
INTRODUCTION

Seed damage is quite a common phenomenon in nature and in agricultural practice. Under natural conditions, many seeds dispersed onto the ground after maturation are consumed or damaged by granivores, such as insects, birds, rodents, sheeps, and other animals [1]. Pathogens, runoff water, strong winds, fertilizers, and high pH values can also partially or entirely damage seeds [2]. In agricultural production, seeds frequently suffer from mechanical damage during threshing, transportation, storage, selection, sowing, etc. [3].

Seed dormancy is defined as the inabilities of a viable seed to germinate, or they poorly germinate under environmental conditions favorable for germination [4]. In particular, barley has developed seed dormancy characteristics that prevent germination after a late rain following seed maturation, before long, hot, and dry summers. This primary dormancy is also termed “after-ripening” [2]. Wild barley, Hordeum spontaneum, the progenitor of cultivated barley, H. vulgare, is distributed throughout the Near East Fertile Crescent from Turkey to Southwest Asia [5]. In Israel, ecotypes of H. spontaneum are abundant and occupy diverse habitats ranging from the mesic Mediterranean to the desert [2]. The significant differences were identified in caryopsis after-ripening [6]. The caryopses of H. spontaneum found in xeric Israel areas have developed the characteristics of deep dormancy [2, 7, 8]. The primary dormancy represents an important survival strategy during the life cycle of H. spontaneum in regulating the proper time for dormancy release. In terms of risk avoidance, the longer the period of dormancy breaking, the higher is the fitness of plants exposed to arid environmental condition, characterized by highly unpredictable amounts and distribution of rain [2].

BRIEF COMMUNICATIONS

Effects of Partial Endosperm Removal on Embryo Dormancy Breaking and Salt Tolerance of Hordeum spontaneum Seeds

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Abstract — Seed damage is a common phenomenon in nature and in agricultural production. In this experiment, partial endosperm removal from wild barley (Hordeum spontaneum) caryopses, sampled from three ecotypes originated from xeric environments in Israel, was conducted. The aim was to examine seed dormancy and germination states in damaged caryopses and salt tolerance of young seedlings derived from them. Six treatments were made: (1) control seeds with intact caryopses; (2–4) removal of 0.25, 0.5, and 0.75 of the length of intact caryopses; (5) transection at the points, at which the endosperm and embryo meet; and (6) slit of endosperm opposite the embryo. A significant negative correlation was found between germination percentage (dormancy release) and the relative distance from the dissection point to embryo. Partial removal of the endosperm could accelerate dormancy release. Seedling salt tolerance was assessed by the ratio of root or coleoptile length in a seedling grown in 100 or 200 mM NaCl solution to that of a seedling grown in water. The seedling salt tolerance was positively correlated with the removed portion of the seed endosperm. For each level of endosperm removal, the salt tolerance to 200 mM NaCl of the seedlings derived from the Dead Sea ecotype was higher than those from both the Sede Boker and the Mehola ecotypes. The results suggest that partial damage to seed endosperms in natural conditions may play a role in increasing the phenotypic plasticity of germination and salt tolerance.

Keywords: Hordeum spontaneum, seed damage, embryo dormancy, salt tolerance.

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Abbreviations: DBP—dormancy breaking percentage; R100/0 or C100/0—ratios of root (R) or coleoptile (C) length of seedlings grown in 100 mM NaCl solution to those grown in water; R200/0 or C200/0—the ratios of root or coleoptile length of seedlings grown in 200 mM NaCl solution to those grown in water.
The partial damage to dormant seeds, in some cases, can influence the dormancy breaking of the seeds. The complete removal of endosperms from embryos of dormant wild barley grains led to a dramatic increase in dormancy breaking [6]. Since caryopses of wild barley with the partially damaged seed coats and endosperms can usually accelerate dormancy breaking [6], the partial damage may be important for earlier release of dormancy. The possible effects of pericarp tissues on the dormancy breaking have been studied previously [2, 7, 9]. However, the relationship between dormancy breaking and seed tolerance to various environmental stresses is still unclear.

Barley is one of the most salt-tolerant cereal crops. Salt tolerance at the germination and seedling stage is important because the initial plant stand affects the final production [10]. Genetic variation for salt tolerance and dormancy in cultivated barley is limited, relative to its wild relatives [2, 11]. In the present study, the effects of seed damage on dormancy breaking as well as on seedling salt tolerance were examined in three genotypes of wild barley *H. spontaneum*.

**MATERIALS AND METHODS**

**Plant material.** Three ecotypes of *Hordeum spontaneum* from xeric environments in Israel were used, including Sede Boker (91 mm annual rainfall), Mehola (270 mm), and the Dead Sea (100 mm). The freshly harvested caryopses of all ecotypes exhibited deep dormancy [8].

**Seed propagation.** In November, the germinating seeds of the genotypes were sown in elevated beds of loess soil with compost and irrigation by a dripping system in the experimental station, Sede Boker Campus, Ben-Gurion University of the Negev, Israel. The fully mature spikes were harvested in May the following year, and the freshly harvested caryopses were stored separately in paper bags at 5°C.

**Caryopsis treatment.** After 11 months of storage at 5°C, a total of 1800 caryopses (3 ecotypes × 6 treatments × 4 replicates × 25 caryopses) were dehulled. Seed endosperms were treated by removing 0.25, 0.5, and 0.75 of the length of intact grains with a sharp knife. A parallel treatment on the naked grains cut off the endosperm at the point, at which the endosperm and embryo meet, i.e., a small part of endosperm still remained close to the embryo. Another treatment was to slit the endosperm just opposite the embryos (from the dorsal side), as shown in Fig. 1. In total, there were five endosperm removal patterns (Fig. 1). In order to estimate the remaining parts, grains were weighed before and after endosperm removal. Simultaneously, the relative distance from the dissection point to the embryo was measured. The length of intact grain was taken as 100%, and the embryo generally occupied 20% of the total length. The relative distance of the remained endosperm is shown in Fig. 1.

**Dormancy breaking.** All 1800 samples of dehulled grains imbibed in 2.5 mL of distilled water in 90-mm Petri dishes on a Whatman No. 1 filter paper at 15°C in darkness for 10 days. Dormancy release measured as germination percentage was checked on 2nd, 4th, and 10th days.

**Salt tolerance at the seedling stage.** Eight young seedlings (1–5 days after germination when the roots reached 1–3 mm) were ranked equidistantly on a piece of filter paper pre-moistened with 0, 100, and 200 mM NaCl solution, respectively. These seedlings were covered with another piece of filter paper and rolled up. The rolls were inserted into a clean 1.5-L Coca Cola bottles truncated at the middle, containing the appropriate solutions up to 3 cm all the time. The bottles were kept at 15°C in darkness for five days. For each treatment of every ecotype, 4 × 8 seedlings were