AGRONOMY

Seed longevity in the soil of japonica and indica rice cultivars and red rice

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A long-term experiment was installed at the Paso de la Laguna research station of INIA Treinta y Tres to assess longevity of seeds from five commercial varieties and two red rice biotypes, buried in the soil at two depths (5 and 15 cm). Four varieties were japonica and one was an indica long-grain cultivar. Two red rice biotypes collected from rice fields were used: straw hull and black hull. The experiment was installed in June 1993 and, each September since then, seeds were removed from the soil and analyzed in the laboratory. Results from the first five extractions (1993-97) are discussed. Depth of burial in all cases favored longevity. Seeds from all japonica-type varieties lost almost all viability before the next spring (3 mo), whereas the indica cultivar maintained some viable seeds until the second spring (15 mo). All viable seeds from this cultivar were quiescent, with no dormancy at all. Both red rice biotypes showed a high capacity of seed survival. After the fifth extraction in September 1997, from 10% to 35% viability was still observed. Red rice seeds maintained fluctuating equilibrium between quiescent and dormant seeds among years.

Length of survival of seeds remaining in the soil from the last harvest is an important management factor in rice production. It permits us to plan changes in cultivars to avoid mixtures with volunteer plants, which may reduce grain or seed quality. Additionally, knowing the seed longevity in the soil of common Uruguayan biotypes of red rice is necessary for applying effective control strategies.

In the past decade, a new indica-type cultivar released in Uruguay and widely used across the country, El Paso 144, produced high levels of volunteer plants in the next crop. This problem was not usually observed with the japonica-type varieties used until then. Red rice infection in Uruguayan rice fields has been growing recently, and there are no studies on red rice seed survival in Uruguay.

The objective of this experiment was to assess seed longevity in the soil of commercial varieties and red rice biotypes under Uruguayan climatic and soil conditions.

Materials and methods

A long-term experiment was installed at the Paso de la Laguna research station at INIA Treinta y Tres in a Solod clay soil typical of rice production fields in Uruguay. Depth of burial, year, and cultivar were the main factors combined in this trial. A split-split-plot design was used with three replications. Large plots were depths of burial (5 and 15 cm), subplots were years (5 y for rice cultivars and 20 y for red rice biotypes), and sub-subplots were cultivars.

Seed samples of five varieties were collected from a breeding experiment at maturity in May 1993, then sun-dried and cleaned in the laboratory. Four varieties were japonica types: Bluebelle, El Paso 48, INIA Tacuarí (American long-grain cultivars), and EEA-404 (medium grain). The fifth variety, El Paso 144, was an indica long-grain cultivar. At the same time, seed samples of two biotypes of red rice—straw hull and black hull—were collected in farmers' rice fields and treated similarly.

Two hundred seed samples were buried in June 1993, 1 mo after harvest. Seeds of rice cultivars presented very low or no dormancy, and both red rice biotypes had 100% dormancy at that time. PVC open cylinders (10 cm diameter, 4 cm height) were used to identify seed sample sites, but did not disturb the soil environment. Soil was removed to the treatment depth in each replication, cylinders were half-buried, and seed samples were distributed in a thin layer into them. Cylinders were then covered with the removed soil and all experiment surfaces leveled.

Each September since then (early spring in the southern hemisphere), a row of seven cylinders corresponding to each replication was cut from below and seeds carefully removed from the soil in the laboratory. Seeds with no visible deterioration were immediately placed in paper towels to germinate. Normal seedlings were counted and recorded as viable quiescent (nondormant) seeds. Seeds that did not rot at the end of the germination test were further analyzed by a tetrazolium test, and the number of viable seeds was recorded as viable dormant seeds. Total viability was obtained by adding quiescent and dormant seed counts, and results were expressed as percentage of total viable seeds buried in the soil. Results from the first five extractions are discussed (1993-97). Statistical analysis was conducted with SAS and mean separations were based on least significant difference when appropriate.

Results

Main treatment effects were very significant, as can be observed in Table 1. Seeds placed 15 cm into the soil survived much better than the ones at 5 cm in all cases. Time was obviously a factor expected to affect seed longevity, and cultivars showed very different trends in the loss of seed viability, making all interactions highly significant.

Figure 1 summarizes results of seed longevity by depth of burial. At 5-cm depth, three types of responses could be defined. Both red rice biotypes showed a high rate of survival, maintaining some viability in spring 1997, 51 mo after burial. On the other hand, seeds from the four japonica varieties (Bluebelle, El Paso 48, INIA Tacuarí,

Table 1. Analysis of variance. $R^2 = 0.966633$, CV = 36.78.

Source	DF[a]	SS	F Value	*P* > F
Depth of burial[b]	1	2,026.17	48.33	0.0201
Block[b]	2	50.32	0.60	0.6249
Depth of burial × block	2	83.84	1.03	0.3592
Year[c]	4	25,516.47	145.94	0.0001
Year × depth of burial[c]	4	405.50	2.32	0.1015
Year × block (depth of burial)	16	699.38	1.08	0.3846
Cultivar	6	89,058.16	365.64	0.0001
Depth of burial × cultivar	6	1,472.79	6.05	0.0001
Year × cultivar	24	18,995.39	19.50	0.0001
Year × depth × cultivar	24	2,816.56	2.89	0.0001
Error	120	4,871.42		
Total	209	145,995.98		

[a]DF = degrees of freedom, CV = coefficient of variation. [b]Depth of burial × block used as an error term. [c]Year × block (depth of burial) used as an error term.

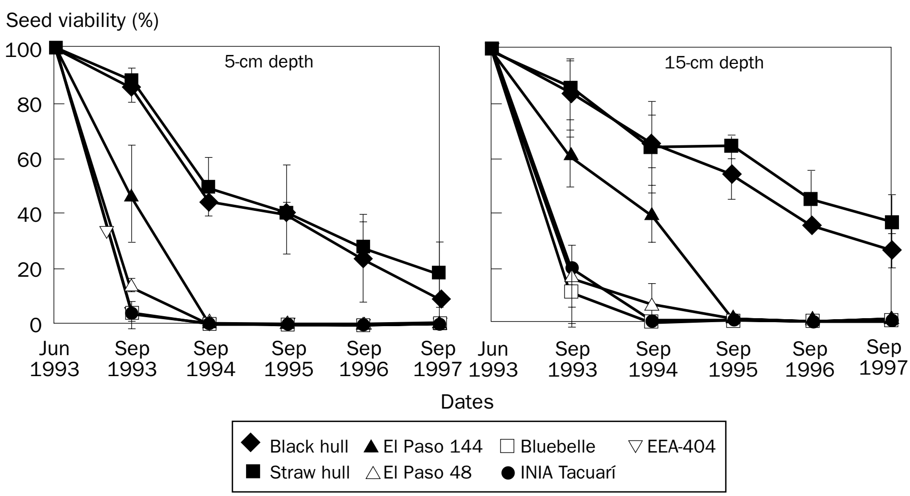

Fig. 1. Evolution of seed viability of Uruguayan cultivars and red rice biotypes buried in the soil at two depths. Japonica cultivars El Paso 48, Bluebelle, INIA Tacuarí, and EEA-404; indica cultivar El Paso 144. Red rice biotypes are straw hull and black hull. Bars indicate standard error.

and EEA-404) lost viability very soon, having few seeds alive in the first spring (September 1993), only 3 mo after burial. El Paso 144, the only indica cultivar, maintained 50% viability in September 1993, but all seeds were dead in the second spring (September 1994).

Results at 15-cm depth show similar trends, but with higher percentages of survival. Red rice biotypes maintained from 20% to 40% viability after 51 mo in the soil, and El Paso 144 had 60% viability in the first spring, 40% in the second spring, and only in the third spring were all seeds dead. Japonica cultivars presented some viable seeds in the first extraction, but had lost almost all viability in the second (September 1994).

Seeds from red rice biotypes and El Paso 144 showed different survival strategies. Red rice seeds were 100% dormant when buried, and after that they maintained a fluctuating equilibrium between quiescent and dormant seeds among years (Fig. 2).

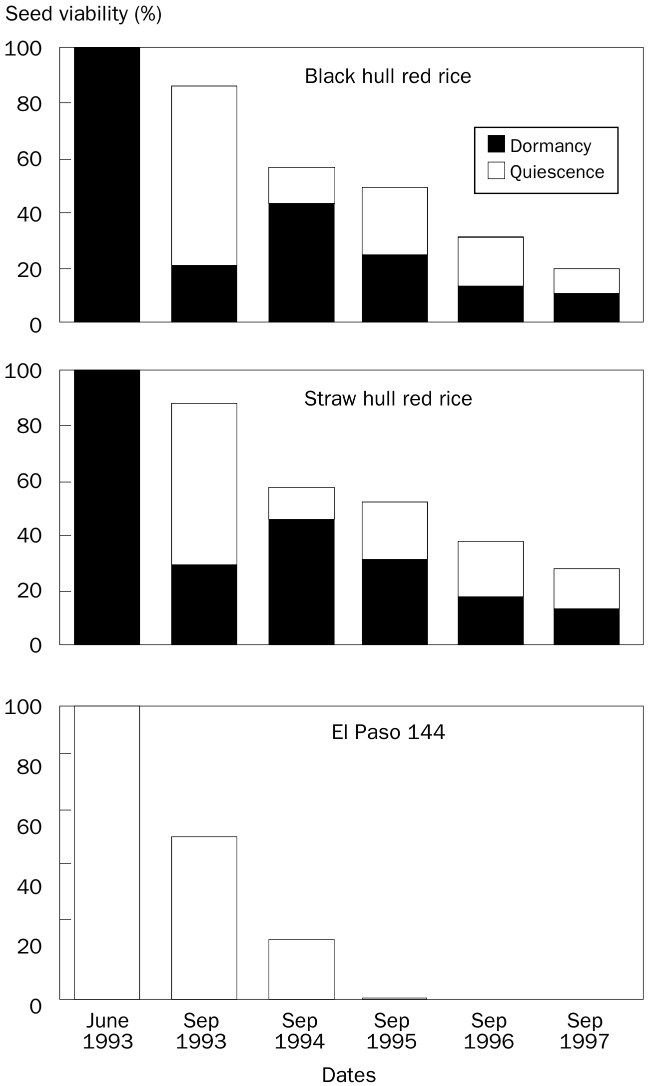

Fig. 2. Quiescence/dormancy fluctuations in rice seeds of straw hull and black hull red rice biotypes and cultivar El Paso 144 (indica type) buried in the soil. Average of 5 and 15 cm depth of burial.

Seeds apparently moved in and out of a secondary dormancy, probably induced by environmental changes.

On the other hand, El Paso 144 seeds were not dormant at all when buried, and no dormancy was detected after that, in any of the following years (Fig. 2). The capacity of survival of these seeds was probably sustained only by their physical structure.

Discussion

Depth of burial benefits seed storage in the soil, not only in rice (Miller et al 1988, Noldin et al 1995), probably by diminishing temperature and moisture fluctuations, and by avoiding germination under low oxygen availability.

Previous studies have found similar longevity of red rice seeds in the soil. A frequently cited study by Goss and Brown (1939) determined that all red rice cultivars in their experiment were germinative after 3 y, whereas none of the white rice cultivars survived. Some of the red rice seeds retained germinability even after 10 y. A new study by Noldin et al (1995), however, showed that current red rice biotypes of the southern United States had a much shorter life span, having lost almost all viability after 17 mo of burial. A continuation of the present study will characterize the potential of survival of Uruguayan red rice biotypes. Results obtained up to now suggest a very strong capacity of survival because more than 20% viability was obtained after 51 mo of burial, and the rate of decay was slowing down in the last two years.

The difference in performance of japonica and indica cultivars cannot be easily described by the subspecies origin. Takahashi (1984), studying the relationship between dormancy and viability, found that japonica cultivars with weak dormancy had a short life span, whereas indica cultivars with strong dormancy had a long life span. The results of the present study coincide with Takahashi's in relation to seed longevity, although the only indica variety (El Paso 144) showed no dormancy.

In another paper discussing longevity and dormancy, Takahashi (1995) cites contradictory results on this relationship by Roberts (1963) and Ikehashi (1974). He concludes that dormancy has an important role in seed longevity of wild plants, but that there is no correlation between dormancy and the length of seed longevity in cultivated plants.

Our results support Takahashi's conclusion. Red rice biotypes, as wild species, relied on strong dormancy to maintain seed viability in the soil. The only cultivated variety that showed some capacity of survival (El Paso 144) did not have dormancy at all, but had some other physical or physiological characteristics protecting the seeds.

From these results, it is possible to give some recommendations to Uruguayan farmers for managing the rice seed bank in the soil. Changing varieties from one year to another may be possible, if a japonica type was used last in the cycle, but at least two years without rice should be allowed with El Paso 144. In this case, repeated superficial soil movement may effectively reduce the seed bank because of the lack of dormancy of this cultivar.

The long survival of red rice seeds in the soil in Uruguay has been confirmed in this study. Control strategies in red rice–infected fields won't be able to rely on short rotations with pastures, and they will need to include other management factors. Plowing immediately after harvest is not recommended if red rice is present because deeply buried seeds will last longer.

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Notes

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