

# Effect of sowing date and harvest time on longevity of rice seeds

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## Abstract

Changes in germination ability and longevity were monitored during seed development in three japonica rice cultivars and one indica rice cultivar sown on three different dates, 14 October 1993, 24 November 1993 and 5 January 1994 at Los Baños, Philippines. Germinability of the seeds varied among cultivars in the early stages of development, but it was generally similar across sowing dates. The estimates of potential longevity (determined by storage at 40°C and 15% moisture and quantified by the values of the seed lot constant  $K_1$  of the viability equation) differed among cultivars and sowing dates. While the maximum potential longevity attained across different sowing dates was similar in the japonica cultivars Ju ku and Chianan 8, it was significantly higher in the first sowing than in the second or third sowings in cv. Akihikari. In the indica cultivar IR 58, maximum potential longevity attained in the second and third sowings was significantly greater than that in the first sowing. The mean potential longevity, averaged over cultivars and sowing dates, was marginally higher in the first sowing ( $K_1=3.81$ ) than in the second (3.65) and third (3.63); and averaged over cultivars and harvest times it was greatest at 34.8 days after flowering (DAF) in the first sowing, 31.8 DAF in the second and 28.3 DAF in the third. These results suggest that sowing in mid-October to allow seed ripening to coincide with the cooler and drier segment of the Los Baños dry season, and harvesting 35 DAF can improve the potential longevity of some japonica cultivars.

**Keywords:** *Oryza sativa* L., indica and japonica cultivars, sowing date, harvest time, potential longevity.

## Introduction

The world collection of rice germplasm in the International Rice Genebank at the International Rice Research Institute (IRRI), Los Baños, Philippines, comprises more than 80 000 accessions. About 8% are

japonica rice (*O. sativa* L.) cultivars, which evolved in temperate environments and are known to be more sensitive to high temperatures than the indica cultivars of tropical regions. Each year, many different rice accessions are regenerated on IRRI's experimental farm between November and May, when the daily mean temperatures vary between 25 and 30°C. Sato (1973) reported the best ripening conditions for germinability and seedling vigour of japonica cultivars to be a 20°C day temperature combined with strong light (12 h natural day light) and low humidity (50–60%). Temperatures as high as 30°C were considered to be unfavourable. In contrast, a day temperature of 30–35°C was found to be the best ripening condition for the indica cultivars. Yoshida and Hara (1977) found that the optimum daily mean temperature for ripening ranged from 16 to 22°C for japonica cultivars, and from 19 to 25°C for an indica cultivar. Recently, Ellis *et al.* (1993) and Ellis and Hong (1994) showed that japonica rices produced seeds with lower potential longevity when grown under simulated tropical conditions (32/24°C) than when grown under cooler conditions (28/20°C). These results suggest that the environmental conditions in Los Baños are somewhat warmer than is optimal for seed ripening in japonica rices. Ellis *et al.* (1993) suggested that the japonica rice germplasm might be better regenerated in a cooler environment than at Los Baños. We have since confirmed that the potential longevity of seeds of japonica rices grown under field conditions (mean temperature 25–30°C) during the dry season (November–May) in Los Baños was significantly less than that of seeds from a controlled cooler environment (24/18°C) (Kameswara Rao and Jackson, 1996b).

Geographical areas with low precipitation, absence of early morning fogs and/or heavy dew, and low relative humidity during the preharvest and harvest periods are known to be conducive for seed production. Under these conditions there is a low incidence of pests and diseases and the quality of seeds is usually good (Delouche, 1980; Andrews, 1982). Although tropical in nature, the environment at IRRI is characterized by a distinct dry season from December to May. The mean daily temperature and mean monthly rainfall ranges

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are 25–30°C and 17–100 mm, respectively. However, close examination of the weather data reveals that the average temperature and rainfall are lowest (25–26°C and 17–40 mm, respectively) between January and February, which should be more favourable for seed ripening in japonica cultivars than at other times of the year.

Altering sowing dates to allow the critical stages of seed maturation to coincide with favourable field environments is known to improve the quality of seeds harvested, for crops grown in non-traditional areas. For example, Green *et al.* (1965) investigating the effect of sowing date on the quality of seeds at Columbia, Missouri (USA), found that soybeans (*Glycine max*) matured during hot weather and produced seeds low in quality when sown early, while seeds from late sowings were of high quality as they reached maturity after the hot and dry weather conditions.

The climatic conditions during the wet season (June–October) in Los Baños are clearly unfavourable for seed production, due to the frequent and prolonged precipitation coupled with high temperatures (23–32°C). Hence, since 1992 germplasm seed regeneration has been undertaken during the dry season (November–May). Sowings are usually made during late November or December and seeds are harvested in April–May. Recently, we confirmed that seeds of japonica rices from a dry season field regeneration had acceptable quality and potential longevity for conservation in the genebank (Kameswara Rao and Jackson, 1996a). However, if seed ripening is allowed to coincide with the cool and relatively dry weather of January and February, and seeds are harvested at optimal maturity, the initial quality and subsequent longevity of the seeds of japonica cultivars would be expected to improve further. Therefore, the present experiment was conducted to study the storage longevity of seeds harvested from sowings on different dates. Three sowing dates were studied, the first in mid-October so that seed ripening would occur in the coolest and driest part of the dry season, the second in late November, coinciding with the normal sowing time for germplasm regeneration at IRRI, and the third in January so that the seed crop would ripen towards the end of dry season, as the temperature and rainfall gradually increase before the onset of the wet season.

## Materials and methods

The experiment was conducted during 1993–94 on the IRRI upland experimental farm block UY 3. Three japonica cultivars and one indica cultivar (Table 1) were sown on three dates at 6-week intervals (14 October and 24 November 1993 and 5 January 1994) in wet seed beds. Seedlings were transplanted four weeks after sowing into 5 × 3 m plots, laid out in a split-plot design. Date of sowing was the main plot with varieties as subplots, replicated four times. The row to row and plant to plant distances were 0.3 m and 0.25 m, respectively, which gave a total stand of 15 plants m<sup>-2</sup>. Standard crop production practices were adopted and routine plant protection measures were taken to control the incidence of pests and diseases. Panicles were harvested at weekly intervals starting from 7 days until 42 days after 75% flowering (DAF). About 10–15 panicles were harvested for the early harvest dates (7 and 14 DAF), but about 50–60 panicles were collected at later harvests (21–42 DAF). The samples were taken from alternate rows, leaving two border rows on either side of the plot. The seeds were threshed gently by hand and unfilled grains removed. Samples of the freshly-harvested seeds were drawn for dry weight, initial moisture content and germinability determinations, and the remaining seeds were dried for 24 h in a mechanical convection incubator at 30°C and 20–30% RH which reduced the moisture content to 10–12%. The seeds were then stored at 1–2°C in sealed laminated aluminium foil packets until longevity determinations began.

Dry weight determinations were made on 200 seeds (two replications of 100 each), dried in a ventilated oven at 80°C for 72 h. The moisture content of the freshly-harvested seeds was determined by the high temperature oven method, and a two-stage drying method was adopted for seeds with moisture contents expected to be >15% (ISTA, 1985a,b). The germination tests of freshly-harvested seeds were conducted on 200 seeds as four replicates of 50 seeds each on top of two moist filter papers in Petri dishes at an alternating temperature regime of 30/20°C (18/6h) as recommended by Ellis *et al.* (1985). The first counts of germination were taken on the seventh day. Seedlings which produced normal roots and shoots were

Table 1. Rice cultivars used in the experiment

Cultivar name	IRGC accession number	Origin	Ecogeographic race	Mean days to 75% flowering	Endosperm type
Ju ku	1144	China	japonica	57	glutinous
Chianan 8	3068	Taiwan	japonica	85	non-glutinous
Akihikari	58302	Japan	japonica	60	non-glutinous
IR 58		Philippines	indica	73	non-glutinous

considered germinated. Considerable dormancy was encountered in IR 58 and the early harvests of Akihikari. The ungerminated but firm seeds, considered to be dormant, were dehulled and germination tests were continued for another seven days, before taking the final counts of germination.

The potential longevity of seed lots harvested at 21, 28, 35 and 42 DAF was determined by adjusting the moisture content of the seed lots to  $15 \pm 0.2\%$ , followed by storage at  $40^\circ\text{C}$  in hermetically sealed laminated aluminium foil packets as described by Kameswara Rao and Jackson (1996a). Samples were taken out at regular intervals and germination was tested as described above.

## Results and discussion

The agrometeorological data recorded at the dryland site of IRRI during the experimental period are presented along with the phenological data in Figure 1. The mean monthly temperatures were only slightly warmer than the long-term averages for 1979–92. The rainfall received during December was significantly higher than the long-term average, but this should not have affected seed quality since 70% of the rain fell in

the first week and the first seed crop did not flower until the second week of December. Sowing date had no major effect on the duration from sowing to flowering (data not presented), indicating the comparative insensitivity of these cultivars to differences in photoperiod.

The dry weight of seeds increased rapidly from 7 DAF in all cultivars until it reached a maximum and changed little thereafter. The end of the grain-filling period, which indicates mass maturity (Ellis and Pieta Filho, 1992), was estimated by fitting a positive relation to dry weights between 7 and 21 DAF and a horizontal relation thereafter, and assessing the date on which the two lines intersect (Fig. 2). The estimates of mass maturity ranged among cultivars between 21 and 25 DAF (mean 23.1 DAF) in the first sowing, and between 20 and 21 DAF in the second and third sowings (Table 2). Differences in these durations were significant among cultivars and between different sowing dates. In Ju ku and Akihikari, there was a significant delay in attaining mass maturity in the first sowing compared with the second and third sowings, while in Chianan 8, the differences were significant only between the first and last sowings. In IR 58, however, no differences were found among sowing dates in the time to attain mass maturity (Table 2).

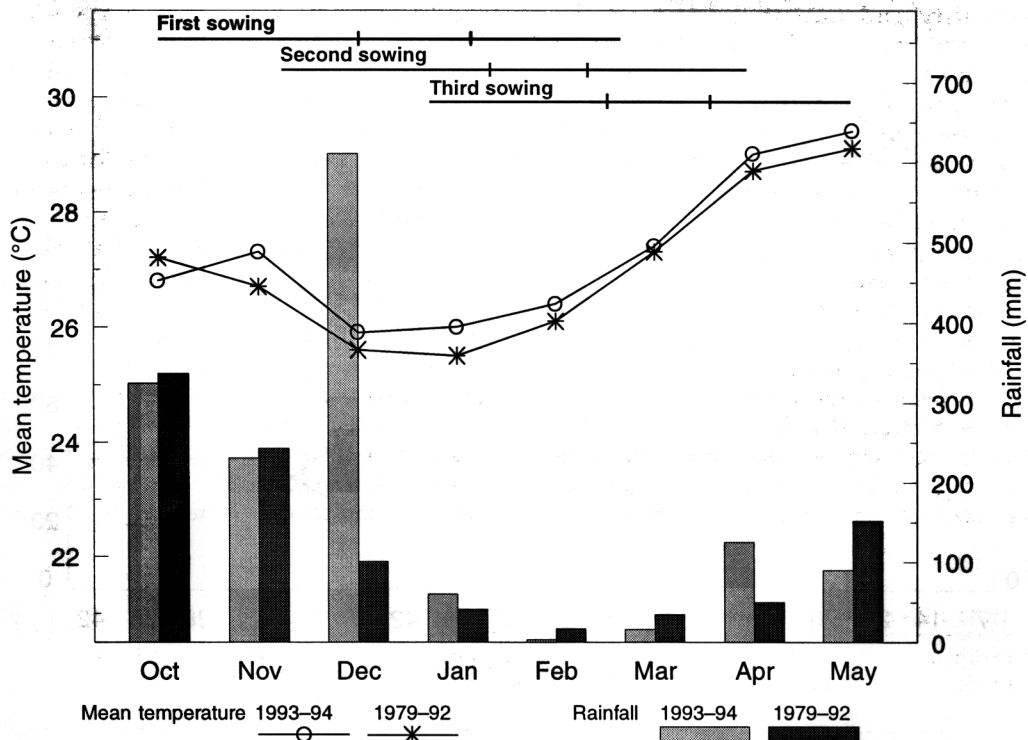
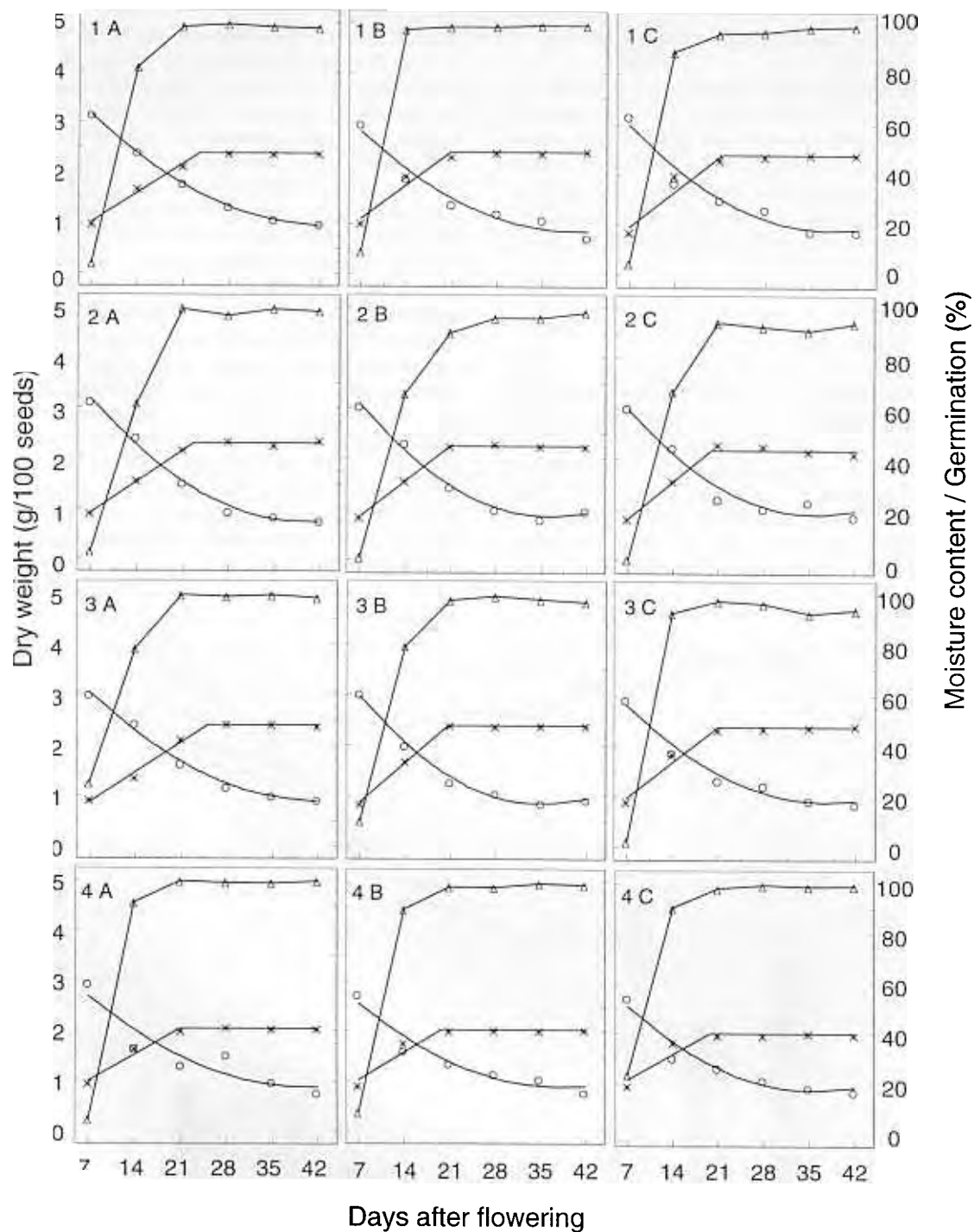


Figure 1. Mean monthly temperature ( $^\circ\text{C}$ ) and rainfall (mm) during the 1993–94 dry season as compared with the long-term means (1979–92) at the IRRI dryland site, Los Baños, Philippines. The time from sowing to the last harvest (42 DAF) is indicated by — and the grain filling duration is indicated by —|—.



**Figure 2.** Mean dry weight (\*), moisture content (○) and initial germination (Δ) during seed development and maturation in three japonica cultivars (1 = Ju ku, 2 = Chianan 8 and 3 = Akihikari) and one indica cultivar (4 = IR 58) of rice sown on three different dates (A = 14 October 1993, B = 24 November 1993 and C = 5 January 1994).

**Table 2.** Mean durations (days) from 75% flowering to mass maturity (end of grain filling period) in three japonica cultivars (Ju ku, Chianan 8 and Akihikari) and one indica cultivar (IR 58) of rice sown on three different dates during 1993–94 at Los Baños, Philippines

Sowing date	Cultivar				Mean
	Ju ku	Chianan 8	Akihikari	IR 58	
13 Oct 1993	23.9	22.7	25.1	20.8	23.1
24 Nov 1993	20.9	21.1	20.7	20.1	20.7
5 Jan 1994	20.6	19.9	20.8	19.6	20.2
Mean	21.8	21.2	22.2	20.1	21.3

LSD (5%) for comparison of two sowing date means within each cultivar = 1.6

LSD (5%) for comparison of cultivar means within each date = 1.7

The seeds from early harvests generally had higher moisture contents in the first sowing than in the second and third sowings (Fig. 2). Changes in moisture content during seed ripening were described by fitting second degree polynomials to the data for each cultivar within each sowing date. Though significant differences were observed among cultivars and sowing dates, the interaction was not significant, suggesting no evidence of differential response of cultivars to different dates of sowing. The moisture content at mass maturity, derived from the quadratic relationship, varied between 25.7 and 31.4% (mean  $28.8 \pm 0.45\%$ ) among cultivars across sowing dates.

Changes in germinability were also similar among sowing dates, although germinability of seeds in the early stages of development varied among cultivars (Fig. 2). For example, in the first sowing at 7 DAF, germination ranged from 2% (Chianan 8) to 25% (Akihikari), with a mean of 9%; from 1% (Chianan 8) to 10% (Akihikari) with a mean of 7% in the second sowing; and from 0% (Chianan 8) to 23% (IR 58) with a mean of 8% in the third sowing. However, germinability of nearly mature and mature seeds did not differ and maximum germination was attained by 21 DAF by most cultivars, for all sowing dates.

### Potential longevity

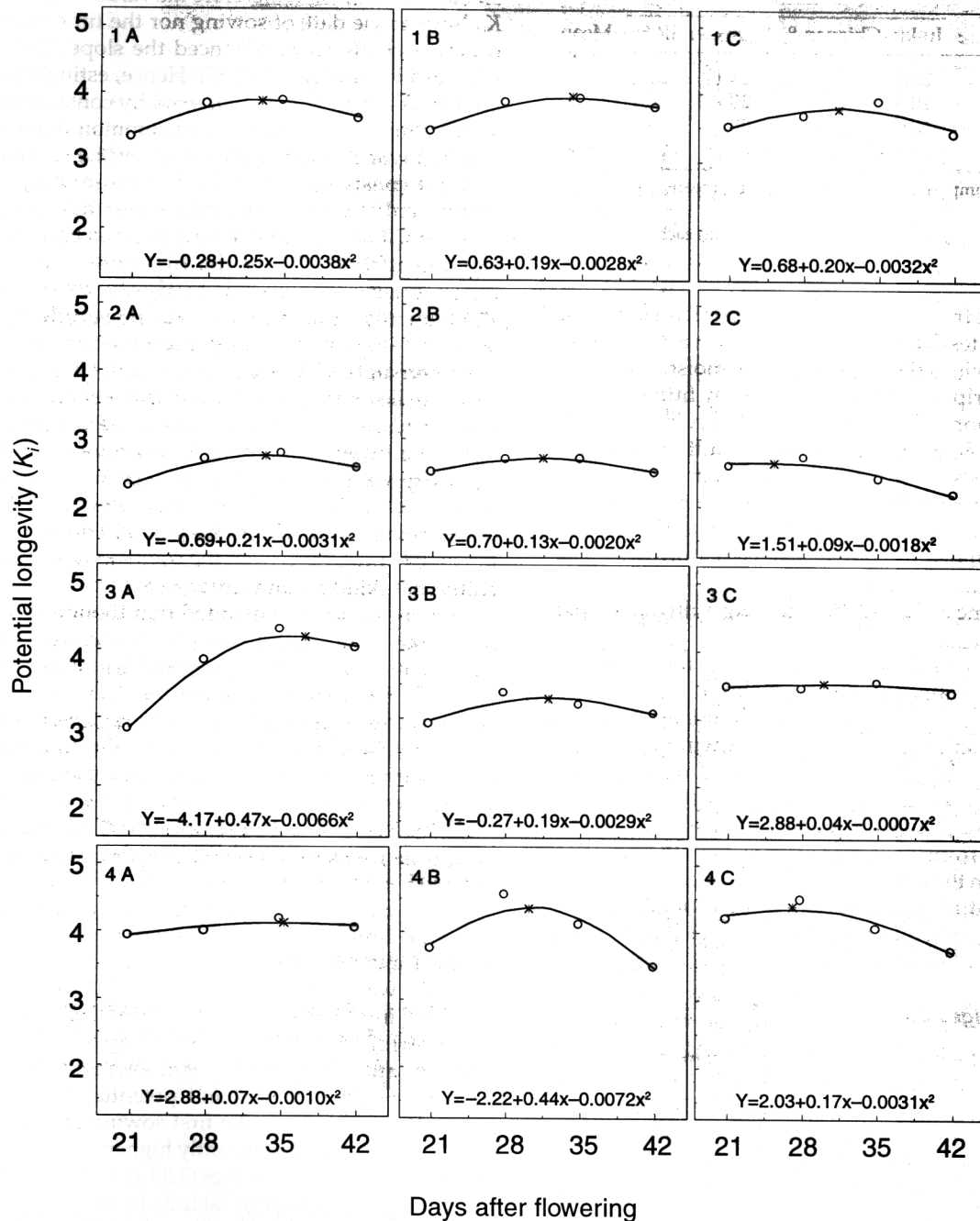
All seed lots lost viability gradually during storage. As expected, loss of viability was faster in the japonica cultivars than in the indica cultivar (data not presented). Nevertheless, the seed survival curves of all seed lots were sigmoidal. Therefore, the data for normal germination were subjected to probit analysis according to the equation

$$v = K_i - p/\sigma$$

where  $v$  is probit viability after  $p$  days of storage,  $K_i$  is the seed lot constant and  $s$  is the standard deviation of seed deaths over time (Ellis and Roberts, 1980). Potential longevity of each seed lot was quantified by the value

of the seed lot constant ( $K_i$ ), which was provided by the intercept of the transformed seed survival curves. The genotype and the pre-storage environment, including the degree of seed maturity and the environmental conditions around the time of harvest, affected the storage potential, and therefore the value of the constant  $K_i$ . Neither the date of sowing nor the time of harvest within each cultivar influenced the slope ( $1/s$ ) of the seed survival curves ( $P > 0.05$ ). Hence, estimates of the seed lot constant  $K_i$  were obtained by constraining the slopes of the survival curves to a common slope within each cultivar. Analysis of variance of the estimates of seed lot constant  $K_i$  showed significant differences among cultivars, sowing dates and harvest times ( $P < 0.01$ ). The interactions among these factors were also significant ( $P < 0.001$ ). In the first sowing, potential longevity increased from 21 to 35 DAF and decreased subsequently in all cultivars. In the second sowing, seeds achieved the highest longevity at 28 DAF in Akihikari and IR 58, and at 35 DAF in Chianan 8 and Ju ku. In the third sowing, however, potential longevity was highest at 28 DAF in Chianan 8 and IR 58, and at 35 DAF in Ju ku and Akihikari. Changes in potential longevity were described more objectively by fitting second degree polynomials to the values of  $K_i$  (Fig. 3) and estimating the maximum potential longevity and the time to attain this from the coefficients of the fitted regression line for each cultivar within each sowing date. Analysis of variance of estimates of maximum potential longevity, thus derived, again revealed significant differences among cultivars and sowing dates ( $P < 0.01$ ). The interaction between the two was also significant, suggesting differential responses of cultivars to different dates of sowing in the degree of improvement of potential longevity during seed maturation.

In the japonica cultivar Ju ku, potential longevity of seeds was greatest at 33.8 DAF in the first sowing, at 34.5 DAF in the second sowing and at 31.6 DAF in the third sowing (Table 3). The values of mean maximum potential longevity attained were not significantly different among the sowing dates. In Chianan 8, potential longevity was greatest at 34.3 DAF in the first sowing, at 30.6 DAF in the second sowing and at 25.3 DAF in the third sowing. The values of mean maximum potential longevity attained across different sowings were similar. In Akihikari, on the other hand, potential longevity was greatest at 36.6 DAF in the first sowing and the value attained (4.34) was significantly higher than those from the second and third sowings (3.35 at 31.9 DAF and 3.55 at 28.3 DAF, respectively) (Table 3). In the indica cultivar IR 58, the potential longevity attained by seeds in the second and third sowings (4.46 at 30.3 DAF and 4.41 at 28.1 DAF, respectively) was significantly higher than that in the first sowing (4.14 at 34.6 DAF). Averaged over cultivars and times of harvest, mean potential longevity was highest for the first sowing (Table 3).



**Figure 3.** Changes in potential longevity (estimates of seed lot constant  $K_i$  of the seed viability equation  $v = K_i - p/\sigma$ ) of seeds harvested at different stages of maturity in three japonica cultivars (1 = Ju ku, 2 = Chianan 8 and 3 = Akihikari) and one indica cultivar (4 = IR 58) of rice sown on three different dates (A = 14 October 1993, B = 24 November 1993 and C = 5 January 1994). The solid lines represent the fitted equation shown in each box and \* indicates maximum potential longevity from the fitted relation.

**Table 3.** Mean maximum potential longevity attained by seeds and mean duration (days) from 75% flowering to maximum potential longevity (in parentheses) in three japonica cultivars (Ju ku, Chianan 8 and Akihikari) and one indica cultivar (IR 58) of rice sown on three different dates during 1993–94 at Los Baños, Philippines. The values of potential longevity were derived from quadratic relationships fitted to the seed lot constants  $K_v$ , estimated by probit analysis of the survival data of seed lots stored hermetically at 40°C and 15±0.2% moisture content following harvest at different stages of maturity

Sowing date	Cultivar				Mean
	Ju ku	Chianan 8	Akihikari	IR 58	
13 Oct 1993	3.95 (33.8)	2.79 (34.3)	4.34 (36.6)	4.14 (34.6)	3.81 (34.8)
24 Nov 1993	3.99 (34.5)	2.77 (30.6)	3.35 (31.9)	4.46 (30.3)	3.65 (31.8)
5 Jan 1994	3.87 (31.6)	2.71 (25.3)	3.55 (28.3)	4.41 (28.1)	3.63 (28.3)
Mean	3.94	2.76	3.75	4.34	3.68

LSD (5%) for comparison of two sowing date means within each cultivar = 0.22 (6.3)

LSD (5%) for comparison of cultivar means within each date = 0.21 (6.0)

The differences in time to attain maximum potential longevity were not significant across the different dates of sowing in Ju ku ( $P>0.05$ ). However, in Chianan 8, Akihikari and IR 58 maximum potential longevity was achieved significantly earlier (25.3, 28.3 and 28.1 DAF, respectively) in the third sowing than in the first sowing (34.3, 36.6 and 34.6 DAF, respectively). Averaged over cultivars, maximum potential longevity was greatest at a mean time of 34.8 DAF in the first sowing, 31.8 DAF in the second sowing and 28.3 DAF in the third sowing (Table 3).

The results presented here indicate that cultivars differ in their sensitivity to the seed production environment. In the japonica cultivar Akihikari potential longevity was highest when sown early, while in IR 58, the values of  $K_v$  were highest in the second sowing. This suggests that early sowing may not be beneficial for seed quality in indica cultivars. On the other hand, sowing date had no significant effect on potential longevity in Ju ku and Chianan 8. Possibly the differences in daily mean temperatures between December and April are not large enough to have any significant effect on seed quality in these cultivars. Nevertheless, early sowing seemed to be beneficial for seed quality at least for some japonica cultivars and did not adversely affect it in the others. The mean potential longevity was also marginally higher for the first sowing. This indicates that advancing the sowing date to allow seed ripening to coincide with the cool and

dry segment of the year can improve seed quality and potential longevity, especially of some japonica cultivars. It is interesting to note that maximum potential longevity was obtained between 25 and 37 DAF, i.e. 5–14 days after mass maturity, in all cases (Table 3). The results are thus in agreement with earlier findings in rice (Ellis *et al.*, 1993) and in other crops (Kameswara Rao *et al.*, 1991; Pieta Filho and Ellis, 1991; Ellis and Pieta Filho 1992; Demir and Ellis, 1993) that seed quality continues to improve after the end of the seed filling period, and contradict the hypothesis that maximum seed quality coincides with physiological maturity (Harrington, 1972). The stage during seed maturation at which potential longevity is maximum was termed as storage maturity (Kameswara Rao and Jackson, 1996a). The moisture content at storage maturity in the present studies ranged between 15.5 and 22.1% among cultivars, with an average of 18.5±0.48% across sowing dates. It is significant to note that mean maximum potential longevity was achieved a few days earlier in the second and third sowings than in the first sowing. The results presented here are also in agreement with our previous finding that endosperm starch composition has no relation with seed longevity (Kameswara Rao and Jackson, 1996a). Thus no consistent differences were found in potential longevity of the glutinous cultivar Ju ku and the other japonica cultivars, Akihikari and Chianan 8.

Finally, it can be concluded that though any of the three sowing dates used here with the four different rice cultivars gave high germinability and potential longevity, some small gains may be obtained by earlier sowing of the japonica cultivars. Therefore, in order to obtain seeds with maximum potential longevity for conservation in the International Rice Genebank, rice germplasm accessions can be sown for regeneration in mid-October and harvested about 35 DAF. This earlier sowing date is more important in japonica than in indica cultivars.

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### References

- Andrews, C.H. (1982) Preharvest environment: weathering. pp 19–25 in Sinclair, J.B., Jackobs, J.A. (Eds) *Soybean seed quality and stand establishment. Proceedings of a Conference for Scientists of Asia, Colombo, Sri Lanka.*
- Delouche, J.C. (1980) Environmental effects on seed development and seed quality. *Horticultural Science* 15, 775–780.

- Demir, I. and Ellis, R.H.** (1993) Changes in potential longevity and seedling growth during seed development and maturation in marrow. *Seed Science Research* 3, 247-257.
- Ellis, R.H. and Hong, T.D.** (1994) Desiccation tolerance and potential longevity of developing seeds of rice (*Oryza sativa* L.). *Annals of Botany* 73, 501-506.
- Ellis, R.H. and Pieta Filho, C.** (1992) Seed development and cereal seed longevity. *Seed Science Research* 2, 9-15.
- Ellis, R.H. and Roberts, E.H.** (1980) Improved equation for the prediction of seed longevity. *Annals of Botany* 45, 13-30.
- Ellis, R.H., Hong, T.D. and Roberts, E.H.** (1985) *Handbook of seed technology for genebanks, volume II. Compendium of specific germination information and test recommendations.* Rome, International Board for Plant Genetic Resources.
- Ellis, R.H., Hong, T.D. and Jackson, M.T.** (1993) Seed production environment, time of harvest and the potential longevity of seeds of three cultivars of rice (*Oryza sativa* L.). *Annals of Botany* 72, 583-590.
- Green, D.E., Pinnell, L.E.C. and Williams, L.F.** (1965) Effect of sowing date and maturity date on soybean seed quality. *Agronomy Journal* 57, 165-168.
- Harrington, J.F.** (1972) Seed storage and longevity. pp 142-245 in Kozlowski, T. (Ed.) *Seed biology, vol. 3.* New York, Academic Press.
- ISTA (1985a)** International rules for seed testing. Rules 1985. *Seed Science and Technology* 13, 299-355.
- ISTA (1985b)** International rules for seed testing. Annexes 1985. *Seed Science and Technology* 13, 356-513.
- Kameswara Rao, N. and Jackson, M.T.** (1996a) Seed longevity of seventeen rice cultivars and strategies for germplasm conservation in genebanks. *Annals of Botany* 77, 251-260.
- Kameswara Rao, N. and Jackson, M.T.** (1996b) Seed production environment and storage longevity of japonica rice (*Oryza sativa* L.). *Seed Science Research* 6, 17-21.
- Kameswara Rao, N., Appa Rao, S., Mengesha, M.H. and Ellis, R.H.** (1991) Longevity of pearl millet (*Pennisetum glaucum* R. Br.) seeds harvested at different stages of maturity. *Annals of Applied Biology* 119, 97-103.
- Pieta Filho, C. and Ellis, R.H.** (1991) The development of seed quality in spring barley in four environments. I. Germination and longevity. *Seed Science Research* 1, 163-177.
- Sato, K.** (1973) The development of rice grains under controlled conditions. III. Germinability of seeds ripened under different environmental conditions. *Tohoku Journal of Agricultural Research* 24, 14-21.
- Yoshida, S. and Hara, T.** (1977) Effect of air temperature and light on grain filling of an indica and a japonica rice (*Oryza sativa* L.) under controlled environmental conditions. *Soil Science and Plant Nutrition* 23, 93-107.

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