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Effect of Duration and Composition of Seed Priming on Germination Indices and Yield of Wheat (cv. Mehregan) in Khorramshahr Region (South west of Iran)

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RESEARCH ARTICLE

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ABSTRACT

BACKGROUND: salicylic acid and gibberellic acid plays a pivotal role in regulating various physiological processes such as growth, plant development, ion absorption, photosynthesis and germination depending on the desired concentration, plant species, growth period and environmental conditions.

OBJECTIVES: This study was investigated the effect of duration and combination of seed priming on the germination indices and yield of wheat cultivar (Mehregan).

METHODS: Current research was conducted in two field and laboratory experiments in Khorramshahr in 2019-20. The first experiment was carried out as a factorial experiment in a completely randomized block design with two factors and three replications and the second experiment was carried out as a factorial based on completely randomized design with 3 replications in the laboratory of Islamic Azad University of Ahvaz branch. Experimental factors included seed priming duration at three levels (including 2, 4 and 6 hours) and priming types at 4 levels including Hydropriming (distilled water), salicylic acid hormone priming at 50 ppm, gibberellic acid hormonal priming at 100 ppm, and urban tap water (control)) were performed.

RESULT: The results showed that the effect of seed priming duration and composition on germination percentage and rate, root length, grain yield, number of spikes per m^2 and number of grains per spike influenced these traits. The highest percentage and rate of seed germination was related to hormonal compounds from 6 hours of seed priming and priming. Interaction duration and seed priming composition had a significant effect on germination rate, seed yield and spike number per m^2. The highest grain yield in soaking the seeds for 6 hours in hormonal substances (average 445.02 gr per m^2) and the lowest yield (with an average 322.41 gr per m^2) to soaking the seeds for 2 hours in tap water allocation Found.

CONCLUSION: In general, in vitro and field priming of wheat seed with hormonal compounds (gibberellic and salicylic acid) for 6 hours can be effective in increasing germination indices and grain yield and the plant responds better than to other treatments applied.

KEYWORDS: *Bread, Germination percentage, Gibberellic acid, Grain yield, Leaf area index.*

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1. BACKGROUND

Cereals provide 70% of the food of people on earth. Among the plants of this region, wheat, rice, corn and barley are the most important sources of food. More than three-fourths of energy and one-half of the protein needed by humans are provided by grains (Nourmohamadi *et al*., 2011). Wheat is one of the main agricultural products and provides the most food needs of humans in developing countries. Wheat is the most important crop in Iran in terms of production and cultivated area. This plant is cultivated in a wide range of climatic conditions of the country (SeyedSharifi and Khalilzadeh, 2017). Germination is the first developmental stage in a plant and one of the most important and sensitive stages in the life cycle of this plant and a key process in the sprouting of seedlings (Kulkarni *et al*., 2015). In this regard, a solution is needed to strengthen the germination and establishment of wheat seedlings and provide the plant with the maximum use of soil moisture, nutrients and solar radiation. The research results indicate that rapid germination, uniform emergence and strong establishment of the plant can be achieved by using treatments that increase seed strength (Shakerian *et al*., 2019). Priming is one of the most important treatments to increase the germination power of seeds. Seed priming is a technique that improves seedling establishment in the environment. In such conditions, the seeds are placed in controlled conditions in terms of humidity, ventilation and temperature (Mazhar *et al*., 2022). Rashid *et al*. (2002) reported that seed priming is a good guarantee for farmers in terms of germination, seedling greening and crop performance under stress conditions, and almost no negative effects of using this method in plants have been reported. Priming has various forms including hydropriming, hydro thermopriming, osmo-priming, matric priming. Different materials are used for priming (Chatterjee *et al*., 2018; Mohammadi, 2010). In the priming method, plant hormones such as salicylic acid and gibberellic acid can be used. Salicylic acid is soluble in water and an antioxidant compound, and it is among plant hormones (Raafat and Radwan, 2011). This hormone plays a pivotal role in regulating various physiological processes such as growth, plant development, ion absorption, photosynthesis and germination depending on the desired concentration, plant species, growth period and environmental conditions (Iqbal and Basra, 2006). In the conditions of priming, seeds germinate faster and germination occurs simultaneously, especially in conditions where planting takes place at unfavorable temperatures. The usefulness of priming remains in the seed for a long time after drying (Gholami Tile Bani *et al*., 2012). The suitable temperature for priming is reported to be between 10 and 35 degrees Celsius. The appropriate duration of priming is reported to be between a few hours and a few weeks depending on the species (Dadrasi, 2014). In such a situation, the seeds are removed from the solution and dried after washing. The optimal priming should be non-toxic, economical and effective on the process of germination and seedling establishment(Chatterjee *et al*., 2018).

2. OBJECTIVES

Therefore, according to the positive effects of seed priming in improving germination and rapid and favorable establishment of plants, this research was conducted in order to study and evaluate the effect of duration and combination of priming on the germination and growth components of Mehrgan cultivar wheat in Khorramshahr area. In general, the objectives of this research were: 1. Determining the best period of seed priming according to the components of germination and yield of wheat, 2. Determining the effect of priming compounds on germination, yield and yield components of wheat, 3. Selection of the most appropriate priming combination and seed priming duration on germination speed and wheat yield.

3. MATERIALS AND METHODS

3.1. Field and Treatments Information

The research was carried out in the agricultural year of 2018-2019 in Khorramshahr city with the longitude of 48 degrees and 10 minutes east and the latitude of 31 degrees and 33 minutes north and with a height of 13 meters from the sea level. In terms of climate, this region has a dry and semi-arid climate, and the average annual temperature is 27.1 degrees Celsius and the average rainfall is 194.2 mm. The research was carried out in the form of field and laboratory experiments Khorramshahr region. The first experiment was conducted as a factorial in the form of a completely randomized design in a farm located in the suburbs of Khorramshahr on a plot of land with an area of 1200 square meters with two factors and three replications, and the second experiment was performed as a completely randomized design with 3 replications in the laboratory of the Islamic Azad University, Ahvaz branch. Became The test factors include seed priming duration in three levels (Including 2 hours (T1), 4 hours (T2) and 6 hours (T3) and types of priming in 4 levels including hydropriming (distilled water) (P1), hormonal priming of salicylic acid with 50 ppm concentration (P2), gibberellic acid hormone priming with 100 ppm concentration (P3) and urban tap water (control) (P4).

3.2. Lab Management

In the laboratory research, the experiment was carried out in the form of cultivation in Petri dishes with a diameter of 10 cm. In each petri dish, 25 uniform seeds of the same size were counted individually and disinfected using a 5% sodium hypochlorite solution for five minutes and then washed several times with distilled water (Don and Committee, 2009). Then the seeds were placed in the mentioned concentrations and duration (prime). To priming the seeds at the prescribed times, first, the seeds are soaked for 2, 4 and 6 hours in a solution of distilled water (hydropriming), hormonal priming (salicylic acid with a concentration of 50 ppm and gibberellic acid with a concentration of 100 ppm) were soaked and in the control treatment, the seeds were also soaked for 24 hours in normal water (custom of the region). After finishing the priming periods, the primed seeds were washed with distilled water and then dried at room temperature for 48 hours in the dark. To evaluate germination, 25 seeds were placed in a Petri dish between two layers of filter paper (disinfected in an oven at 70 degrees Celsius) and then 10 ml of distilled water was added to the Petri dishes and for germination. The Petri dishes were transferred to the germinator with a temperature of 25±2 degrees Celsius (8 hours of light and 16 hours of darkness) (De Castro, 2020). The seeds were counted every 24 hours for 8 days. Seeds were checked for germination every day during the experiment. The criterion for germinated seeds was 2 mm root exit (Mojab *et al*., 2010).

3.3. Measured Traits

On the last day of the germination test, germination percentage, germination speed, seed germination, root length, and stem length were measured. Germination percentage was measured by the following formula (Bradford *et al*., 1993; Hartmann *et al*., 2002):

Equ. 1.

$$\%GP = \frac{\sum G}{N} \times 100$$

GP*:* Germination percentage, G: Number of germinated seeds, N: Total number of seeds

The seed germination rate was calculated through the following formula (Hussain *et al*., 2015):

Equ. 2. $GR = \frac{\sum n}{\sum dn}$

GR: Average germination speed, $\sum n$: The number of germinated seeds on the desired day, $\sum_{dn}$: The number of days since the start of the experiment.

The length of root and shoot was measured with a ruler and with an accuracy of one millimeter. The seed germination index was calculated according to the following formula (Marandi, 2012): **Equ. 3**. VI= (RL+SL) × GP/100.

VI: seed germination index, RL: root length, SL: stem length, and GP: germination percentage. In the field research, in order to investigate the physical and chemical characteristics of the field soil, before planting, five parts of the field soil were sampled from the depth of 0-30 cm and after crushing the clods, the sample was taken. Were passed through a 2 mm sieve and finally a composite sample was prepared. The composite sample was evaluated in the laboratory in terms of physical and chemical properties and results presented in table 1.

Table 1. Physical and chemical characteristics of the test site soil

Soil Texture	Soil particles (%)			K ($mg.kg^{-1}$)	P ($mg.kg^{-1}$)	OC (%)	N (%)	pH	EC ($dS.m^{-1}$)	Sampling depth (cm)
	C	Si	S							
CL	54	43	3	266	12.1	0.62	0.06	7.82	4.42	0-30

The land preparation operation included a 20 cm deep plow, two perpendicular discs and troweling and leveling operations. The research was done in a factorial form in the form of completely randomized design blocks with three replications. The experiment included 36 plots, each plot having seven planting lines, each four meters long, where the distance between the lines was considered to be 20 cm. The distance between each repetition was 2 meters and the distance between each plot was 1 meter. Before planting, the total phosphorus required from triple superphosphate source based on 80 kg of pure phosphorus and half of nitrogen from urea source along with a disk was distributed in the field and the other half of nitrogen was distributed at the end of the tillering stage (beginning of stem development). After the cultivation lines were prepared, planting was done manually at a depth of about 3 cm. The cultivated cultivar Mehrgan (*Triticum aestivum* L.) with an average yield of 5.5 tons per hectare, was suitable for tropical regions and resistant to wheat yellow rust (Moghaddam *et al*., 2017). For seed priming at the prescribed times, first soak the seeds for 2, 4 and 6 hours in distilled water solution (hydropriming), hormonal priming (salicylic acid with a concentration of 50 ppm and gibberellic acid with a concentration of 100 ppm). And in the control treatment, the seeds were soaked in normal water for 24 hours. After drying, the seeds were planted directly in the field with a density of 400 plants per square meter. Then irrigation was done in all plots. During the growth period, weeds were controlled by manual weeding. In order to determine performance and performance components, side lines and half a meter from the beginning and end of the plot were removed as marginal effects, and finally, the final harvest was done from an area equal to 1.5 square meters from lines three, four and five of each plot. To determine the number of spikes per unit area, the total number of spikes harvested in the area of 1.5 square meters was counted and considered as the number of spikes per square meter (Parvazi Shandi et al., 2014). To get the number of seeds in a spike, 20 spikes are completely randomly separated from all the spikes in the final harvest area (1.5 square meters) and after threshing the spikes, count the seeds and divide the number of seeds by the number of spikes. The number of seeds per spike was calculated (Azadeh Khoram *et al*., 2018). To calculate the weight of one thousand seeds, two samples of 500 seeds of each plot were separated and weighed. If the difference in the weight of two samples was less than 5%, the total weight of the two samples was considered as the weight of a thousand seeds (Azadeh Khoram *et al*., 2018). In order to determine the grain yield, in the ripening stage and after removing 0.5 meters from the beginning and end of lines 3, 4 and 5, harvesting was done on an area equal to 1.5 square meters. After threshing, the grain was separated from the straw and after weighing, the grain yield was calculated in grams per square meter (Parvazi Shandi *et al*., 2014).

3.4. Statistical Analysis

Analysis of variance of data was done in the form of factorial design with Minitab 14 software and comparison of averages was done by Duncan's multi-range test at the five percent level.

4. RESULT AND DISCUSSION

4.1. *Germination components*

The results of analysis of variance of the data showed that the effect of the duration and combination of seed priming on all the investigated germination components was significant, although the interaction of the treatments had no significant effect on the percentage of germination and seed germination index. The highest percentage of germination related to the treatment of soaking seeds for 6 hours (with an average of 93%) and the lowest percentage of germination was assigned to the treatment of soaking seeds for 2 hours (with an average of 78%) (Table 2). In priming for two hours, seeds probably do not absorb water and hormonal compounds well, so their enzymes are activated later and as a result the percentage of germination decreased. The results of Yadollahi Nooshabadi *et al*. (2012) confirmed the results of this research Karbalaee gholizadeh *et al*. (2014) have pointed out the increase in germination percentage in the longest period of seed priming, which was consistent with the results of this research. The highest germination percentage with an average of 96% was obtained from the hormone priming treatment with gibberellic acid (which was not statistically significantly different from the salicylic acid treatment) and the lowest germination percentage with an average of 73.2% was obtained from the normal water treatment, which compared to Gibberellic acid treatment showed about 23% reduction (Table 2). Usually, during hormonal priming, the embryo is stimulated and the endosperm thickens. The pressure caused by the development of the embryo and the activity of hydrolytic enzymes in the endosperm cell walls during water loss may cause changes in the shape of tissues. This situation leads to the production of free space and ease in sprouting and rooting(Karbalaee gholizadeh *et al*., 2014). Rouhi *et al*. (2012) According to the report of Rouhi *et al*. (2012), increasing the speed and percentage of germination and increasing enzymatic activity and digestion probably depend a lot on hormonal activity, so that in the present experiment, germination improved with the use of gibberellic acid hormone and salicylic acid. Various reports indicate that hormonal priming increases the percentage, speed and uniformity of seed germination and greening (Bahrani and Pourreza, 2012; Sharma *et al*., 2005). The highest germination speed related to the treatment of soaking seeds for 6 hours with an average of 27.56 seeds per day and lowest germination speed was related to treatment of soaking seeds for 2 hours with average of 19.44 seeds per day. The highest seed germination rate with average 28.1 seeds per day was obtained from hormone priming treatment with gibberellic acid and lowest germination rate with an average of 18.08 seeds per day was obtained at normal water treatment (Table 3).

Table 2. Summary of the results of mean square variance analysis of the studied traits

S.O.V	df	Germination percentage	Germination rate	Root length	Stem length	Seed germination index
Seed priming time	2	841.6**	163.1**	80.27**	290.11**	0.24ns
Seed priming composition	3	205.11*	320.04**	71.03**	158.03**	345**
Priming time × priming combination	6	8.52ns	190.41**	52.47**	80.35**	0.89ns
Error	24	51.09	4.82	0.61	0.55	1.8
CV (%)		8.24	9.29	10.55	8.7	9.62

ns, * and **: no significant, significant at 5% and 1% of probability level, respectively.

Table 3. Mean comparison seed characteristics traits affected time and seed combination priming

Treatments	Germination percentage (%)	Germination rate (day)	root length (cm)	Stem length (cm)	Seed germination index
Priming combination					
Hydropriming	22.01 b	85.00 b*	6.04 b	7.04 bc	11.11a
Salicylic acid priming with a concentration of 50 ppm	26.25 a	92.44 a	8.79 a	9.84 a	17.22a
Gibberellic acid priming with a concentration of 100 ppm	28.10 a	96.00 a	8.82 a	10.49 a	18.53 a
Ordinary water	18.08 c	73.2 c	5.97 b	6.72 c	9.3c
Priming time					
2 hours	19.44 c	78.00 c	6.20 b	7.15 c	10.41 a
4 hours	23.83 b	89.00 b	6.24 b	8.42 b	13.04 a
6 hours	27.56 a	93.00 a	9.76 a	10 a	18.37 a

*The numbers of each column in each treatment that have at least one letter in common are not statistically significant at the 5% level according to Duncan's test.

The treatment of soaking seeds for 6 hours with gibberellic acid hormone has the highest germination rate (1/3 number of seeds per day) and the lowest germination rate from soaking seeds for 2 hours in normal water (16.41 number of seeds per day) was obtained (Fig. 1). Probably, the increase in germination speed under the conditions of application of plant hormones in a period of 6 hours was due to the increase in the transfer of nutrients from the cotyledons to the embryo. In this way, the accumulation of dry matter in the tissue of the embryo increases, and the seeds that have more food reserves or the amount of food reserves in them are less affected by the environment, will have a higher germination rate. Factors such as gibberellic acid hormone, which affect the growth rate of the embryonic axis, can affect the movement of nutrients and their transfer from the cotyledons to the embryonic axis (Sharma *et al.*, 2005). Gibberellins and salicylic acid are needed both for the elongation of the embryo cells and for the loosening of the endosperm during seed germination. Gibberellin causes cell growth by increasing enzymes that cause proteins to penetrate the cell wall *(Keikha et al.*, 2017). In this regard, Bahrani and Pourreza (2012) also reported that wheat seed priming with gibberellic acid increased its germination rate. The maximum length of the root and stem of the seed soaking treatment for 6 hours was obtained with an average of 9.76 cm and 10 cm, respectively. Also, the maximum length of root and shoot with an average of 8.82 and 10.49 cm, respectively, from hormone priming treatment with gibberellic acid (which was not statistically significantly different from salicylic acid treatment) (Fig. 2) and the lowest root length The average length of shoot and stem was 5.97 and 6.72 cm, respectively, from normal water treatment (Table 3). The amount of amylase and Sucrsyntase enzymes increased in the stem and root of the primed seedlings, the increase of such enzymes can be one of the reasons for the increase in the length of the root and stem of the primed seeds (Kaur *et al.*, 2005). The treatment of seed soaking for 6 hours with gibberellic acid hormone had the highest root and stem length (9.2 and 10.7 cm) (which was not statistically significantly different from the treatment of seed soaking for 6 hours with salicylic acid hormone) and the lowest root and stem length (5.7 and 6.5 cm) were obtained from soaking the seeds for 2 hours in normal water (Fig. 2 and Fig. 3). Increasing the time of soaking the seeds in hormonal compounds such as gibberellic acid and salicylic acid provides enough time to absorb these compounds, and with the activation of seed enzymes, endosperm decomposition is done faster and the result is that the root leaves the seed earlier (Yadollahi nooshabadi *et al.*, 2012).

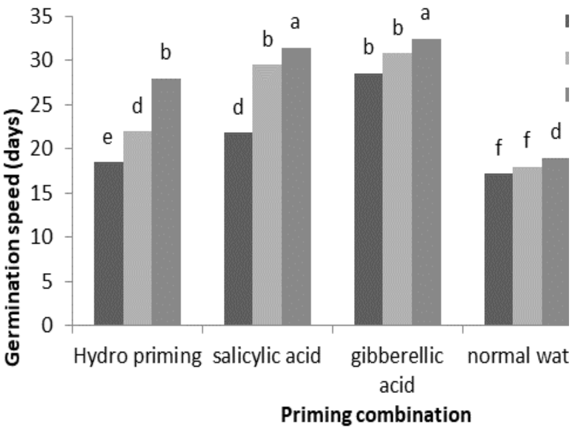

Fig. 1. Comparison of the average interaction effect of duration and priming combination on germination rate.

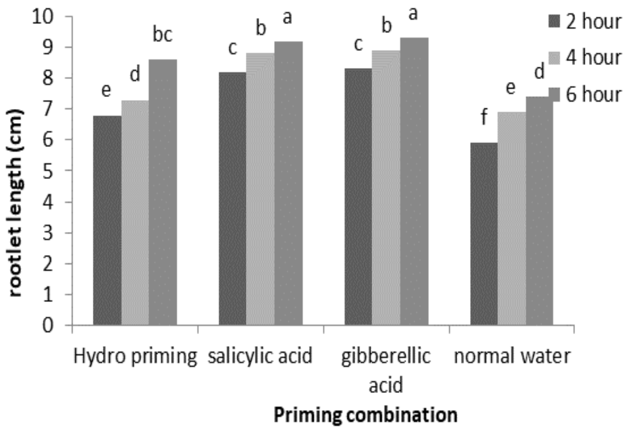

Fig. 2. Comparison of the average interaction effect of duration and priming combination on root length (cm)

The seed germination index under the influence of the seed priming combination was significant at the probability level of 1%. However, the duration of seed priming and the interaction of duration and combination of seed priming did not have a significant effect on seed germination index. The highest seed germination index with an average of 18.53 was obtained from the hormone priming treatment with gibberellic acid (which was not statistically significantly different from the salicylic acid treatment) and the lowest seed germination index with an average of 9.3 was obtained from the normal water treatment, which compared to the gibberellic acid treatment. Acid showed a decrease of about 49% (Table 3). Seed set is the result of germination percentage and seedling length traits, and any treatment that increases these two components also increases seed set. Since the gibberellic acid treatment produced the longest stem length and root length, it increased the seed set. The present results were consistent with the results of researchers such as Mohammadi and Shekari (2015) who reported that hormonal priming increased the percentage of germination and seed set. Other researchers also reported that seed priming increased seedling growth and seed germination (Yağmur and Kaydan, 2008).

4.2. Yield components and grain yield

4.2.1 Number of spikes per unit area

The results of variance analysis of the data showed that the number of spikes per unit area was affected by different levels of duration and combination of seed priming and their interaction at the five percent probability level (Table 4). The highest and lowest number of spikes per unit area were obtained from seed soaking treatment for 6 hours (with an average of 376.4 spikes) and seed soaking treatment for 2 hours (with an average of 340.18) respectively (Table 5). The highest number of spikes per unit area with an average of 377.42 was obtained from the hormone priming treatment with gibberellic acid (which was not statistically significantly different from the salicylic acid treatment) and the lowest number of spikes per square meter with an average of 330.01 was obtained from the normal water treatment (Table 5). The comparison of the average interaction of the treatments showed that the treatment of soaking seeds for 6 hours with gibberellic acid hormone produced the highest number of spikes per square meter (380.04) (which was not statistically significantly different from the treatment of soaking seeds for 6 hours with salicylic acid hormone) was superior to other treatments (Fig. 4). The increase in the number of spikes in wheat due to 6 hours of seed priming and hormonal compounds was due to the germination and favorable establishment of plants obtained from treated seeds. In this condition, the process of vegetative growth and consequently the reproductive growth of the plant is improved, which results in an increase in the number of fertile claws. On the other hand, the use of gibberellic and salicylic acid will increase photosynthetic substances and also increase the amount of auxin hormone, which increases vegetative growth and claw production, and this causes an increase in the number of spikes in wheat plants (Oghbaie *et al*., 2011). They reported that the use of salicylic acid in wheat increased the number of spikes in this plant (Amin *et al*., 2008). The results of this research were consistent with the results of Abdolahi and Shekari (2016) and Afzal *et al.* (2013) in wheat plant.

4.3. Seed yield and its components

4.3.1. Number of spikes per unit

The results of variance analysis of the data showed that the number of spikes per unit area was affected by different levels of duration and combination of seed priming and their interaction at the five percent probability level (Table 4). The highest and lowest number of spikes per unit area were obtained from seed soaking treatment for 6 hours (with an average of 376.4 spikes) and seed soaking treatment for 2 hours (with an average of 340.18) respectively (Table 5). The highest number of spikes per unit area with an average of 377.42 was obtained from the hormone priming treatment with gibberellic acid (which was not statistically significantly different from the salicylic acid treatment) and the lowest number of spikes per square meter with an average of 330.01 was obtained from the normal water treatment (Table 5). The comparison of the average interaction of the treatments showed that the treatment of soaking seeds for 6 hours with gibberellic acid hormone produced the highest number of spikes per square meter (380.04) (which was not statistically significantly different from the treatment of soaking seeds for 6 hours with salicylic acid hormone) was superior to other treatments (Fig. 4). The increase in the number of spikes in wheat due to 6 hours of seed priming and hormonal compounds was due to the germination and favorable establishment of plants obtained from treated seeds. In this condition, the process of vegetative growth and consequently the reproductive growth of the plant is improved, which results in an increase in the number of fertile claws. On the other hand, the use of gibberellic and salicylic acid will increase photosynthetic substances and also increase the amount of auxin hormone, which increases vegetative growth and claw production, and this causes an increase in the number of spikes in wheat plants (Oghbaie *et al.*, 2011).

Table 4. Results of analysis of variance of seed yield and its components

S.O.V	df	Number of spikes per unit	Number of seeds per spike	1000 seed weight	Seed yield
Replication	2	89.08 ^{ns}	2.05 ^{ns}	5.11 ^{ns}	350.78 ^{ns}
Seed priming period (T)	2	6450.3 *	200.4 **	2.7 ^{ns}	10285.21 **
Priming compound (H)	3	3808.1 *	310.2 **	401.64 **	11461.96 **
Priming duration × priming combination (T*H)	6	5500.1 *	190.6 **	0.88 ^{ns}	8015.7 *
Error (E)	22	800.32	15.74	14.27	996.9
CV (%)		8.08	11.66	10.60	8.02

^{ns}, * and **: no significant, significant at 5% and 1% of probability level, respectively.

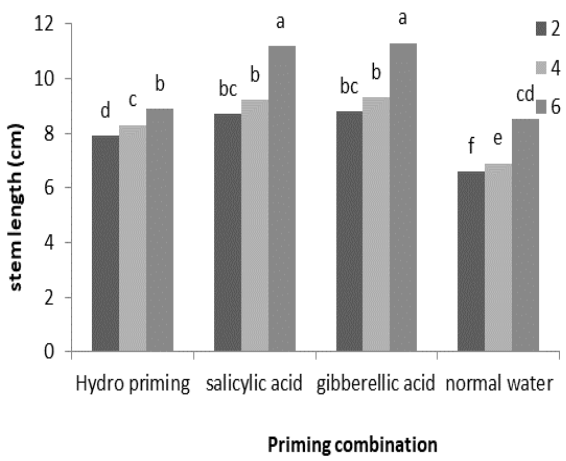

Fig. 3. Comparison of the average interaction effect of duration and priming combination on stem length (cm)

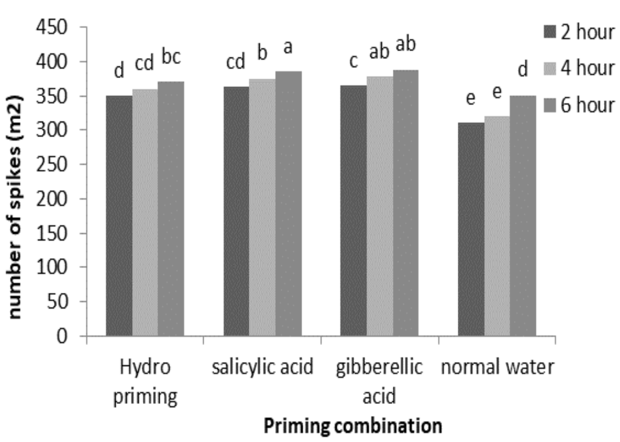

Fig. 4. Comparison of the average interaction effect of duration and priming combination on number of spikes

4.3.2. Number of seeds per spike

The effect of different levels of duration and combination of seed priming and their interaction on the number of seeds per spike was significant at the 1% probability level (Table 4). The highest number of seeds per spike was obtained from the treatment of soaking seeds for 6 hours with an average of 37.01 seeds and the lowest number of seeds per spike was obtained from the treatment of soaking seeds for 2 hours with an average of 31 seeds (Table 5). The highest number of seeds per spike with an average of 36.86 seeds was obtained from the hormone priming treatment with gibberellic acid (which was not statistically significantly different from the salicylic acid treatment) and the lowest number of seeds per spike with an average of 31.49 seeds was obtained from the normal water treatment (Fig. 5). According to the reports published by Duman (2006) in the primed seeds of wheat and barley due to favorable germination and rapid growth at the beginning of the season, the number of fertile tillers is more and as a result of this The number and at the same time the length of spikes increases. In addition, in these plants, seeding and filling of seeds also improved significantly.

4.3.3. The weight of 1000-seeds

Based on the results of the analysis of variance table (Table 4), the thousand seed weight was significantly affected by the combination of seed priming, but the duration of seed priming and the interaction effect of the treatments had no significant effect on the thousand seed weight. The highest weight of 1000 seeds with an average of 38.3 grams was obtained from hormone priming treatment with gibberellic acid (which was not statistically significantly different from salicylic acid treatment) and the lowest weight of 1000 seeds with an average of 3.87 grams was obtained from normal water treatment (Table 5). It is possible to explain the reason for the increase in the weight of the seeds in the way of photosynthetic materials and growth materials during the period of filling of the seeds. The benefits of salicylic acid and gibberellin on grain yield may be related to the transfer of more assimilates to the grain during the filling period and, as a result, the increase of grains (Gunes *et al*., 2005). In this regard Keikha *et al*. (2017) stated that the highest 1000 seed weight was obtained from gibberellin treatment, which showed a 28% increase compared to the control treatment.

Table 5. Mean comparison of seed yield and its components affected time and combination of seed priming

Treatments	Number of spikes per unit	Number of seeds per spike	1000 seed weight (gr)	Seed yield (gr.m^{-2})
Priming combination				
Hydropriming	351.7 ^{b*}	33 ^{b}	33.64 ^{b}	356.86 ^{b}
Salicylic acid priming with a concentration of 50 ppm	373.2 ^{a}	34.67 ^{ab}	37.78 ^{a}	440.48 ^{a}
Gibberellic acid priming with a concentration of 100 ppm	377.42 ^{a}	36.86 ^{a}	38.3 ^{a}	455.9 ^{a}
Ordinary water	330.01 ^{c}	31.49 ^{bc}	32.87 ^{b}	320.77 ^{c}
Priming time				
2 hours	340.18 ^{c}	31 ^{c}	34.79 ^{a}	339.22 ^{c}
4 hours	357.7 ^{b}	34 ^{b}	35.2 ^{a}	391.14 ^{b}
6 hours	376.4 ^{a}	37.01 ^{a}	36.94 ^{a}	450.4 ^{a}

*The numbers of each column in each treatment that have at least one letter in common are not statistically significant at the 5% level according to Duncan's test.

4.3.4. Seed yield

The effect of different levels of duration and combination of seed priming was significant at one percent probability level and their interaction on seed yield was significant at five percent probability level (Table 4). The highest and lowest seed yields were obtained from the treatment of soaking seeds for 6 hours with an average of 450.4 grams per square meter and soaking seeds for 2 hours with an average of 339.22 grams per square meter (Table 5). Also, the highest seed yield with an average of 455.9 grams per square meter was obtained from the hormone priming treatment with gibberellic acid (which was not statistically significantly different from the salicylic acid treatment) and the lowest seed yield with an average of 320.77 grams per square meter was obtained from the normal water treatment (Table 5). Seed soaking treatment for 6 hours with gibberellic acid hormone has the highest seed yield (445.02 g.m^{-2}) (which was not statistically significantly different from seed soaking treatment for 6 hours with salicylic acid hormone) and the lowest seed yield (322.41 g.m^{-2}) were obtained from soaking the seeds for 2 hours in normal water (Fig. 6). Seed priming for 6 hours with hormonal compounds accelerates germination and greening, and these developmental stages are completed in a shorter period of time, and this makes the plant more tolerant of a series of adverse environmental conditions. As a result, seedlings with a better foundation are produced, flowering and maturation occur faster and more yield is produced. The application of gibberellic acid and salicylic acid hormones can increase the weight of seeds and yield of plants by increasing the speed of photosynthesis and transferring more assimilated materials to the seeds (Gunes *et al*., 2005). In this regard, Basra *et al*. (2003) stated that different methods of seed priming have resulted in efficiency in plant production and uniformity in germination and better yield and quality. Moshynets *et al*. (2019) investigated the effect of priming on the growth and yield of wheat seeds and reported that seed priming has a significant and positive effect on germination, cleoptile growth, root growth, biomass dry weight, plant height, and number of seeds. In spike and seed yield. Also, Hussain *et al*. (2015) stated that seed priming improves root formation and as a result improves nitrogen absorption and increases amylase enzyme activity in seeds. In justifying the performance caused by priming, we can refer to the quick and favorable establishment of plants and their greater use of nutrients, soil moisture and solar radiation. The results of this research with the results of Keikha *et al*. (2017), Afzal *et al*. (2013) and Moshynets *et al*. (2019) were consistent in wheat plant.

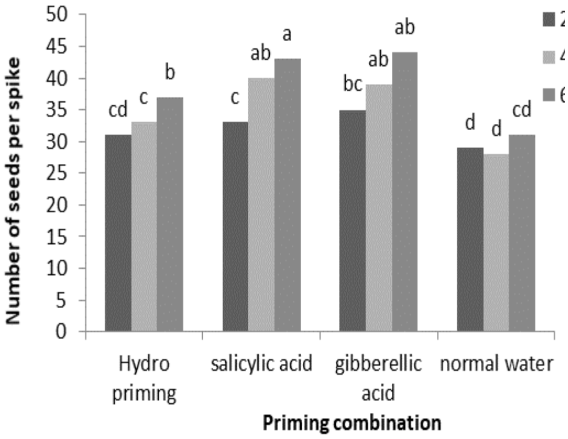

Fig. 5. Comparison of the average interaction effect of duration and priming combination number of seed per spike

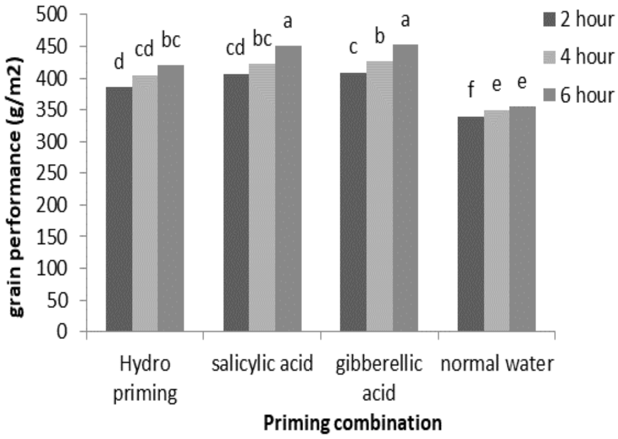

Fig. 6. Comparison of the average interaction effect of duration and priming combination on grain performance

5. CONCLUSION

The results of this research showed that in addition to the use of plant hormones, the duration of seed contact with these substances is very important. In the present experiment, by increasing the duration of priming, the penetration of hormones into the seeds increased, and the percentage and speed of seed germination increased due to the increase in the activity of germination stimulating enzymes. Plants obtained from primed seeds make better use of available resources due to faster germination, greening and establishment. The primed plants in 6 hours had higher germination and yield indicators than the control plants due to better penetration of hormones into the seeds, faster germination and earlier completion of the vegetative growth period. The maximum germination characteristics, such as the percentage and speed of seed germination, root length, stem length, as well as seed stem, were related to the 6-hour seed priming treatment and priming with hormonal compounds. Yield and yield components were also affected by the duration and combination of seed priming. The results showed that the highest seed yield was obtained in the treatment of seed soaking for 6 hours with gibberellic acid hormone (455.9 $g.m^{-2}$) (there was no statistically significant difference in the treatment of seed soaking for 6 hours with salicylic acid hormone). By priming the seeds, germination and greening are done faster and in a shorter period of time, these stages of development are completed, and this has made the plant more tolerant of a series of adverse environmental conditions, as a result, seedlings They are produced with a better foundation, flowering and maturation occur faster, and as a result, more yield is obtained. In general, it can be stated that the primed seeds have a higher germination rate than the control, as a result, they produced more dry matter and yield in a given time than the control seeds. Therefore, laboratory and field priming of wheat seeds for 6 hours with hormonal compounds such as (gibberellic acid and salicylic acid) were effective in increasing germination and yield indicators and showed a greater reaction than other applied treatments. Therefore, this method can be suggested to farmers so that they can have a higher percentage and uniformity of seed germination in the field.

FOOTNOTES

AUTHORS' CONTRIBUTION: All authors are equally involved.

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