

Effects of Aging on Seedling Emergence and Establishment of Barley under Soil Moisture Stress

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ABSTRACT Early establishment and growth of barley is essential to achieve optimum yield in the semi-arid Mediterranean region, where soil moisture stress is common at planting time. Seed aging may reduce seedling emergence and establishment of barley under soil moisture stress. Seeds of two barley cultivars, ACSAD 176 and Rum, were subjected to aging at 42°C and 100% relative humidity for 0, 2, 4, 6, 8, or 10 days. Seed quality, as estimated by standard germination test, germination rate index, and seedling dry weight, was evaluated for the aged seeds. In a greenhouse experiment, aged seeds were grown in soil maintained at 10, 30, 50, 70, and 90% of field capacity (FC) to evaluate seedling emergence, emergence rate index (ERI), and seedling dry weight (SDW). Seedling emergence of aged seeds was further evaluated at two field locations, characterized by low and high annual rainfall (Jordan University of Science and Technology (JUST) and Jomha, respectively). Aging treatments reduced seed germination, germination rate index (GRI), and seedling dry weight. Seed aging reduced seedling dry weight, but this reduction was higher in Rum than ACSAD 176. In the greenhouse experiment, aged seeds had lower seedling emergence, ERI, and SDW than those of unaged seeds. The ability of seeds to emerge under moisture stress (10 and 90% FC) decreased as seed aging increased. Emergence rate index was more sensitive to moisture stress than emergence percentage and SDW. In the field experiment, aged seeds (2-, 4-, and 6-day) had lower emergence at the drier location (JUST) than that at Jomha. These results indicate that aged seeds should not be planted, where moisture stress is common at planting time.

Key words: Seedling emergence, soil moisture, barley

A barley-based farming system exists in wide areas along the dry margins (200-300 mm annual rainfall) of cultivation in semi-arid rainfed Mediterranean region of Jordan [1, 2]. More than 90 per cent of the total area planted with field crops in Jordan is grown mainly in semi-arid region, where moisture stress often occurs during establishment, growth, and development. Significant reduction in seedling emergence of barley has been reported under moisture stress [3]. Matthews and Collins [4] reported that emergence rate of barley was negatively correlated with excessive moisture. The sensitivity of barley emergence to moisture stress may be associated with seed aging.

Natural and artificial aging has been reported to reduce seed germination and seedling vigour of

many grass species [5-7]. Aging treatments caused drastic losses in seed germination and seedling vigour in maize (*Zea mays* L.) [8]. In barley, the effects of aging on seed germination and seedling emergence under moisture stress is not well investigated and needs to be studied. Therefore, the objective of this experiment was to study the effects of aging treatments on seed germination and seedling establishment of barley under various soil moisture conditions.

MATERIALS AND METHODS

Laboratory experiment

Seeds of two barley (*Hordeum vulgare* L.) cultivars, ACSAD 176 and Rum were obtained from Jordanian Cooperative Corporation. Seeds were subjected to artificial aging treatments by placing

a single layer of seeds (25 g) over a wire mesh screen suspended over 40 ml water in 11.5 x 6 cm plastic containers, and placed in an incubator at $42 \pm 0.5^\circ\text{C}$ for 0, 2, 4, 6, 8 and 10 days. After aging, seeds were left for air-drying at ambient conditions ($24 \pm 2^\circ\text{C}$) until seed moisture content reached less than 10 per cent on a wet weight basis. Seeds were stored at 5°C until they were used for seed germination and seedling emergence.

Standard germination test

Standard germination test was conducted according to ISTA rules [9]. Four replicates of 50 seeds were placed between folded germination papers, moistened with distilled water in 17 x 11 x 7 cm plastic containers and placed in an incubator at 20°C for 14 days. At the end of the test, number of normal seedlings was recorded. Seedlings were counted as normal, when the shoot appeared from the coleoptile and the seedlings have strong root system [9].

Germination rate index

In standard germination test, number of normal seedlings at 3, 6, 9, 12 and 14 days from seed planting was counted to calculate germination rate index (speed of germination) based on Maguire [10] equation as follow:

$$\text{GRI} = \frac{\text{S Number of normal seedlings at day } x}{\text{Day } x}$$

where, x is number of days from seed planting

Seedling dry weight

At the end of the standard germination test (14 days later from seed planting), normal seedlings were endosperm-extracted and weighed after drying in an oven at 70° for 3 days. Total dry weight of normal seedlings was expressed as mg seedling^{-1} .

Greenhouse experiment

Seeds were sown in pots containing a mixture of soil: sand: peat in a ratio of 2:2:1 (V/V) maintained at 10, 30, 50, 70 or 90 per cent of field capacity to study the effects of aging on seedling emergence and establishment under different soil moisture contents. Soil mixture was saturated with water

and its weight after draining stop was recorded and considered as field capacity. Pots were weighed daily and maintained at the desired soil moisture content. Pots were covered with plastic sheets to reduce water evaporation throughout the experiment period. Number of emerged seedlings was counted daily until no further emergence has occurred. Total number of emerged seedlings at 21 days from seed sowing was used to calculate seedling emergence percentage. Seedling dry weight was determined for emerged seedling at 21 day from sowing by weighing them after an oven-drying at 70°C for 48 h. Emergence rate index was calculated according to Maguire [10] equation as shown in GRI.

Field experiment

For each aging treatment, four replicates of 100 seeds were sown on 1 November 2002 at two locations in northern Jordan: Jordan University of Science and Technology Experimental Station (JUST) and Jomha, characterized by a variation in annual rainfall, to study the effects of aging on field emergence of barley. At JUST location ($32^\circ 34' \text{N}$ latitude, $36^\circ 01' \text{E}$ longitude and 520 m altitude), soil is loamy, mixed, thermic calcic paleargid [11]. At Jomha ($32^\circ 55' \text{N}$ latitude, $35^\circ 78' \text{E}$ longitude and altitude 526 m), soil is very fine, smectitic, thermic, typic pelloxererts [12]. Seeds were sown by hand at 8 cm depth, 30 cm between rows, and 10 cm between seeds.

Seedling emergence was counted 30 days from seed planting, when no further seedlings had emerged. Maximum, minimum temperature, rainfall, and soil moisture content during emergence period were recorded at both locations.

Statistical analysis

Lab experiments were a split plot arranged in a completely randomized block design with 4 replications. The main factor was cultivars and the split factor was the aging treatments. In the greenhouse experiment, the design was in a strip plot arranged in a completely randomized block design with 4 replications. Cultivar was the main factor, soil moisture levels were arranged in strips, and aging treatments were arranged within soil moisture level. In the field experiment, the

experiment design was split plot in a completely randomized block design with four replications. The main factor was the cultivar and the split factor was the aging treatments.

Data were subjected to analysis of variance (ANOVA) using MSTATC programme (Michigan State University, East Lansing, MI). Probability of significance was used to indicate the significant effects. Means were compared according to the least significant difference (LSD) at probability of 0.05.

RESULTS AND DISCUSSION

Effects of aging on seed quality

It was estimated by measuring germination percentage, germination rate index, and seedling dry weight. Aging treatments reduced germination percentage, germination rate index, and seedling dry weight for both cultivars (Fig. 1). Germination percentage was declined by 4 days of aging, whereas, germination rate index was declined by 2 days. Seedling dry weight differed between cultivars and was declined by 6 and 8 days of aging for Rum and ACSAD 176, respectively.

Effects of aging on seedling emergence under moisture stress

Aging \times moisture content \times cultivar had no significant interactive effects on emergence percentage, emergence rate index (ERI), and seedling dry weight (SDW). Therefore, aging \times moisture content interaction was averaged over cultivar. As aging increased, emergence percentage, ERI and SDW decreased (Fig. 2). For any aging treatment, emergence percentage did not differ between soil moisture contents of 30, 50, and 70 per cent FC. Low soil moisture content (10% FC) significantly decreased emergence percentage and ERI for aging treatments (0, 2, 4 and 6d) and SDW for aging treatment (8 d) compared with soil moisture contents of 30, 50, and 70 per cent FC. High soil moisture content (90% FC) decreased the emergence percentage and ERI for aging treatments (4 and 8 d) compared with soil moisture contents of 30, 50 and 70 per cent FC, but had no significant effect on SDW with any aging treatment.

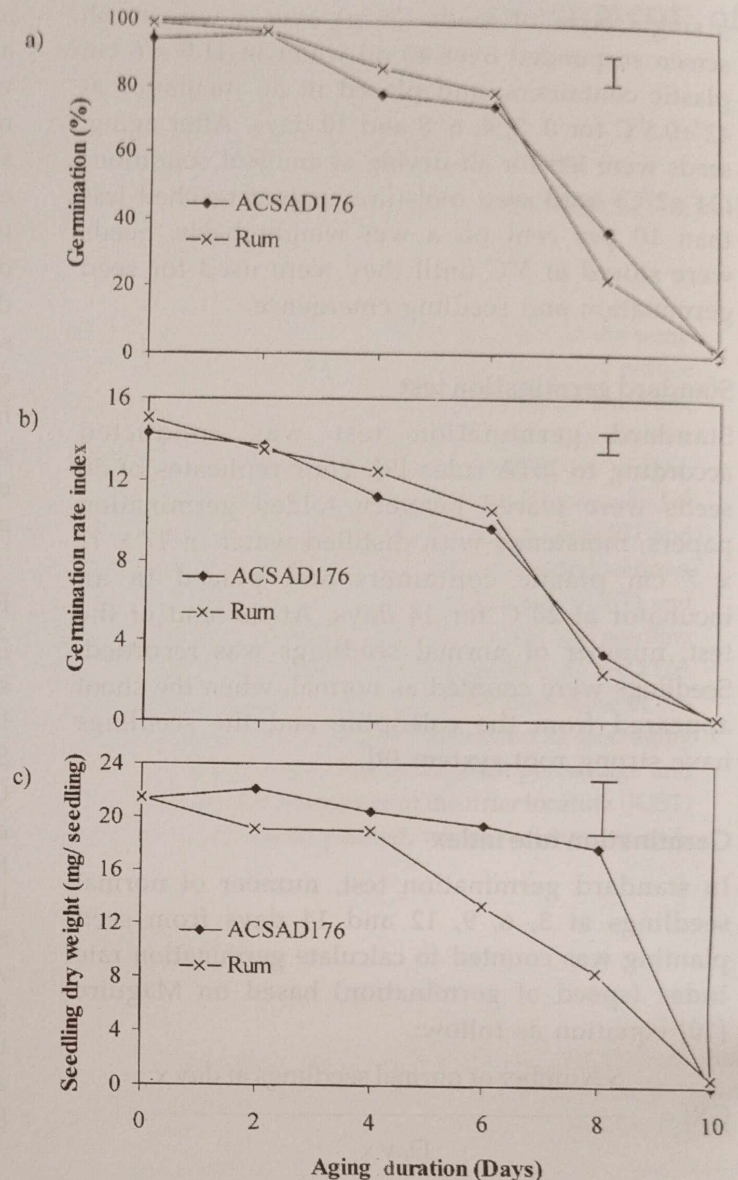


Fig. 1. Effects of aging treatments on: a) Standard seed germination, b) Germination rate index and c) Seedling dry weight of two barley cultivars, ACSAD 176 and Rum. Vertical bars indicate LSD values ($P=0.05$) for mean comparison

Effects of aging on field emergence

Rainfall, temperature and soil moisture content during the emergence period was measured at the two locations. In general, Jomha had higher rainfall and soil moisture content, lower maximum temperature than Jordan University of Science and Technology (Fig. 3). As aging duration increased, field emergence decreased at both locations (Fig. 4). For unaged seeds (0 d), field emergence did not differ between locations. For the aging treatments (2, 4 and 6 d), field emergence at JUST was lower than that at Jomha. For the aging treatment (8 d),

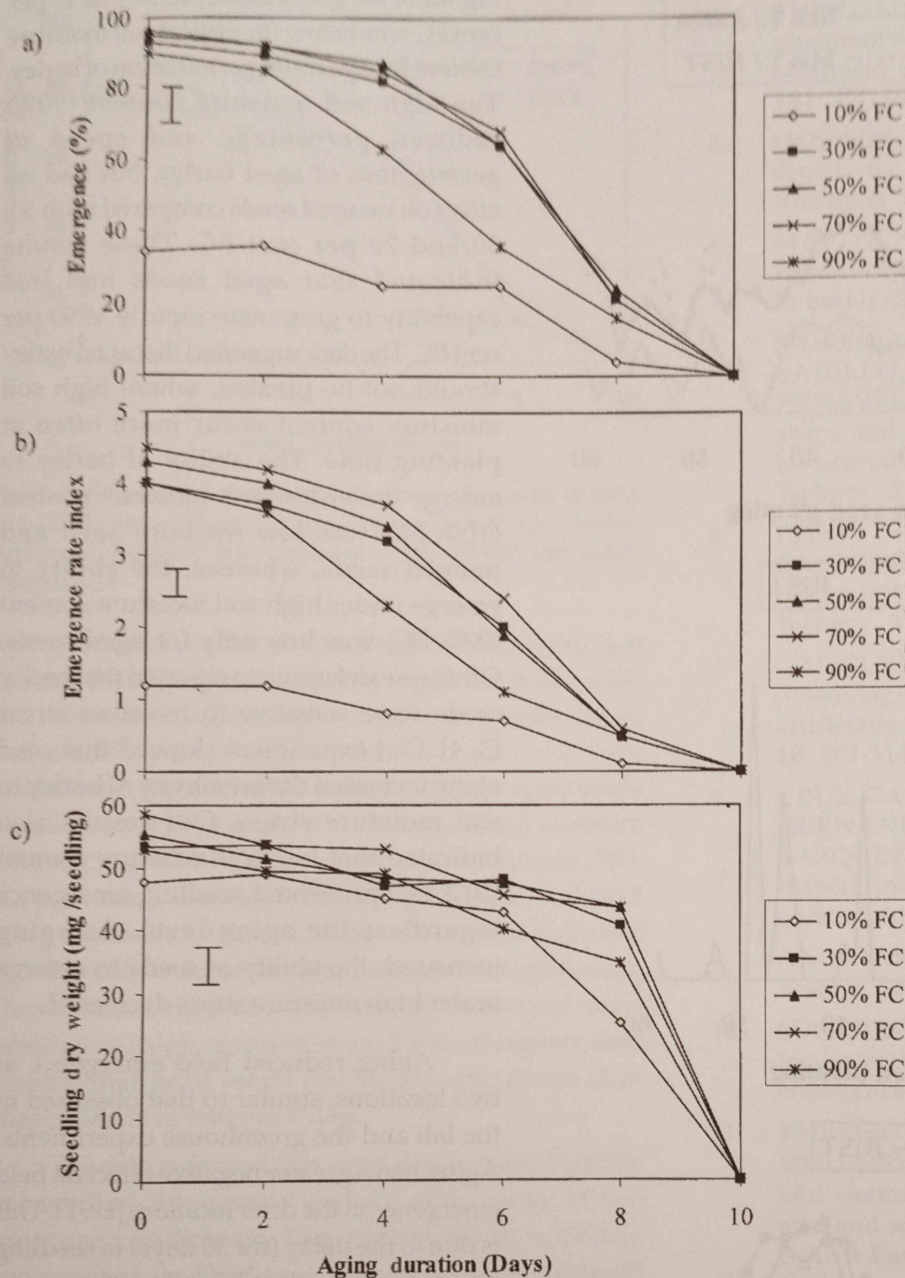


Fig. 2. Effects of aging treatments on: a) Seedling emergence percentage, b) Emergence rate index and c) Seedling dry weight of barley under different soil moisture contents averaged over cultivars. Vertical bars indicate LSD values ($P=0.05$) for mean comparison

field emergence was higher at JUST than that at Jomha.

Two-days of aging did not change germination percentage or seedling dry weight, but significantly reduced speed of germination, as estimated by the germination rate index, compared with the unaged seeds (0 d). This data suggest that aging affected speed of germination at greater extent than germination

percentage or seedling dry weight. Seedling dry weight was the least affected by aging. Speed of germination can be a useful test to assess aging in barley seeds. Other researchers have reported that speed of germination was closely related with seed aging in wheat (*Triticum aestivum* L.) [13] and corn (*Zea mays* L.) [14]. Seed aging reduced seedling dry weight of Rum at greater rate than that of ACSAD 176, suggesting that seedling vigour of Rum was more negatively affected by aging than ACSAD 176.

Seedling emergence, emergence rate index and seedling dry weight under different soil moisture contents decreased as aging increased. For each aging treatment, the soil moisture contents of 30, 50 and 70 per cent FC did not affect emergence percentage. These data suggest that barley seeds can germinate under a wide range of soil moisture content (from 30 to 70% FC). These data indicate that light rainfall after planting can initiate germination of barley. Early planting (before rainfall) is recommended in barley grown in the semi-arid Mediterranean region of Jordan to gain an advantage of the growing season before the onset of drought stress during the reproductive growth [1]. Our data suggested that planting high quality unaged seeds was a pre-requisite to achieve optimum seedling emergence and speed of emergence under a wide range of soil moisture content.

The low soil moisture content (10% FC) reduced emergence and emergence rate index for all aging treatments and seedling dry weight for 8-d aging compared with 30, 50 and 70 per cent FC. These data suggested that 10 per cent FC reduced seed germination of unaged and aged barley but had less effect on seedling

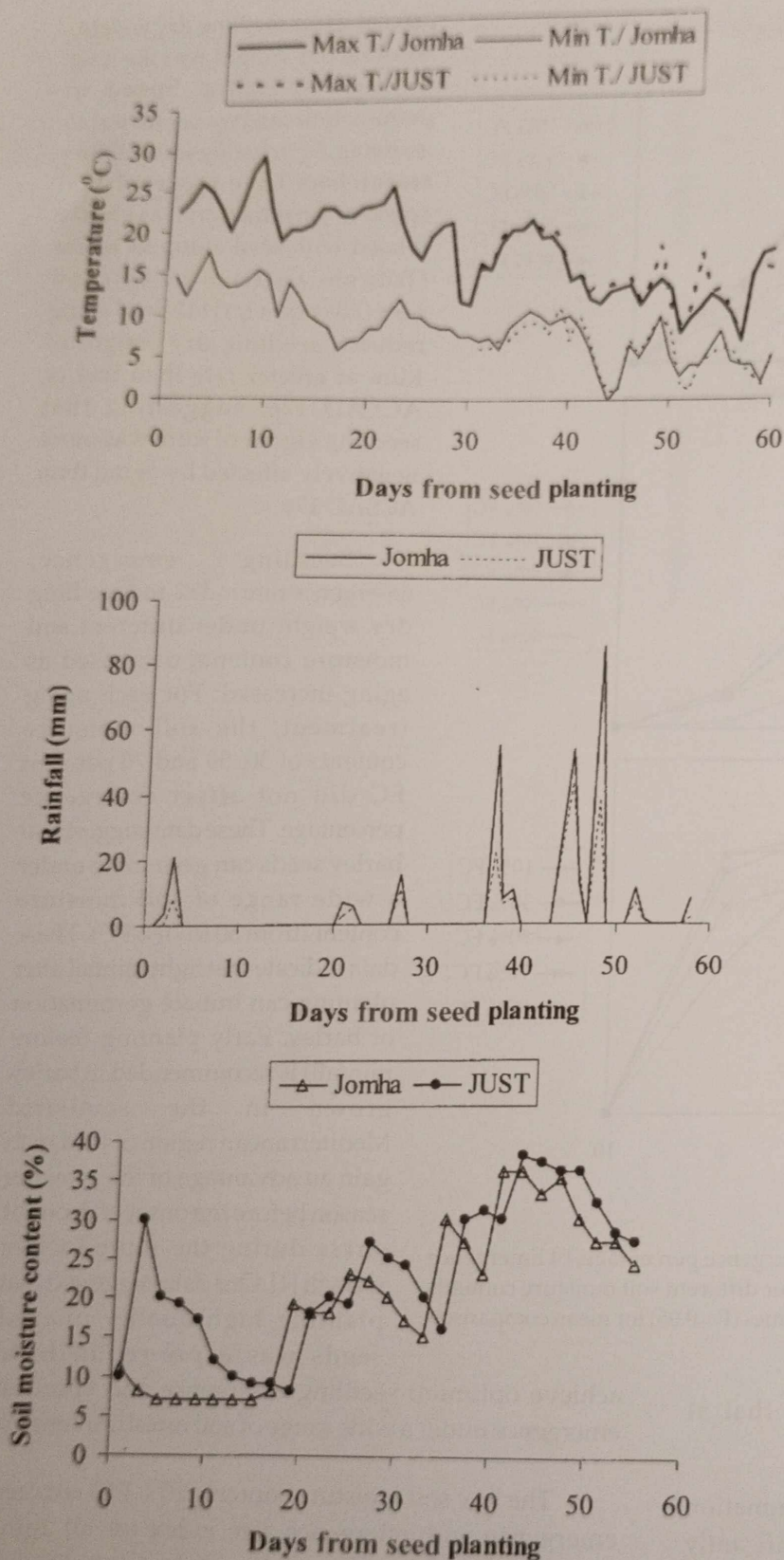


Fig. 3. Daily minimum and maximum temperature, rainfall and soil moisture percentage at two locations (Jomha and JUST) in northern Jordan

vigour of the germinated seeds. The 10 per cent FC was below the critical soil moisture content for optimum germination of barley. The high soil moisture content (90%) reduced percentage and speed of germination of aged barley, but had no effect on unaged seeds compared with 30, 50 and 70 per cent FC. These results indicated that aged seeds had less capability to germinate rapidly at 90 per cent FC. The data suggested that aged barley should not be planted, where high soil moisture content occur more often at planting time. The ability of barley to emerge under low soil moisture content (10% FC) was low for both aged and unaged seeds, whereas, the ability to emerge under high soil moisture content (90% FC) was low only for aged seeds. Other researchers have reported that barley seeds were sensitive to moisture stress [3, 4]. Our experiment showed that seed aging increased the sensitivity of barley to soil moisture stress. Our results also indicated that low soil moisture content (10% FC) prevented seedling emergence regardless the aging level. As aging increased, the ability of seeds to emerge under high moisture stress decreased.

Aging reduced field emergence at two locations, similar to that observed in the lab and the greenhouse experiments. Aging had a greater negative effect on field emergence in the drier location (JUST). This is due to the delay (for 30 days) in seedling emergence in the drier location until rainfall was received, which might cause more deterioration in the planted seeds. For 8-d aging treatment, field emergence was more negatively affected in the wetter location (Jomha). This was consistent with our results in the greenhouse, which showed that as aging increased, the ability of seeds to emerge under high soil moisture content decreased. These data suggest that use of high quality unaged seeds was essential to achieve adequate stand of barley under a wide range of condition in the semi-arid rainfed region of Jordan.

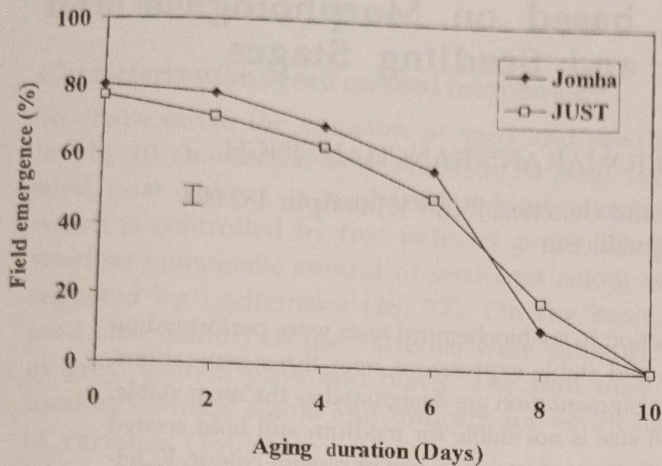


Fig. 4. Field emergence percentage at two locations (Jomha and JUST) in northern Jordan averaged over two barley cultivars. Vertical bar indicates LSD (0.05) for mean comparison

Aging reduced seedling emergence and this reduction increased under moisture stress. Aged seeds of barley had lower seedling emergence, emergence rate index, and seedling dry weight under all soil moisture conditions compared with unaged seeds. Unaged seeds were able to emerge under a wide range of soil moisture content (30 to 70% FC). Low soil moisture content (10% FC) prevented seedling emergence regardless of seed aging treatments, whereas, high soil moisture content (90% FC) only reduced seedling emergence of aged seeds. These data suggested that aging increased seed sensitivity to high moisture stress. Field emergence data showed that aged seeds had lower emergence than unaged seeds in both locations.

The data indicated that aging reduced seed quality and seedling emergence under a wide range of soil moisture conditions. The reduction in seedling emergence of aged barley was increased when the seeds were planted under soil moisture stress. Aged seeds should not be planted, where soil moisture stress is common at planting time.

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