SOME PHYSIOLOGICAL RESPONSES AND YIELD OF MAIZE AFFECTED BY SEED AGING AND PRIMING DURATION

ABSTRACT

Seeds of maize (cv. SC AR68) were divided into three sub-samples, one of which with a 100% germination was kept as high vigor seed lot (V₁). The other two samples were artificially aged at 40°C for 2 and 3 days, reducing normal germination to 98% (V₂) and 93% (V₃), respectively. Each of these samples was subsequently divided into four sub-samples, one of which was kept as unprimed and three other samples were hydro-primed at 15°C for 7, 14 and 21 h, and then their moisture content reduced to about 20% in a room at 20–22°C. The experiment was undertaken in 2016 as factorial based on randomized complete block design in three replicates. Seed aging and hydro-priming had no significant effects on leaf temperature, Fv/Fm, CCI and plant biomass due to regular irrigation. Seed aging reduced, but hydro-priming enhanced LAI, grain yield and harvest index of the resultant plants. Grain yield of plants from high vigor seed lot (V₁) was 23.5% and 64.5% greater than that of V₂ and V₃ plants. Seed hydro-priming for 21 h also increased grain yield of maize by about 32%. Therefore, hydro-priming for 21 h is the best pretreatment to improve field performance and yield of maize.

Key words: aging, grain yield, harvest index, hydro-priming, leaf area index, maize

INTRODUCTION

Maize grains may be consumed by humans or could be used as the main component of animal feed (Steduto et al., 2012). The area devoted to this plant and the yield per hectare have been increasing over time. The total production in 2014 was 1017 million tons in the world (FAO, 2016). Field performance of maize may be influenced by many internal and external factors. One of the most important internal factors which may affect field emergence and yield of maize is seed vigor (Ghassemi-Golezani et al., 2011).

Seed vigor is defined as, the sum of those properties that determine the activity and performance of seed lots of acceptable germination in a wide range of

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environments (ISTA, 2010). Aging and deterioration could reduce seed vigor at later harvests and during storage (Ghassemi-Golezani et al., 2014). The rate of seed deterioration, due to aging, is positively related to the ambient temperature, relative humidity and seed moisture content (Ellis et al., 1981). The oxidative damages are responsible for the deteriorative changes observed in aged seeds (Ghassemi-Golezani et al., 2010b). Free radical oxidations, enzymic dehydrogenation and oxidation of aldehydes of protein molecules might contribute to the progress of seed deterioration (Kapilan and Thiagarajah, 2015).

Seed deterioration is inexorable, and the best that can be done is to control its rate. In general, deteriorated parts of seeds might be repaired by priming (McDonald, 1999; Ghassemi-Golezani and Hossainzadeh-Mahootchi, 2013). Seed priming induces a range of biochemical changes in the seed that are required to start the germination process (Asgedom and Becker, 2001). Priming allows seed hydration to initiate the early events of germination, but not permit radicle emergence, followed by drying to initial moisture (McDonald, 2000; Ashraf and Foolad, 2005). One of the simple techniques for on-farm priming is hydro-priming. The beneficial effects of hydro-priming have been reported for many field crops such as sugar beet (Sadeghian and Yavari, 2004), lentil (Ghassemi-Golezani et al., 2008), sorghum (Moradi and Younesi, 2009), chickpea (Ghassemi-Golezani and Hossainzadeh-Mahootchi, 2013) and milk thistle (Yaghoubian et al., 2016).

Poor stand establishment of maize plants from low vigor seeds was led to deductions in leaf area index (LAI), dry matter accumulation (DMA), crop growth rate (CGR) and consequently grain yield per unit area (Ghassemi-Golezani and Dalil, 2014). Priming appears to reverse the detrimental effects of seed aging (McDonald, 2000). The early improvements may increase the rate and uniformity of seed germination and seedling emergence (Farooq et al., 2005; Ghassemi-Golezani et al., 2010a). It was reported that hydro-priming can improve relative water content, membrane stability, chlorophyll content and grain yield of chickpea plants from differentially deteriorated seed lots via invigoration of the seeds (Hossainzadeh-Mahootchi and Ghassemi-Golezani, 2013).

However, responses of maize seed lots with different levels of seed aging to priming were not evaluated. Thus, this research was aimed to assess the effects of hydro-priming duration on some physiological traits and grain yield of different seed lots of maize.

**MATERIALS AND METHODS**

**Seed treatments**

Seeds of maize (cv. SC AR68) were obtained from the Dryland Agricultural Research Institute of Moghan, Iran, and divided into three sub-samples. A sub-sample, with a tested germination of 100%, was kept as control (V₁). The other two sub-samples, with a final moisture content (MC) of about 20%, were artificially aged at 40°C for 2 and 3 days, reducing normal germination to 98% and
93% ($V_2$ and $V_3$), respectively. Consequently, three seed lots with different levels of vigor were provided. Each seed lot was divided into four sub-samples, one of which kept as a control (unprimed, $P_1$) and the other three soaked in distilled water at 15°C for 7 ($P_2$), 14 ($P_3$) and 21 ($P_4$) h, and then dried back to initial MC at a room temperature of 20–22°C for 24 h.

**Experimental design**

The field experiment was conducted in 2016 at the Research Farm of the University of Tabriz, Iran (latitude 38°05'N, longitude 46°17'E, altitude 1360 m above sea level). The experiment was arranged as factorial laid out in a RCB design with three replications. Seeds were treated with Benomyl at a rate of 2 g × kg$^{-1}$ before sowing and sown on plots at a depth of about 4 cm in May 2016. Weeds were controlled by hand during crop growth and development.

**Leaf temperature**

Leaf temperature (°C) of upper, middle and lower leaves of a plant in each plot was measured by an infrared thermometer (TES-1327) at tasseling stage (VT) and then the mean value for each plot was calculated.

**Efficiency of photosystem II ($F_v/F_m$)**

The efficiency of photosystem II ($F_v/F_m$) was measured in leaves by a chlorophyll fluorometer (OS-30, OPTISCIENCES, USA) at flowering stage, just before irrigation of each plot. Fluorescence emission was monitored from the upper surface of the leaves. Dark-adapted leaves (30 min.) of a plant in each pot were initially exposed to the weak modulate measuring beam, and then exposed to saturated white light and initial ($F_0$) and maximum ($F_m$) fluorescence values were recorded. Variable fluorescence ($F_v$) was calculated as:

$$F_v = F_m - F_0$$

**Chlorophyll content index (CCI)**

Leaf chlorophyll content index (CCI) was measured using a portable chlorophyll meter (CCM-200, Opti-Sciences, USA). Three plants were marked in each plot and the CCI of the upper, middle and lower leaves of each plant was measured at the flowering stage. Subsequently, the mean CCI for each treatment and replicate was calculated.

**Leaf area index (LAI)**

Two plants were randomly selected from the central rows of each plot and then all of the leaves were counted and detached from the shoots. Leaf area was measured by a leaf area meter (LI-COR, Model Li-3100C Area Meter, USA). The leaf area index was calculated as:
where $\text{LAI} = \frac{L_A}{G_A}$

**Grain yield**

At maturity, the plants in 1 m$^2$ of each plot were harvested and grains were detached from the ear. These plants were then dried in an oven at 75°C for 48 h and weighed. Finally, plant biomass, grain yield per unit area and harvest index were determined for each plot.

**Statistical analysis**

All the data were analyzed on the basis of the experimental design, using MSTATC and SPSS. The means of each trait were compared according to Duncan multiple range test at $P \leq 0.05$. Excel software was used to draw figures.

**RESULTS AND DISCUSSION**

Analyses of the data showed that seed aging had significant effects on leaf area index (LAI), grain yield and harvest index. Leaf area index and harvest index were significantly affected by hydro-priming. The interaction of aging $\times$ hydro-priming was also significant for leaf area index and harvest index (Table 1).

| S.V. | DF | Leaf temperature | Fv/Fm | CCI | LAI | Plant biomass | Grain yield | Harvest index |
|------|----|------------------|-------|-----|-----|---------------|-------------|---------------|
| Error | 22 | 0.71             | 0.001 | 68.94 | 0.095 | 181622.42 | 89274.55 | 51.27 |
| Priming (P) | 3 | 1.25** | 0.00028** | 1.97** | 0.475** | 3921.79 | 141997.88 | 210.57* |
| Aging (A) | 2 | 0.40* | 0.00122** | 63.89* | 2.101** | 405073.58** | 804540.33** | 377.62** |
| Replication | 2 | 3.34* | 0.00262** | 12.90* | 0.618** | 1054661.10** | 218673.15** | 15.43** |

Table 1

Analysis of variance of the effects of seed aging and hydro-priming duration on leaf temperature, Fv/Fm, CCI, LAI, plant biomass, grain yield and harvest index of maize

Since plots were irrigated regularly, no significant changes in leaf temperature, Fv/Fm, CCI and plant biomass due to seed aging and priming were not observed (Table 1). Nevertheless, mean plant biomass of plants from high vigor seed lot ($V_1$) was 13.3% and 20.4% more than the plants from $V_2$ and $V_3$ seed lots, respectively (the data are not shown). Seed aging was generally led to reductions in LAI of plants from primed and unprimed seeds. Hydro-priming of all seed lots enhanced LAI of the resultant plants.
However, LAI of the plants from different seed lots was best improved by hydro-priming for 21 h (P₄). This improvement was the highest for the non-aged seed lot (V₁) (Fig. 1). Reductions in LAI of plants from aged seed lots was the consequence of delayed and less emergence of seedlings in the field, compared with high vigor seed lot (Chadordooz-Jeddi et al., 2015). Soltani et al. (2009) also found that leaf area of wheat plants reduced as a result of seed aging. Less leaf area means less photosynthesis which can potentially reduce final yield (Ghassemi-Golezani and Dalil, 2014). The advantage of seed priming in improving LAI was closely related with rapid seedling emergence and optimal stand establishment. Optimum stand establishment and early achievement of maximum LAI are essential for the efficient use of resources (Mohammadi, 2009).

Grain yield of maize decreased with enhancing seed aging, although there was no significant difference between V₁ and V₂ plants. Grain yield of plants from high vigor seed lot (V₁) was 23.5% and 64.5% greater than that of V₂ and V₃ plants, respectively (Fig. 2). This superiority was directly related with high leaf area index of plants from vigorous seed lot (Fig. 1). Ghassemi-Golezani et al. (2010b) reported that low grain yield of lentil plants from aged seed lots was associated with slow emergence of seedlings, poor stand establishment and delayed flowering of these plants. With increasing aging LAI of plants decreases which may result in reducing in mean grain number and weigh and consequently grain yield per unit area (Ghassemi-Golezani and Dalil, 2014).

Seed hydro-priming for 21 h increased grain yield of maize by about 32%, although this increment was not statistically significant (Table 1). The increased grain yield of plants from primed seeds, particularly those from hydro-primed seeds, can be attributed to improvements in leaf area index of these plants (Fig. 1). This ad-
Vantage in grain yield most likely was achieved by rapid seedling emergence and optimal stand establishment of plants from primed seeds. The early emergence of seedlings from primed seeds leads to more efficient use of light and soil resources during growth and development of plants (Ghassemi-Golezani et al., 2012).

Fig. 2. Mean grain yield for seed aging V₁, V₂, V₃: control and aging for 2 and 3 days at 40 °C, respectively.

Fig. 3. Mean harvest index for interaction of seed aging × priming; V₁, V₂, V₃: control and aging for 2 and 3 days at 40 °C, respectively; P₁, P₂, P₃, P₄: unprimed and hydro-primed seeds for 7, 14 and 21 h, respectively.
Harvest index of maize was generally decreased by enhancing seed aging. However, seed hydro-priming, particularly for 21 h, considerably enhanced harvest index of plants from all seed lots (Fig. 3). These results are compatible with plant biomass and grain yield of plants from differentially treated seeds. This means that seed aging reduced grain yield more than plant biomass, but priming enhanced grain yield more than plant biomass.

CONCLUSION

Seed aging was generally led to reductions in LAI, grain yield and harvest index of plants from primed and unprimed seeds. However, these field traits for all seed lots were enhanced by hydro-priming, especially for 21 h. Grain yield of plants from aged seed lots was considerably less than plants from non-aged seed lot. Seed hydro-priming for 21 hours improved grain yield by about 32%. This suggests that hydro-priming for 21 h is the best pretreatment for enhancing field performance and yield potential of differentially aged maize seed lots.

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