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# Influence of Hydro-Priming on Oil and Protein Production of Plants from Differentially Deteriorated Seeds of Maize

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## ABSTRACT

A seed lot of maize (cv. SC AR68) with about 20% moisture content was divided into three sub-samples. A sub-sample with a 100% normal germination was not artificially aged (A1), but two other sub-samples were deteriorated at 40 °C for 2 and 3 d, reducing normal germination to 98% and 93% (A2 and A3), respectively. Each of these seed samples was then divided into four sub-samples, one of which was not primed and the other three samples were hydro-primed at 15 °C for 7, 14 and 21 hours, and then gradually dried back to initial moisture content in normal air. The field experiment was laid out as factorial, based on randomized complete block design with three replications. Effects of seed deterioration and hydro-priming on 1000 grain weight were not significant, but plants per unit area, number of grains for plant and grain yield per unit area were decreased with increasing seed deterioration. Seed hydro-priming for 21 hours enhanced grains per plant by about 22% and grain yield by about 32%, although these improvements were not statistically significant. Deterioration of seeds reduced, but hydro-priming enhanced oil and protein yields per unit area of the resultant plants, which related with the variation in grain yield, since no effect of these factors on oil and protein percentages were observed. Hydro-priming for 21 hours was the best treatment for improving yield parameters of maize in the field.
**KEYWORDS**: Grain yield, hydro-priming, maize, oil, protein, seed deterioration

## INTRODUCTION

The importance of maize with the highest grain production in the world [1] was related to the nutritional quality of the grain, especially protein and oil contents [2]. Maize grains contain 4-5 % oil, 8-10 % protein and 70-75 % starch [3]. The maize proteins could be classified on the basis of their solubility. The highest protein in maize grains is α-zein with 50-60 % of the total protein. Nevertheless, the protein content of grains may vary in different genotypes [4].

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 [5]. Evidently seed vigor has a considerable effect on plant establishment [6]. Seed vigor considerably influences rate and percentage of germination and seedling emergence in a wide range of environmental conditions [7]. Genetic structure, environment and plant nutrition, stage of maturity at harvest, seed reserves, seed aging, mechanical damages and pathogens are the most important factors influencing seed vigor [8]. It was stated that seed aging has significant effects on seed vigor [9, 8]. Temperature, relative humidity of the environment and seed moisture content are the most important factors affecting seed vigor during storage. Seed deterioration is a physiological phenomenon that enhances at high temperature and humidity of storage environment. This gradually leads to degradation of DNA and ribosomal RNA [10], increment of respiration and penetrability of cell membranes that all together decrease seed germinability, seedlings vigor and yield [11, 12]. It was shown that seed deterioration causes low field emergence and yield loss in rapeseed [13], lentil [14] and maize [15].

Seed deterioration may be somehow repaired by priming techniques such as hydro-priming [16]. Seed priming could increase synthesis of proteins and repairs nucleic acids and membranes [17 The activities of anti-oxidative enzymes may be also enhanced by priming of seeds [10, 5]. The harmful effects of seed deterioration on field performance of plants may be alleviated by hydro-priming [16], through enhancing seedling vigor [18] and seedling emergence [19]. Some of the beneficial effects of hydro-priming on field performance of plants from deteriorated seeds was reported for chickpea [20]. However, the effects of hydro-priming duration on deteriorated and non-deteriorated seed lots of maize with acceptable normal germination were not documented. Thus, this research was undertaken to evaluate the influence of hydro-priming duration on grain production and oil and protein contents of the plants from differentially deteriorated seed lots of maize.

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## MATERIALS AND METHODS

***Seed treatments***

Seeds of maize (cv. SC AR68) were obtained from the Dryland Agricultural Research Institute of Moghan, Iran. The moisture content of seeds was about 13.5%, which was augmented to about 20% in the laboratory [21]. These seeds were divided into three sub-samples, one of which with a 100% normal germination was not artificially deteriorated ($A_1$). Two other sub-samples were artificially deteriorated at 40 °C for 2 and 3 d, reducing normal germination to 98% and 93% ($A_2$ and $A_3$), respectively. Each seed sample was then divided into four sub-samples, one of which was not primed ($P_1$) and the other three samples were hydro-primed at 15 °C for 7 ($P_2$), 14 ($P_3$) and 21 ($P_4$) hours, and then gradually dried back to initial moisture content in normal air at 20–22 °C.

***Experimental design***

The field experiment was undertaken in a sandy-loam soil at the Research Farm of the University of Tabriz, Iran (38°5'N, 46°17'E). The altitude of this area is 1360 m with the mean annual rainfall of 285 mm. The experiment was laid out as factorial based on randomized complete block design (RCBD) with three replicates. Each plot consisted of 6 sowing rows of 3 m long with 50 cm distance from each other. The maize seeds were treated with 2 g kg-1 Benomyl and then were sown in 4 cm depth and 20 cm apart on mid-May 2016. Hand weeding of the plots was carried out during crop growth and development.

***Grain, oil and protein yields***

Plants in 1 $m^2$ of each plot were harvested at maturity, and then plants per unit area, grains per plant, 1000 grain weight and grain yield per unit area were determined. Percentages of oil and protein for each sample were separately measured by a seed analyzer (model: Zeltex ZX-50) and thereafter, oil and protein yields per unit area were calculated.

***Statistical analysis***

The MSTATC and SPSS-20 were used for analyzing the data, and Duncan multiple range test was applied to compare the means of each trait at $P \leq 0.05$. The Excel software was used to draw figures.

## RESULTS

***Analysis of variance***

Seed deterioration had significant effects on plants per unit area, grains per plant and grain yield, but had no significant effect on 1000 grain weight. The effect of seed deterioration on 1000 grain weight and the effect of seed priming and also interaction of these two factors for plants per unit area, grains per plant, 1000 grain weight and grain yield per unit area were not significant (Table 1).

***Plant establishment and grain yield***

Plants per unit area was decreased with increasing seed deterioration. The highest plants per unit area was obtained for the $A_1$ seed lot, with no significant difference with $A_2$ seed lot. Number of grains for plants from $A_3$ seeds was significantly lower than those from $A_1$ and $A_2$ seeds. However, no significant difference between $A_1$ and $A_2$ plants was observed. The highest grain yield per unit area was recorded for $A_1$ plants, that was statistically similar with $A_2$ plants. The lowest grain yield was produced by plants from the most deteriorated seed lot ($A_1$). Seed hydro-priming for 21 hours enhanced grains per plant by about 22% and grain yield by about 32%, although these improvements were not statistically significant (Table 2).

***Oil and protein contents***

Seed deterioration was not significantly influenced oil and protein percentages, but it had significant effects on oil and protein yields. The effects of hydro-priming and deterioration × hydro-priming on oil and protein percentages and yields were not significant. (Table 3). Oil and protein yields per unit area were significantly reduced in plants from deteriorated seed lots. The highest oil and protein yields were produced by plants from $A_1$ seed lot and decreased with increasing seed deterioration (Figs. 1 A, B). Seed hydro-priming for 21 hours enhanced oil yield by about 22% and protein yield by about 37%, although these improvements were not statistically significant.

**Table 1**. Analysis of variance of the effects of seed deterioration and hydro-priming duration on field performance of maize.

| S.V. | df | MS | | | |
|---|---|---|---|---|---|
| | | Plant per unit area | Grains per plant | 1000 grain weight | Grain yield |
| Replication | 2 | 5.53* | 31482.26ns | 304.64ns | 218673.15ns |
| Deterioration (D) | 2 | 6.78* | 120497.98* | 440.58ns | 804540.33** |
| Hydro-priming (Hp) | 3 | 0.41ns | 36627.49ns | 295.76ns | 141997.88ns |
| D × HP | 6 | 0.74ns | 74285.31ns | 2500.94ns | 151539.75ns |
| Error | 22 | 1.74 | 34495.29 | 988.67 | 89274.53 |
| CV% | - | 24.48 | 29.29 | 12.07 | 14.25 |

ns, *, **: No significant and significant at $p \leq 0.05$ and $p \leq 0.01$, respectively.

**Table 2**. Means of plants per unit area, grains per plant and grain yield of maize affected by seed deterioration and hydro-priming duration

| Treatments | Plants per uni area | Grains per plant | 1000 grain weight (g) | Grain yield (g/m$^2$) |
|---|---|---|---|---|
| **Deterioration** | | | | |
| $A_1$ | 6.16a | 811.23a | 268.80a | 1320.80a |
| $A_2$ | 5.33ab | 810.37a | 260.07a | 1069.20a |
| $A_3$ | 4.66b | 641.38b | 272.05a | 802.521b |
| **Hydro-priming** | | | | |
| $P_1$ | 5.11a | 702.30a | 262.72a | 930.69a |
| $P_2$ | 5.33a | 742.621a | 263.92a | 1066.26a |
| $P_3$ | 5.55a | 728.62a | 261.34a | 1027.16a |
| $P_4$ | 5.55a | 844.23a | 265.98a | 1231.93a |

Different letters in each column indicate significant difference at $p \leq 0.05$.
$A_1$, $A_2$, $A_3$: Non-deteriorated and deteriorated seeds for 2 and 3 days at 40 °C, respectively.
P1, P2, P3, P4: Unprimed and hydro-primed seeds for 7, 14 and 21 hours, respectively

**Table 3.** Analysis of variance of the effects of seed deterioration and hydro-priming duration on oil and protein contents of maize

| S.V. | df | MS | | | |
|---|---|---|---|---|---|
| | | Oil (%) | Oil yield | Protein (%) | Protein yield |
| Replication | 2 | 3.035* | 1119.67* | 0.034ns | 2000.34ns |
| Deterioration (D) | 2 | 0.734ns | 2851.61** | 0.830ns | 8313.72** |
| Hydro-priming (Hp) | 3 | 1.085ns | 315.7ns | 0.670ns | 1715.90ns |
| D × Hp | 6 | 0.580ns | 566.68ns | 0.670ns | 1259.17ns |
| Error | 22 | 0.635 | 305.32 | 0.868 | 909.17 |
| CV% | - | 15.04 | 30.93 | 13.73 | 28.85 |

ns, *, **: No significant and significant at $p \leq 0.05$ and $p \leq 0.01$, respectively.

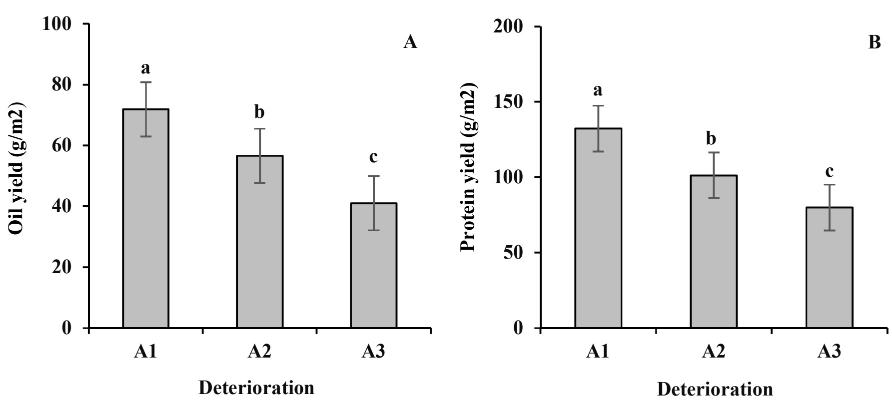


**Fig. 1**. Means of oil (A) and protein (B) yields affected by seed deterioration
$A_1$, $A_2$, $A_3$: Non-deteriorated and deteriorated seeds for 2 and 3 days at 40 °C, respectively.

## DISCUSSION

Reduction in grain yield per unit area of maize due to seed deterioration was the consequence of diminishing plant establishment and grains per plant (Table 2). Cultivation of low vigor seeds causes a decrease in emergence rate and plant population density [20]. These are may be resulted from disruption in RNA transcription and protein synthesis [22], membrane damage [23] and solute leakage [24] as a consequence of seed deterioration. Further deterioration could considerably reduce seed vigor and field establishment [5]. Since grain yield per unit area strongly related with plant density [25], poor stand establishment due to cultivation of low vigor seeds can potentially reduce crop yield. Sub-optimal plant density resulted from seed deterioration also reduced grains per plant and grain yield in pinto bean [26].

Hydro-priming enhanced grain yield through increasing grains per plant (Table 2) as a result of rapid seedling emergence [27]. Hydro-priming improved seedling emergence rate due to enhanced supply of soluble carbohydrates to the growing embryo, which was caused by an increase in α-amylase activity [28]. The high rate and uniformity of seedling emergence are essential for improving crop yield and quality [29]. The seedlings that emerge earlier could be vigorous [30] and capable of producing high yield under different environmental conditions [31]. Rapid and uniform emergence of seedlings due to seed priming enable the plants to use available resources efficiently, leading to increase grain yield per unit area [20].

Deterioration of seeds reduced oil and protein yields per unit area of the resultant plants (Figs. 1 A, B), mainly due to large reduction in grain yield per unit area (Table 2). Improving oil and protein yields by hydro-priming for 21 hours were also related with the increment of grain yield. Therefore, differences in oil and protein yields of the plants from deteriorated and hydro-primed seeds could be attributed to variation in grain yield, since no effect of these factors on oil and protein percentages were observed (Table 3). Similarity in protein and oil percentages among the plants from differentially treated seeds could be caused by various combinations of rate and duration of component accumulation [32]. Nevertheless, oil and protein percentages of maize grains could be influenced by the factors such as genotype and environmental conditions [33], but not by cultivated seed vigor as shown in this research (Table 3).

## CONCLUSION

Seed deterioration reduced field establishment and grains per plant, leading to a considerable loss of grain yield in maize. Hydro-priming improved grain yield per unit area through increasing grains per plant. Neither seed deterioration, nor hydro-priming had significant effects on oil and protein percentages of grains from the resultant plants. However, oil and protein yields of plants from deteriorated seeds decreased, while those from hydro-primed seeds increased. These variations in oil and protein yields were directly associated with grain yield. Hydro-priming for 21 hours was the best pretreatment for improving grain, oil and protein yields of maize plants from differentially deteriorated seeds.

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