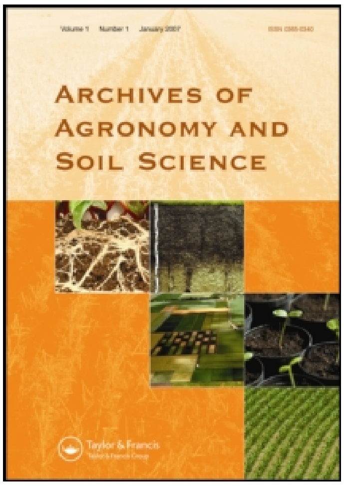


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# Effects of late-terminal drought stress on seed germination and vigor of barley (*Hordeum vulgare* L.)

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# Effects of late-terminal drought stress on seed germination and vigor of barley (*Hordeum vulgare* L.)

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Late-terminal drought stress during grain filling has recently become more common in the semi-arid Mediterranean region, where barley (*Hordeum vulgare* L.) is grown as an important winter cereal crop. Little information is available in the literature about the effect of late-terminal drought stress on seed germination and vigor of barley. The objective of this experiment was to study the effect of late-terminal drought stress on seed germination and vigor of barley as estimated by the germination after accelerated aging test. Drought stress reduced grain yield of barley. Grain yield was correlated positively with leaf gross photosynthetic rate and negatively with leaf osmotic potential. Late-drought stress had no effect on standard germination, but reduced the germination after the accelerated aging test. These data suggested that late-terminal drought stress had a greater effect on seed vigor than standard germination in barley.

**Keywords:** drought; barley; standard germination test; accelerated aging test; grain yield



## Introduction

Drought is becoming more common worldwide, causing devastating effects on crop production (Ludlow and Muchow 1990). Several reports have suggested that drought stress during seed development of barley reduced leaf photosynthetic rate (Samarah 2004; Masoud et al. 2005), decreased grain filling duration (Sanchez et al. 2002; Samarah 2004), enhanced plant maturity, resulting in a serious reduction in grain yield and yield components (Forster 2004; Samarah 2004). The most drought resistant among wild and cultivated barley were those with the uppermost leaves having a high photosynthetic rate in the terminal growth stage (Andrzej 2001). The closure of stomata (Lösch et al. 1992; Sanchez et al. 2002; Sayed 2003), the reduction in $CO_2$ diffusion (Earl 2003), and the decrease in chlorophyll content (Sairam et al. 1997; Chandrasekar et al. 2000) are known to decrease photosynthetic rate under severe drought stress.

In addition to its effects on the physiological processes in plants, drought stress during seed development can reduce seed germination and vigor. In barley, the unsuitable weather conditions in three out of seven years studies resulted in production of low seed vigor (ranged from 61–86%) as compared with the high seed vigor (exceeded 94%) of the seeds produced in the remaining four years

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(Chloupek et al. 2003). Yaklich (1984) reported that drought stress during seed filling period of soybean (*Glycine max*) did not affect bench seedling emergence, but reduced seed vigor as evaluated by the accelerated aging test. Drought stress during seed development also reduced seed quality of soybean (Dornbos et al. 1989; Smiciklas et al. 1992; Heatherly 1993). Drought stress is frequently confounded in the field and affects the accelerated-aging germination in soybean (Egli et al. 2005b). Samarah et al. (2009) reported that drought not only reduced the germination in the small seed size category, which consisted of shriveled, misshapen, and hard seeds, but also reduced the vigor (AA-germination) of the large seeds of soybean. Moreover, seed vigor was much more sensitive to high temperature than standard germination in both cultivars of soybean (Spears et al. 1997; Egli et al. 2005a, b). These findings are consistent with the concept that vigor declines before germination during seed deterioration (Byrd and Delouche 1971). Dry conditions at harvest may increase physical injury and reduce quality if seeds are handled at low moisture levels (TeKrony et al. 1987).

In the semi-arid Mediterranean region of Jordan, rainfall is distributed from mid-December to mid-March. In recent years, grain yield of barley grown in Jordan was severely reduced by the late-terminal drought stress. Seed quality of barley plants produced under such conditions needs to be assessed. Therefore, the objective of the present study was to examine the effect of late-terminal drought stress on seed germination and vigor of barley as estimated by the accelerated aging test.



## Materials and methods

A greenhouse experiment was conducted at Jordan University of Science and Technology (JUST) campus, Irbid, (32°34′ N, 36°01′ E) during the growing season of 2001/2002. Twelve seeds of six-row barley (*Hordeum vulgare* L. con. var. Rum) cultivar 'Rum' were planted in 6-l pots containing a mixture of soil:sand:peat in a volume ratio of 2:1:1. The field capacity of the soil mixture was determined by saturating the soil with water before planting. The weight of soil moisture at field capacity was calculated as the difference between the soil weight after drainage and the soil weight after oven drying at 105°C for 24 h. At the beginning of grain filling period (on 10 March 2002), two watering treatments were imposed on barley plants until grain harvest maturity: 1) 100% field capacity (well-watered), and 20% field capacity (severe stress). The pots were weighed twice daily to maintain them at the desired soil moisture content. At mid of grain filling period (at 15 days after imposing treatments) (on 25 March), leaf photosynthetic rate using a Plant Photosynthesis Meter (PPM-EARS, The Netherlands) and leaf osmotic potential using a Wescor-5500 Vapor pressure were recorded for the leaves from the upper part of the plants to document drought stress. Grain yield per plant and 1000-grain weight were measured by weighing the grains from the harvested plants.

### *Standard germination test (SG)*

Standard germination test was conducted according to International Seed Testing Association rules (ISTA 1985). Four replicates of 50 seeds [with same size and weight (averaged 52 g per 1000 grains)] (Table 1) were placed between folded germination papers, moistened with distilled water in plastic containers (17 × 11 × 7 cm) and incubated at 20°C for 14 days. Before incubation at 20°C, the seeds were prechilled

Table 1. Effects of watering treatments on grain yield, normal seedlings in standard germination test (SG) and accelerated aging test (AA).

| Treatments† | Grain yield (g plant$^{-1}$) | 1000-grain weight (g) | Seed quality tests (%) | |
|---|---|---|---|---|
| | | | SG | AA |
| Well-watered* | 16a | 53.0 a | 92a | 49a |
| Severe stress** | 7b | 50.5 a | 96a | 23b |

*Well-water treatment [soil maintained at 100% of field capacity (FC)]; **Severe stress plants were exposed to severe-drought stress (soil maintained at 20% FC); †Treatment means followed by the same letter indicate no significant difference according to the Least Significant Difference (LSD) test at probability level ($p \leq 0.05$).

at 5°C for five days to overcome seed physiological dormancy. Percentage of normal seedlings was recorded at the end of incubation period according to ISTA rules (1985).



### *Accelerated aging test (AA)*

Four replicates of 100 seeds were exposed to 100% relative humidity and 45°C for 48 h as described in Seed Vigor Testing Handbook (Association of Official Seed Analysts [AOSA] 1983). Seeds were then incubated as described in the standard germination test. Percentage of normal seedlings was recorded 14 d after seeding.

### *Experimental design and statistical analysis*

The experimental design was a randomized complete block design with four replications. Data were analyzed using the SAS Program (SAS 1996). Means were separated according to the Least Significantly Difference (LSD) at probability level ≤0.05.

## Results and discussion

Plants grown under the severe drought stress treatment produced less grain yield than those grown under well-watered treatment (Table 1). The decline in total grain yield under the drought stress treatment was due to the reduction in grain number per spike (Agueda 1999; Garcia 2003; Samarah 2004), spike number per square meter (Agueda 1999; Sanchez et al. 2002; Garcia 2003) and number of tillers per plant (Samarah 2004). Grain yield was positively correlated with leaf gross photosynthetic rate and negatively correlated with leaf osmotic potential (Figure 1a, 1b).

The effect of drought stress during grain filling period on seed quality varied within and among species. Several reports suggest that drought stress during seed development reduces seed quality (Dornbos et al. 1989; Smiciklas et al. 1992; Heatherly 1993). Low temperature (10°C) and drought stress (−0.2 MPa) reduced seed germination percentage in several years in barley (Chloupek et al. 2003). In soybean (*Glycine max*), Dornbos and Mullen (1985) showed that drought stress reduced standard seed germination in one of the two-year study and decreased seed vigor as estimated by the decrease in seedling axis dry weight and the increase in the

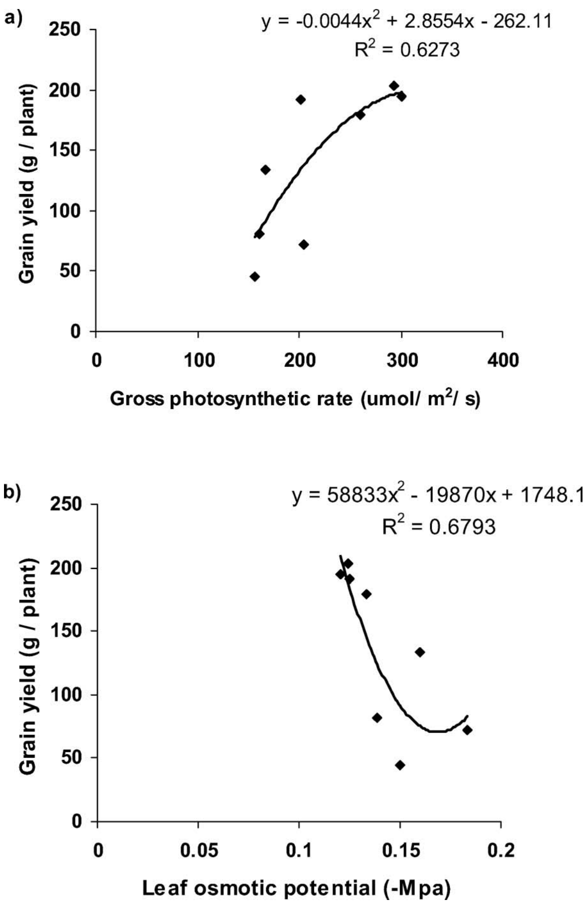


Figure 1. Relationship of gross photosynthetic rate and leaf osmotic potential with grain yield of barley exposed to late-terminal drought stress.

electrical conductivity of seed leachate. In contrast, Vieira et al. (1991) indicated that drought stress during seed filling period of soybean had no effect seed germination, but had little effect on seed vigor as measured by accelerated aging test, electrical conductivity test, and cold test. In four annual clovers (*Trifolium* spp.), Iannucci et al. (1996) found that drought stress during seed filling period had no effect on standard germination test, germination rate index, and accelerated aging test. Only seedling dry weight was significantly reduced in seeds exposed to drought stress during seed filling period. In peanut (*Arachis hypogaea*), seed germination was the lowest for seed produced under drought stress during development (Ketring 1991). In peas (*Pisum sativum*), drought stress during the entire reproductive period reduced the seed quality (cold germination and electrical conductivity) (Fougereux et al. 1997).

In the present study, late-terminal drought stress imposed on barley plant after beginning of seed filling period had no effect on standard germination, but significantly reduced seed vigor of barley as estimated by the germination after accelerated aging test (Table 1). These results were consistent with the findings of Samarah et al. (2009) on soybean, who found that drought stress did not affect the standard germination of large seeds compared with large seeds produced under well-watered treatment, but decreased the germination after accelerated aging test of the large seeds, indicating that drought stress was detrimental to the AA germination of the large seeds. The results in these experiments indicated the complexity of the effect of drought stress on seed quality and how this effect might vary with stress timing, maturity stage, stress severity, stress duration, and the interaction of other environmental conditions.

## Conclusion

In conclusion, late-terminal drought stress significantly reduced barley grain yield, gross photosynthetic rate, leaf osmotic potential, and seed vigor as estimated by the germination after accelerated aging test but had no effect on seed germination. Late-terminal drought stress had a greater effect on seed vigor than on standard germination in barley. Further work is needed to understand the factors related to the reduction in vigor (accelerated aging) germination of seed produced under drought stress.

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