marks the end of grain filling period, was estimated by fitting a positive relation to the dry weights between 7 and 21 days and a horizontal line thereafter, determining the day on which the two lines intercept each other. Mass maturity, thus estimated, was attained by about 21 days in Fujisaka 5 and Minehikare, and at 28 days after flowering in Shuang cheng nuo, in the cooler controlled environment (data not presented). In the field environment, mass maturity was achieved by 18 days in Minehikare and Shuang cheng nuo, and at 21 days after flowering in Fujisaka 5 (data not presented).

The trend of changes in moisture content of the seeds during ripening was similar among the three cultivars within each environment. The mean moisture content at mass maturity derived from a quadratic relationship fitted to the data was 32.3% in the cooler environment and 34.3% in the field harvest. The moisture content of Shuang cheng nuo, which has glutinous endosperm, was higher than that of other cultivars at all levels of maturity, in both the environments. The mean moisture content of the seeds from the cooler environment was marginally higher than under field conditions (Table 1).

The ability of the seeds to germinate from early harvests differed significantly among cultivars within each seed production environment and also between the two environments. However, differences among later harvests were not significant as near maximum or maximum germination was attained by 21–28 days in all cultivars in both the environments (Table 1).

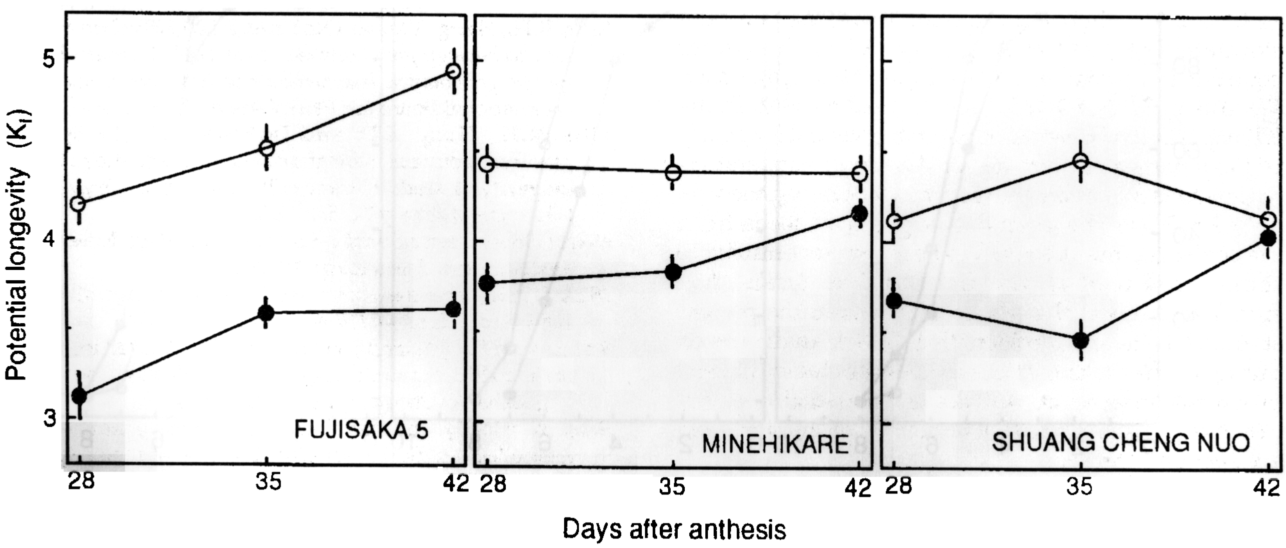

Figure 2. Potential longevity (estimated as seed lot constant K_i of the viability equation, $v = K_i - p/\sigma$ in three japonica cultivars grown in the field (●) during the dry season (November–May) 1992–93 or under cooler controlled environment (24°/18°C) in growth cabinets (○). The vertical bars indicate the standard error of estimates of K_i. The seeds were harvested at 28, 35 and 42 days after flowering and stored at 35°C with 15 ± 0.2% moisture content. The seed survival curves of both the environments have a common slope ($1/\sigma$) of –0.6836 (s.e. 0.0077).

Seed longevity

The seed survival curves obtained for the various seed lots were sigmoid in shape (Fig. 1); therefore, the data were subjected to probit analysis, in which a weighted regression of transformed percentage germination against time was performed, following the equation,

$$v = K_i - p/\sigma \qquad (1)$$

where v is probit percentage viability after storage for p days, K_i is a seed lot constant, and σ is the standard deviation of the frequency distribution of seed deaths in time (Ellis and Roberts, 1980). Within each cultivar, neither the seed production environment nor harvest time influenced the slopes of the seed survival curves, and the interaction between these two factors was also not significant (data not presented). The time of harvest had no effect on potential longevity, but seed production environment influenced potential longevity significantly ($P<0.025$). Thus, the estimates of K_i were higher for the seeds produced under the cooler controlled environment than those from the field (Fig. 2). A comparison of slopes and estimates of potential longevity among cultivars and the time of harvest within each seed production environment indicated no significant differences.

The results of these investigations confirm that japonica cultivars are sensitive to warmer seed production environments, and the potential longevity of seeds produced under such conditions will be less than that for cooler conditions (see Ellis *et al.*, 1993). However, the magnitude of differences between the controlled environment and field harvests was not as great as those observed by Ellis *et al.* (1993) in the two contrasting environments (32°/24°C and 28°/20°C, 12/12 h) used in their experiment. Thus, the common estimate of potential longevity (K_i) in the cooler controlled environment was 4.0 (s.e. 0.0225), against a K_i value of 3.5 (s.e. 0.0391) for the field harvest. In the UK experiment however, maximum potential longevity of the japonica cultivar under the cooler temperature regime was 3.1, while that for the warmer regime was only 1.5. Thus, the potential longevity of seeds from the cooler regime in the UK experiment was similar to those produced in the field at Los Baños, but significantly lower than the cooler regime of the present studies. It is therefore evident that the field environment during the dry season at Los Baños is not harsh for seed production in japonica cultivars, and that seed longevity can marginally improve under even cooler seed production regimes.

The mean temperature in the field during seed ripening of japonica cultivars, which ranged between 25°C and 26°C was closer to the cooler seed production regime (24°C) of the UK experiment, and not surprisingly, the values of potential longevity were also similar for the two seed production environments. The average temperatures during the wet season (June–October) at Los Baños are high (± 29°C) and unlikely to be favourable for seed production in japonica cultivars as shown by Ellis *et al.* (1993). The frequent and prolonged precipitation and adverse conditions due to tropical depressions and typhoons can seriously affect the initial quality and their subsequent longevity. It is therefore advisable to regenerate rice germplasm accessions during the dry season.

The mean temperature of the cooler regime (21°C) in the present study was 3–6°C less than that used in the UK experiment or that experienced in the field. Although the present studies indicate that seed longevity can be improved under cooler seed production regimes, the practical constraints in undertaking seed multiplication at an alternative temperate location to IRRI outweigh the marginal advantage and make it an uneconomical proposition. Further, a close examination of the Los Baños weather data reveals that within the dry season, the months of January and February are the coolest and driest. Therefore, the initial seed quality of japonica cultivars can probably be improved further by advancing the sowing date so that the critical stages of seed maturation coincide with these months.

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