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ORIGINAL ARTICLE

Response of Yield and Yield Components of Safflower to hydro-priming durations and Water stress

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ABSTRACT
A field experiment was conducted in 2014, to evaluate the effects of hydro-priming durations (P_0, P_1, P_2: 0, 8 and 16 hours, respectively) on yield and yield components of safflower (Carthamus tinctorius L.) under different irrigation treatments (I_1, I_2, I_3, I_4: Irrigation after 60, 90, 120 and 150 mm evaporation from class A pan, respectively). Irrigation treatments and hydro-priming durations were allocated to the main and sub-plots, respectively. The results indicated that grain number per plant, 1000 grains weight, biological yield, grain yield and harvest index decreased with decreasing water availability. Means of all these traits for plants from primed seeds were higher than those for plants from un-primed seeds. Number of plants per m^2 was significantly affected by seed priming and priming increased this trait. Result showed optimal time of hydro-priming for safflower seeds is about 16 hours, which can be successfully applied to enhance grain yield of safflower in the field.
Key words: *field, hydro-priming, safflower, water stress, yield*

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INTRODUCTION

The safflower plant (*Carthamus tinctorius*L.) is a member of the Compositae family, tolerant to severe drought and an important alternative oil sources [7].Generally that is produced on marginal lands that are relatively dry and relatively deprived the benefit of fertilizer inputs or irrigation. Among the different environmental stresses, drought is the constraint that induces a highly negative effect on crop production. Marita and Muldoon [14], reported that flowering phase in safflower is the most sensitive stage to drought stress. Drought is known as a major abiotic factor that limits plant growth and production in arid and semi-arid regions more than other environmental stresses [20].Since plant growth is the result of cell division and enlargement, water stress directly reduces growth by decreasing CO_2 assimilation, cell division and elongation. There are a number of modifications in plant structures and processes as a consequence of drought stress including stomatal closure, osmotic adjustment, smaller cell volume, reduced leaf area, increased leaf thickness, hairy leaves, and increased root/shoot ratio, as well as several changes in enzyme and hormone syntheses and activity[18].

There is a seed technology which is called seed priming with many advantages including help in improving speed of seed germination and early seedling establishment [13].This technology can increase the range of seed germination and emergence under stress conditions such as drought [16],salinity [2],low and high temperatures [4, 5]. Seed priming is a treatment which is carried out before seed germination and a controlled amount of water is absorbed by the seed during this treatment [15].The main objective in seed priming is partial irrigation of seeds so that seeds pass the first (physical water absorption) and second (initiating biochemical and processes and sugar hydrolysis) stages of germination, while the third (sugars consumption by the embryo and seed growth) stage is avoided [6].One of the most practical and cheapest methods of seed priming is on-farm seed priming using tap water [12].The objectives of this study were to evaluate the effects of hydro-priming durations on the yield and yield components of safflower under water deficit.

MATERIALS AND METHODS

A field experiment was conducted in 2014 at the farm of the Hashtrood, East Azerbaijan, Iran (Latitude 37◦ 28′ N, Longitude 46◦ 52′ E, Altitude 1643 m above sea level) to evaluate the effects of hydro-priming durations on yield and yield components of safflower (*Carthamus tinctorius* L.) under water stress. The climate is characterized by mean annual precipitation of 304.05 mm per year and mean annual temperature of 10°C. The experiment was arranged as split plot on the basis of RCB design with three replications. The factors were four levels of irrigation (Irrigation after 60 (I_1), 90 (I_2), 120 (I_3) and 150 (I_4) mm evaporation from class A pan) and hydro-priming durations (0 (P_0), 8 (P_1) and 16 (P_2) hours) which were allocated to main and sub plots, respectively.

Each plot had 6 rows of 3 m length, spaced 25 cm apart. Before sowing, seeds were divided into three sub-samples, one of which was kept as control (non-primed, P_0) and two other samples were soaked in distilled water at 20°C for 8 (P_1) and 16 (P_2) hours and then dried back to initial moisture content at room temperature of 22± 2°C. Seeds were treated with Benomyl at a rate of 2 g/kg before sowing. The seeds were then sown by hand on 1 May 2014 in 4 cm depth of a sandy loam soil. All plots were irrigated immediately after sowing, but subsequent irrigations were carried out according to the treatments. Weeds were controlled by hand during crop growth and development as required.

Plants per unit area were counted and plant establishment was determined. At maturity, plants of 1m^2 in the middle part of each plot were harvested and grain number per plan, 1000 grains weight, plant biomass, grain yield per unit area as well as harvest index were determined. Analysis of variance appropriate to the experimental design was conducted, using GenStat 12software. 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 variance of the data indicated that number of plants per m^2 was significantly affected by seed priming, but not by water supply. Grain number per plant,1000 grains weight, biological yield, grain yield and harvest index were significantly affected by irrigation treatments and hydro-priming durations. The interaction of irrigation × hydro-priming for this traits were not significant (Table 1).

Table1. Analysis of variance of the yield and yield components of safflower affected by hydro-priming durations and water stress

Source of Variation	Df	Mean Square					
		Number of plant per m^2	Grain number per plant	1000 grains weight	Biological yield	Grain yield	Harvest index
Replication	2	1.750	2.38	4.40	54249	588.3	1.253
Irrigation (I)	3	1.926^{ns}	2620.23**	279.29**	701119**	39235.7**	15.306**
Error	6	4.231	16.24	9.34	66466	1193.0	0.7612
Hydro-priming (P)	2	93.083**	294.78**	483.38**	1070963**	49345.7**	14.262**
I × P	6	1.457^{ns}	37.53^{ns}	15.91^{ns}	11575^{ns}	337.8^{ns}	1.3789^{ns}
Error	16	3.153	30.30	12.67	54351	800.8	0.3724
CV (%)	-	4.0	4.1	6.9	12.5	9.1	5.2

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

Irrigation had no effect on plant number, because supplementary irrigations were applied after plant establishment at reproductive stages (Table 1). Hydro-priming enhanced number of plant per m^2 by 9.33% (P_1) and 13.19 % (P_2), compared with control (P_0) (Figure 1).This result suggests that hydro-priming for 16 hours is the best duration for seed invigoration and seedling emergence of safflower. The efficiency of seed hydro-priming for better seedling emergence is also reported in barley [1]and lentil [9]. Mean grains per plant under I_2, I_3 and I_4 treatments were 4.48, 12.72 and 26.05% less than that under I_1, respectively (Table 2). Ghassemi-Golezani *et al.*[8]reported that reduction in grains per plant in safflower as water stress associated with deduction in number of capitols per plant rather than with number of grains per capitol. Hydro-priming caused the highest grain number per plant. However, the differences among P_1 and P_2 plants were not statistically significant (Table 2).Shabbir *et al.* [23]found that different priming techniques improve number of grains per plant in fennel.

Increasing water limitation led to 2.41-22.07 % reduction in 1000 grains weight, compared with well watering (I_1).However, there was no significant difference between I_1 and I_2 and also between I_2 and I_3 treatments. Plants from P_1 and P_2 seeds produced largest grains and highest 1000 grains weight in compared with P_0,However, P_3 had no significant difference with P_2 (Table 2).Severe water stress levels significantly shortened the duration of grain filling.Decrease of assimilate supply during grain filling stage may cause the limitation of seed storage capacity and decrease grain weight [3].Water shortages, especially during grain filling, cause reductions in photosynthesis and remobilization of stored materials and hence, grain filling duration [21].Increasing in 1000 grains weight with hydro-priming may be due to enhanced endosperm cells division and cytokinin activities resulting in improved grain filling rate. Pre-sowing treatment reduces accumulation of abscisic acid (ABA) and accelerates the grain filling rate [22].

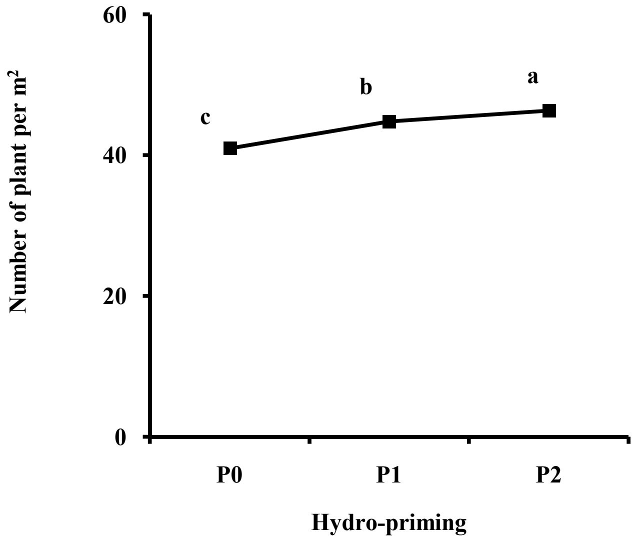

Figure 1. Changes in number of plant per m^2 of safflower in response to hydro-priming durations
P_0, P_1 and P_2: non-primed and hydro-primed seeds for 8 and 16 h, respectively.

Table 2. Means of the yield and yield components of safflower affected by hydro-priming durations and water stress

Treatments	Grain number per plant	1000 grains weight (g)	Biological yield (g/m^2)	Grain yield (g/m^2)	Harvest Index (%)
Irrigation					
I_1	149.3^a	56.36^a	2121^a	372.7^a	17.65^a
I_2	142.6^b	55.00^{ab}	2039^a	346.0^a	16.93^{ab}
I_3	130.3^c	51.86^b	1828^a	296.8^b	16.16^b
I_4	110.4^d	43.92^c	1495^b	222.4^c	14.61^c
Hydro-priming					
P_0	127.9^b	44.65^b	1532^b	238.9^c	15.30^c
P_1	133.9^a	53.93^a	1988^a	325.3^b	16.24^b
P_2	127.9^a	56.79^a	2093^a	364.2^a	17.47^a

Different letters in each column indicate significant difference at $p \leq 0.05$.
I_1, I_2, I_3, I_4: irrigation after 60, 90, 120 and 150 mm evaporation from class A pan, respectively
P_0, P_1 and P_2: non-primed and hydro-primed seeds for 8 and 16 h, respectively.

Biological yield was reduced by decreasing water availability. However, biomass production under I_1, I_2 and I_3 were statistically similar. This trait for P_2 treatment was higher than that for P_0 and P_1 treatments, but P_2 had no significant difference with P_1 (Table 2). Drought stress decreases water potential of plant at later stages of growth, leading to stomata closure and reduction in photosynthesis rate and leaf growth[17],which ultimately decreases plant biomass. Hydro-priming enhanced seedling establishment of upland rice, maize and chickpea, resulting in faster development, earlier flowering and maturity and higher yields[11].

The highest and the lowest grain yields per unit area were obtained by well watering (I_1) and severe water deficit (I_4),respectively. However, there was no significant difference between I_1 and I_2 treatments.

Grain yield per unit area was improved with hydro-priming. The highest grain yield was recorded for P_2 (Table 2). Water deficit affects every aspect of plant growth and modifying the anatomy, morphology, physiology, biochemistry and finally the productivity of crop [10].Since there is a strong relationship between plant density and yield [19],the superiority of plants from hydro-primed seeds in grain yield per unit area resulted from higher plant per m^2 (Figure 1) and production of more grains per plant, 1000 grains weight and biological yield (Table 2) compared with those from un-primed seeds.
Harvest index decreased as water stress increased and the lowest of this was for severe water deficit (I_4) treatment. Decreasing harvest index with increasing water stress could be mainly related with larger reduction in grain yield per unit area. Hydro-priming especially priming for 16 hours increased this trait with increasing grain yield too (Table 2). Grain yield of safflower was not significantly reduced by mild water deficit, but it was decreased under moderate and severe water stress mainly due to reduction in grains per plant, 1000 grains weight and plant biomass. Hydro-priming of seeds for 16 hours before sowing improved field performance of safflower, as reflected in higher plant per m^2, grains per plant, 1000 grains weight, biological and grain yields per unit area. Thus, optimal time of hydro-priming for safflower seeds is about 16 hours, which can be successfully applied to enhance grain yield of safflower in the field.

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