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Research article

RELATIONSHIP OF GRAIN FILLING WITH GRAIN YIELD OF MUNG-BEAN AFFECTED BY HYDRO-PRIMING DURATION AND WATER SUPPLY

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ABSTRACT: Grain filling is a crucial determinant of yield. Thus, a split-plot experiment based on RCB design with three replications was conducted in 2013, in order to evaluate the effects of water supply (I_1, I_2, I_3 and I_4: irrigation after 70, 100, 130 and 160 mm evaporation from class A pan, respectively) and hydro-priming duration (P_1, P_2 and P_3: 0, 8 and 16 h, respectively) on grain filling of mung bean (*Vigna radiata* L). The highest grain filling rate was observed for P_3, but there was no statistical difference between P_1 and P_2**.** Grain filling duration and maximum grain weight decreased with decreasing water availability**.** Seeds hydro-primed for 16h had the highest maximum grain weight, but there was no significant difference between P_2 and P_3**.** Water stress significantly reduced grain yield per unit area, although no significant difference between I_1 and I_2 treatments was observed. Grain yield per unit area for P_3 plants was higher than that of P_1 and P_2 plants. Grain filling duration and maximum grain weight had the highly positive correlations with grain yield per unit area**.** Hydro-priming for 16 h had the highest beneficial effects on field performance of mung-bean seeds.
Key words: Grain filling, Grain yield, Mung-bean, Water stress

INTRODUCTION

Mung-bean (Vigna radiata L.) is one of the most nutritious grain legumes used in different parts of the world [1]. Although this plant is a relatively drought tolerant crop and performs well under conditions of low soil moisture [2], severe water stress can result in yield loss [3]. Drought stress is the most common form of abiotic stress and plants are likely to encounter periods of water shortage in their life cycle [4]. Water is essential to plant growth because it provides the medium within which most cellular functions take place [5]. Water stress causes membrane damage, and stimulates molecular signal transduction and hormone activation [6], leading to a reduction in plant growth and productivity [7, 8, 9, 10]. The degree of yield reduction is determined by the timing, severity and duration of the water deficit. Water stress during vegetative stages has the greatest impact on plant height and biomass [11], but during the reproductive growth it is considered to have the most adverse effect on crop productivity [12]. Grain filling is a crucial determinant of yield and is characterized by duration and rate of filling [13]. Water stress occurring during grain development curtails the kernel sink potential by reducing the number of endosperm cells and amyloplasts formed [14], thus reducing grain weight as a result of a reduction in the capacity of the endosperm to accumulate starch [15]. Some of the deleterious effects of environmental stresses such as water stress on crop performance may be overcome by seed priming [16, 9]. Seed priming is the soaking of seeds in a solution of any priming agent followed by drying of seeds that initiates germination related processes without radicle emergence [17]. Various seed priming techniques have been developed, including hydro-priming (soaking in water), halo-priming (soaking in inorganic salt solutions), osmo-priming (soaking in solutions of different organic osmotica), thermo-priming (treatment of seeds with low or high temperatures), matrix priming (treatment of seed with solid matrices) and bio-priming (hydration using biological compounds) [18]. Seed invigoration by priming treatments has been associated with various biochemical, cellular and molecular events including synthesis of RNA and proteins [19, 20]). Priming also restores activities of enzymes involved in the cell detoxifying mechanisms [21]. Earlier works showed that the success of seed priming is influenced by the complex interaction of factors including plant species, water potentiality of priming agent, duration of priming, temperature, seed vigor and storage conditions of the primed seeds [22]. The beneficial effects of seed priming have been demonstrated for many field crops such as pinto [23], rapeseed [24], borage [25], chickpea [26] and lentil [27]. This research was conducted to evaluate the effects of hydro-priming duration on grain filling of mung-bean under different irrigation treatments.

MATERIALS AND METHODS

The experiment was conducted in 2013 at the Research Farm of the Faculty of Agriculture, University of Tabriz, Iran (Latitude 38°05′ N, Longitude 46°17′ E, Altitude 1360 m above sea level). Seeds of mung-bean (*vigna radiata* L.) were divided into three sub-samples, one of which was kept as control (non-primed, P_1) and two other samples were soaked in distilled water at 20°C for 8 (P_2) and 16 (P_3) hours and then dried back to initial moisture content at room temperature of 20-22°C. All the seeds were treated with benomyl at a rate of 2 g kg^{-1} before sowing. Seeds were hand sown in about 4 cm depth with a density of 80 seeds per m^2 on 7 May 2013. Each plot consisted of 6 rows with 3.5 m length, spaced 25 cm apart. The experiment was arranged as split-plot, based on RCB design with three replications. All plots were irrigated immediately after sowing and subsequent irrigations were carried out after 70 (I_1), 100 (I_2), 130 (I_3) and 160 (I_4) mm evaporation from class A pan. Weeds were frequently controlled by hand during crop growth and development.

Grains were harvested in five day intervals at eight stages. The grains of each harvest were separately dried in an oven at 80°C for 48 hours, and then weighed. Grain filling rate was calculated by using the following equation:

Grain filling rate (mg d^{-1}) =Maximum grain weight (mg) / Grain filling duration (day)

At maturity, plants in 1 m^2 of the middle part of each plot were harvested and grain yield per unit area was determined. Analysis of variance of the data appropriate to the experimental design and comparison of means at $p \leq 0.05$ were carried out, using MSTATC and SPSS softwares.

RESULTS AND DISCUSSION

Analysis of variance indicated that hydro-priming significantly influenced grain filling rate, but there was no significant difference among irrigation treatments. However, grain filling duration was significantly affected by irrigation treatments and hydro-priming durations had no significant effect on this trait. Maximum grain weight and grain yield were significantly affected by both hydro-priming and irrigation (Table 1).

The highest grain filling rate was observed in P_3, However, there was no statistical difference between P_1 and P_2 (Table 2). This 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 [28].

Severe water stress levels significantly shortened the duration of grain filling. The highest grain growth period was observed under I_1, but it was statistically similar with I_2 (Table 2). Environmental stresses such as water shortages, especially during grain filling, cause reductions in photosynthesis and remobilization of stored materials and hence, grain filling duration [29]. Water stress generally accelerates leaf senescence and shortens grain filling duration [30]. Similar results were reported for faba-bean [10] and chickpea [31]. Maximum grain weight decreased with increasing drought stress. The highest and the lowest maximum grain weights were obtained under I_1 and I_4, respectively (Table 2). Maximum grain weight of mung-bean seeds was mainly influenced by grain filling duration rather than by grain filling rate, which is also reflected in the highest positive correlation of grain filling duration with maximum grain weight (Table 3). These results are strongly supported by the work of Ghassemi-Golezani *et al.*[10] on faba-bean. Seeds hydro-primed for 16h had the highest maximum grain weight, but there was no significant difference between P_2 and P_3 (Table 2). This may be due to higher sink activity in plants derived from primed seeds, which in turn is caused by more activity of enzymes involved in sucrose [32]. Bakht *et al*. [33] also reported that primed seeds produce plants with larger grains.

Table 1. Analysis of variance of the effects of hydro-priming duration on grain filling, maximum grain weight, and grain yield of mung-bean

Source of Variation	df	MS			
		Grain filling rate	Grain filling duration	Maximum grain weight	Grain yield
Replication	2	0.006^{ns}	2.282^{ns}	0.759^{ns}	198.347^{ns}
Irrigation (I)	3	0.004^{ns}	95.120^{**}	248.174^{**}	8072.477^{**}
Error a	6	0.002	0.923	0.681	134.201
Hydro-priming (HP)	2	0.01^{*}	0.949^{ns}	6.783^{**}	3153.889^{*}
I × HP	6	0.001^{ns}	0.769^{ns}	0.796^{ns}	72.836^{ns}
Error b	16	0.002	0.764	0.781	516.084
CV		2.79%	2.16%	1.5%	15.8%

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

Table 2. Means of mung-bean field traits influenced by irrigation and hydro-priming duration

Treatments	Grain filling rate (mg d^{-1})	Grain filling duration (day)	Maximum grain weight (g)	Grain yield (g m^{-2})
Irrigation				
I_1	1.473 a	43.386 a	63.863 a	174.7 a
I_2	1.461 a	42.846 a	62.561 b	162.3 a
I_3	1.477 a	38.899 b	57.436 c	128.2 b
I_4	1.433 a	36.584 c	52.370 d	109.9 c
Hydro-priming				
P_1	1.437 b	40.607 a	58.345 b	126.9 b
P_2	1.454 b	40.574 a	58.984 b	145.2 ab
P_3	1.492 a	40.105 a	59.843 a	159.2 a

Different letters at each column for each treatment indicate significant difference at $p \leq 0.05$.
I_1, I_2, I_3, I_4: irrigation after 70, 100, 130 and 160 mm evaporation from class A pan, respectively
P_1, P_2 and P_3: non-primed and hydro-primed seeds for 8 and 16 h, respectively

Table 3. Correlation coefficients of traits

Trait	1	2	3	4
1- Grain filling rate	1			
2- Grain filling duration	0.233	1		
3- Maximum grain weight	0.486	0.963**	1	
4- Grain yield	0.567	0.848**	0.920**	1

**: Statistically significant at $p \leq 0.01$

Water stress significantly reduced grain yield per unit area, although no significant difference between I_1 and I_2 treatments was observed (Table 2). Water limitation during flowering stage leads to flower abortion, poor pod set and formation of infertile pods, which can potentially reduce grain yield per unit area [34]. Grain yield per unit area for P_3 plants was higher than that of P_1 and P_2 plants, but P_3 plants had no significant difference with P_2 plants (Table 2). Harris *et al.* [35] found that hydro-priming resulting in faster development, earlier flowering and maturity and higher yields of upland rice, maize and chickpea. The resultant effects of priming depend on duration of seed soaking, beyond which it could be damaging to the seed or seedling [36]. Optimal times of hydro-priming were 7 h for pinto bean [23], 12 h for chickpea [26], and 8 h for lentil [27]. In our research, the best duration for hydro-priming of mung-bean seeds was 16 h. Correlation of grain filling duration with maximum grain weight and correlations of grain filling duration and maximum grain weight with grain yield were positive and significant. However, grain filling rate had no significant correlation with other traits. Thus, grain filling duration and maximum grain weight have the major roles in determining grain yield of mung-bean.

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