Seed priming effect on field emergence and grain yield in sorghum

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Abstract

Most cultivars of sorghum have low field emergence as common problem. Three experiments were carried out at Agriculture College, Baghdad University. First experiment was conducted in laboratory according to Complete Randomized Design (CRD) with four replicates. Second and third experiments were conducted at field according to Randomized Complete Block Design (RCBD) during the spring and the fall seasons of 2015, respectively, with four replicates for each one. Same two factors were studied at each experiment. First factor was seed priming by seed soaking for 10 hours in distilled water, solvents of GA3, KCl and thiamine (300, 40 and 30 mg*L^{-1}, respectively) and non-primed seed. Second factor was three cultivars of sorghum (Inqath, Kafier and Rabeh). The aim was to improve field emergence and grain yield of sorghum under wide range of environmental conditions by using seed priming. Data were analyzed at $P<0.05$. The results showed significant effects of seed priming, cultivars of sorghum and their interaction on most traits under this study. A significant superiority of interaction was found between thiamine and Rabeh on length of plumule and dry weight of seedling at laboratory experiment. A significant superiority of interaction was found between thiamine and Rabeh on percentage of field emergence and total grain yield during spring season. A significant superiority of interaction was found between KCl and Inqath on percentage of field emergence and total grain yield during fall season. It can be concluded that technique of seed priming is effective to improve field emergence and grain yield of sorghum under wide range of environmental conditions.

Keywords: cold test, electrical conductivity, germination, gibberellic acid, potassium chloride, *Sorghum bicolor* L., thiamine, vigour

Introduction

In spite of planting high quality seed of sorghum, it is rarely a substitute of replanting for reaching to the typical density of plants. Seed priming technique is used to increase viability of deteriorated seed or to increase their ability to grow under wide range of environmental conditions or to get high, fast and homogeneous percentages of germination and field emergence, strong seedling and good field establishment.

Seed priming technique means control on process of seed imbibition during soaking or moisturizing and allows proceeding with metabolic events before planting without allowing emergence of radicle or plumule (Murungu et al., 2004; Nawaz, 2013). Seed priming technique is being developed to include many methods. It has advantages or disadvantages depending on plant type, growth stage, priming factor concentration and priming duration (Ashraf and Foolad, 2005). That technique may lead to improve initiate germination, homogeneous growth of seedlings, field establishment and high yield even under conditions of environmental stress compared with non-primed seed. Moradi and Younesi (2009) found that osmo or hydro priming seed led to reduce rate of emergence time and improved percentage of germination, but it gave negative results during test of accelerated ageing compared to non-primed seed.

Richards et al. (2001) mentioned that secretion of gibberellins and transition to aleurone layer at early stages of germination led to decode curbed genes that control on synthesis of seed enzymes such as amylase, beta amylase, protease and hydrolysis. Gibberellins lead to accelerating growth of embryo maybe through decreasing physical hindrances of seed coat, which help emergence of radicle and plumule (Olszewski et al., 2002). Seed of sorghum that soaked in 300 $mg*L^{-1}$ of GA3 gave the highest percentages of germination at first and final counts, lengths of radicle and plumule, dry weight of seedling and percentage of germination at cold test, but percentage of germination decreased during test of accelerated ageing (Cheyed, 2008).

Potassium chloride (KCl) is a source of K and Cl, it is needed at crops planting (Fixen, 1993). Percentage of normal seedling at final count, speed of germination, length of radicle, dry weight of seedling, speed of field emergence and yield of grain per plant during spring and fall seasons were increased when seed of sorghum soaked in 40 $mg*L^{-1}$ of KCl (Dawood, 2014). Priming of rice seed with KCl led to improve growth of seedling with significant increasing at lengths of radicle and plumule (Farooq, 2005). Soaking of rice seed for 24 h with 300 or 20 $mg*L^{-1}$ of GA3 or KCl, respectively, at dry planting led to increase percentages of germination and field emergence and yield of grain (Al-Selawy, 2011). Cheyed (2008) and Al-Selawy (2011) concluded that regulation of seed germination through priming may lead to pre-adaptation. Priming of corn seed with KCl gave higher percentage of germination, germination rate index, coefficient velocity germination and index of seedling vigour compared with non-primed seed under salt stress (Badar uz Zaman et al., 2012). Lemrasky and Hosseini (2012) soaked seed of wheat for 45 h in 2 and 4 $mg*L^{-1}$ of KCl, and the result was longer radicle and plumule. Solang et al. (2014) soaked seed of wheat in 0, 10, 20 and 40 $mg*L^{-1}$ of KCl, and higher value for each one of germination percentage, lengths of radicle and plumule, dry weights of radicle and plumule, growth rates of radicle and plumule associated with control treatment, and lower value associated with higher level of KCl.

Content of corn seedling from thiamine increased when exposed to drought, salt and oxidative stresses and that reflects metabolism of thiamine under such environmental stresses (Rapala-Kozik et al., 2008). Treating of millet seed with 20 mM of thiamine led to improve vegetative, reproduction and plant resistance to disease of downy mildew under growth conditions of greenhouse and field (Pushpalatha et al., 2011). Hamada and Jonsson (2013) found that soaking of barley seed or pea seed with thiamine (150 mM) or added it to nutrient solutions led to reduce growth and

reproduction of aphids. Balliu et al. (2016) added thiamine with irrigation to roots of milieu pea led to increase tolerance of seedling to adverse conditions and good establishment under conditions of salt stress.

Reducing the difference between percentages of germination in laboratory condition and field emergence has become one of important goals in addition to increase yield. This study was conducted to improve field emergence and grain yield of sorghum under wide range of environmental conditions by using technique of seed priming.

Materials and methods

Three experiments were carried out at Agriculture College, Baghdad University. First experiment was conducted in laboratory according to Complete Randomized Design (CRD) with four replicates. Second and third experiments were conducted at field according to Randomized Complete Block Design (RCBD) during the spring and the fall seasons of 2015, respectively, with four replicates for each one.

Same two factors were studied at each experiment. First factor was seed priming by seed soaking for 10 hours in distilled water, solvents of GA3, KCl and thiamine (300, 40 and 30 mg*L^{-1}, respectively) and non-primed seed as control. Second factor was three cultivars of sorghum (Inqath, Kafier and Rabeh).

Pure seed were used for the three experiments. After soaking, seed were air-dried at room temperature on tissue paper till it reached to safe moisture content (12%). Then, seed surface was sterilized in sodium hypochlorite (1%) for 2 minutes to remove contamination (Danazumi et al., 2015). Then, seed were immersed in distilled water for three times to remove remnants of the solution.

A laboratory tests were conducted according to the standards of international rules for seed testing (International Seed Testing Association [ISTA], 2013). For field experiments, seed were planted in 1st third of April and last third of July during the spring and the fall seasons of 2015, respectively. One seed for each hole was planted. Depth, distance between holes and distance between lines were 2, 15 and 75 cm, respectively. Area of trial unit was 15 m^2 (3*5 m). Management operations of soil and crop were conducted according to specific recommendation (Hamdan, 2006).

Traits that were studied in laboratory experiment were percentage of germination at first count (%), percentage of germination at final count (%), length of radicle (cm), length of plumule (cm), dry weight of seedling (mg), percentage of germination at cold test (%), test of electrical conductivity (µS*cm^{-1}*g^{-1}) (Hampton and TeKrony, 1995; ISTA, 2013) and index of seedling vigour (Abdul-Baki and Anderson, 1973). Traits that were studied at field experiments were percentage of field emergence (%), weight of grain (mg), number of grain per plant, yield of grain per plant (g) and total grain yield (ton*ha^{-1}) during spring and fall seasons of 2015. Total grain yield was calculated by multiply yield of grain per plant with actual density of plants at harvesting.

Data were analyzed statistically according to analysis of variance (ANOVA) at the level of probability less than 0.05 ($P<0.05$). Differences between means were

compared by using the test of less significant difference at the level of probability equal to 0.05 (LSD 5%) (Steel and Torrie, 1981).

Results

Analysis of variance in tables 1 and 2 showed significant effects of seed priming and cultivars of sorghum and their interaction on all traits studied, except for effect of sorghum cultivars on percentage of germination at first count, which was not significant. Seed priming was behind the largest proportion of variation at all traits studied, except percentage of germination at cold test and number of grain per plant during spring and fall seasons which attributed to effect of sorghum cultivars.

Table 1. Mean of squares according to analysis of variance for effect of seed priming, cultivars of sorghum and their interaction on traits studied in laboratory experiment

Source of Variance	df	Percentage of germination at first count	Percentage of germination at final count	Length of radicle	Length of plumule	Dry weight of seedling	Index of seedling vigour	Percentage of germination at cold test	Test of electrical conductivity
Seed priming	4	403.13*	363.86*	75.07*	15.85*	40.871*	1,413,047*	438.24*	609.81*
Cultivars of sorghum	2	0.9 ns	10.39*	9.53*	8.61*	10.217*	210,917*	2,194.45*	104.94*
Seed priming × cultivars of sorghum	8	64.41*	121.81*	5.36*	1.42*	5.21*	149,683*	491.98*	39.14*
Error	45	1.62	3.14	0.31	0.1081	0.039	5,523	0.39	0.043
SE	45	1.273	1.771	0.558	0.329	0.197	74.315	0.624	0.208
CV	45	1.9	2.5	4.2	4.8	2.6	5.3	2	1.5

* Significant at P<0.05; ns Not significant at P<0.05

Table 2. Mean of squares according to analysis of variance for effect of seed priming, cultivars of sorghum and their interaction on traits studied at field experiments in 2015 (A) for the spring season and (B) for the fall season

(A) Source of Variance	df	Percentage of field emergence	Weight of grain	Number of grain per plant	Yield of grain per plant	Total grain yield
Reps	3	3.69	1.61	17246	28.29	0.18
Seed priming	4	796.65*	44.73*	337,590*	679.39**	6.07*
Cultivars of sorghum	2	239.47*	18.39*	439,913*	336.51**	2.6*
Seed priming × Cultivars of sorghum	8	73.86*	1.42*	65,611*	54.91**	0.34*
Error	42	0.16	0.1	8,407	6.45	0.02
SE	42	0.398	0.323	91.688	2.539	0.152
CV	42	0.7	1.1	5.3	5.1	5.6

* Significant at P<0.05

(B) Source of Variance	df	Percentage of field emergence	Weight of grain	Number of grain per plant	Yield of grain per plant	Total grain yield
Reps	3	1.37	1.03	5,905.4	19.95	0.09
Seed priming	4	326.66*	62.48*	434,720*	1,174.9**	7.66*
Cultivars of sorghum	2	21.8*	39.95*	514,189.6*	912.3**	3.5*
Seed priming × Cultivars of sorghum	8	23.48*	5.29*	88,195.5*	176.27**	0.9*
Error	42	0.66	0.14	988.5	1.47	0.01
SE	42	0.814	0.37	31.44	1.213	0.089
CV	42	1.3	1.2	1.5	1.9	2.4

* Significant at P<0.05

Percentage of germination at first count (%)

Results in table 3 showed a significant superiority of GA3 compared with others and gave 73.9% as average of germination percentage at first count, while non-primed seed gave 60.3%. Interaction between GA3 and Inqath had a significant superiority compared with others and gave the highest average (80.4%), while interaction between non-primed seed and Inqath gave 58.1% as average of germination percentage at first count.

Table 3. Percentage of germination at first count (%) was affected by seed priming, cultivars of sorghum and their interaction in laboratory experiment

Seed priming	Cultivars of sorghum			Average
	Inqath	Kafier	Rabeh	
Non-primed seed	58.1	62.4	60.7	60.3
Distilled water	60.2	66.4	62.5	63
GA3 (300 mg*L^{-1})	80.4	71.1	70.3	73.9
KCl (40 mg*L^{-1})	65.5	68.6	72	68.7
Thiamine (30 mg*L^{-1})	75	69.3	71.7	72
Average	67.8	67.6	67.4	

LSD 5% for seed priming, cultivars of sorghum and their interaction were 1.1, n.s and 1.8, respectively.

Percentage of germination at final count (%)

Results in table 4 showed a significant superiority of GA3 compared with the rest of priming treatments and gave 76.7% as average of germination percentage at final count, while non-primed seed gave 62.5%. Rabeh had a significant difference with kafier, but it had not significant difference with Inqath, and gave 70.5% as average of germination percentage at final count, while Kafier gave 69.1%. Interaction between GA3 and Inqath had a significant superiority compared with others and gave the highest average (82%), while interaction between non-primed seed and Inqath gave 60.5% as average of germination percentage at final count.

Length of radicle (cm)

Results in table 5 showed a significant superiority of thiamine compared with others and gave 16.8 cm as average of radicle length, while non-primed seed gave 10 cm. Inqath had a significant difference compared with others and gave 13.8 cm as average of radicle length, while Kafier gave 12.4 cm. Interaction between thiamine and Inqath had a significant superiority compared with others and gave the highest

average (18.4 cm), while interaction between non-primed seed and Rabeh gave 9.5 cm as average of radicle length.

Table 4. Percentage of germination at final count (%) was affected by seed priming, cultivars of sorghum and their interaction in laboratory experiment

Seed priming	Cultivars of sorghum			Average
	Inqath	Kafier	Rabeh	
Non-primed seed	60.5	64.3	62.6	62.5
Distilled water	62.2	71.7	65.6	66.5
GA3 (300 mg*L^{-1})	82	74.8	73.1	76.7
KCl (40 mg*L^{-1})	67.6	71.2	75.2	71.3
Thiamine (30 mg*L^{-1})	78	63.6	76.1	72.6
Average	70.1	69.1	70.5	

LSD 5% for seed priming, cultivars of sorghum and their interaction were 1.5, 1.1 and 2.5, respectively.

Table 5. Length of radicle (cm) was affected by seed priming, cultivars of sorghum and their interaction in laboratory experiment

Seed priming	Cultivars of sorghum			Average
	Inqath	Kafier	Rabeh	
Non-primed seed	10.1	10.5	9.5	10
Distilled water	11.9	12.4	13.4	12.6
GA3 (300 mg*L^{-1})	14.7	14.1	13.5	14.1
KCl (40 mg*L^{-1})	14	10.1	12.6	12.3
Thiamine (30 mg*L^{-1})	18.4	15.1	16.9	16.8
Average	13.8	12.4	13.2	

LSD 5% for seed priming, cultivars of sorghum and their interaction were 0.5, 0.4 and 0.8, respectively.

Length of plumule (cm)

Results in table 6 showed a significant superiority of thiamine compared with others and gave 8.3 cm as average of plumule length, while non-primed seed gave 5.6 cm. Rabeh had a significant difference compared with others and gave 7.6 cm as average of plumule length, while Kafier gave 6.3 cm. Interaction between thiamine and Rabeh had a significant superiority compared with others and gave the highest average (9.6 cm), while interaction between non-primed seed and Inqath gave 5.3 cm as average of plumule length.

Table 6. Length of plumule (cm) was affected by seed priming, cultivars of sorghum and their interaction in laboratory experiment

Seed priming	Cultivars of sorghum			Average
	Inqath	Kafier	Rabeh	
Non-primed seed	5.3	5.5	5.9	5.6
Distilled water	6.2	6.7	6.5	6.5
GA3 (300 mg*L^{-1})	7.7	6.7	9.1	7.8
KCl (40 mg*L^{-1})	6.1	5.5	6.8	6.2
Thiamine (30 mg*L^{-1})	8.1	7.1	9.6	8.3
Average	6.7	6.3	7.6	

LSD 5% for seed priming, cultivars of sorghum and their interaction were 0.3, 0.2 and 0.5, respectively.

Dry weight of seedling (mg)

Results in table 7 showed a significant superiority of thiamine compared with others and gave 9.822 mg as average of dry weight of seedling, while non-primed seed gave 5.333 mg. Rabeh had a significant difference compared with others and gave 8.093 mg as average of dry weight of seedling, while Kafier gave 6.7 mg. Interaction between thiamine and Rabeh had a significant superiority compared with others and gave the highest average (11.167 mg), while interaction between non-primed seed and Inqath gave 5.133 mg as average of dry weight of seedling.

Index of seedling vigour

Results in table 8 showed a significant superiority of thiamine compared with others and gave the highest average of seedling vigour index (1,831.9), while non-primed seed gave the lowest average (974.9). Rabeh had a significant difference with Kafier, but it had not significant difference with Inqath, and gave the highest average of seedling vigour index (1,479), while Kafier gave the lowest average (1,295.5). The

highest average of seedling vigour index (2,068.9) associated with interaction between thiamine and Inqath, which had a significant superiority compared with others, except for interaction between thiamine and Rabeh, the difference was insignificant. Interaction between non-primed seed and Inqath gave the lowest average of seedling vigour index (932.5).

Table 7. Dry weight of seedling (mg) was affected by seed priming, cultivars of sorghum and their interaction in laboratory experiment

Seed priming	Cultivars of sorghum			Average
	Inqath	Kafier	Rabeh	
Non-primed seed	5.133	5.567	5.3	5.333
Distilled water	6.167	6.7	6.4	6.422
GA3 (300 mg*L^{-1})	10.2	7.167	9.433	8.933
KCl (40 mg*L^{-1})	6.1	6.533	8.167	6.933
Thiamine (30 mg*L^{-1})	10.767	7.533	11.167	9.822
Average	7.673	6.7	8.093	

LSD 5% for seed priming, cultivars of sorghum and their interaction were 0.162, 0.126 and 0.281, respectively.

Table 8. Index of seedling vigour was affected by seed priming, cultivars of sorghum and their interaction in laboratory experiment

Seed priming	Cultivars of sorghum			Average
	Inqath	Kafier	Rabeh	
Non-primed seed	932.5	1,025.7	966.6	974.9
Distilled water	1,131	1,367.5	1,303.6	1,267.4
GA3 (300 mg*L^{-1})	1,839	1,557	1,650.2	1,682.1
KCl (40 mg*L^{-1})	1,363.7	1,115	1,460.1	1,312.9
Thiamine (30 mg*L^{-1})	2,068.9	1,412.2	2,014.7	1,831.9
Average	1,467	1,295.5	1,479	

LSD 5% for seed priming, cultivars of sorghum and their interaction were 61.1, 47.3 and 105.8, respectively.

Percentage of germination at cold test (%)

Results in table 9 showed a significant superiority of thiamine compared with others and gave 39.9% as average of germination percentage at cold test, while non-primed seed gave 24.2%. Rabeh had a significant difference compared with others and gave 39% as average of germination percentage at cold test, while Kafier gave 18.8%. The highest average of germination percentage at cold test (55%) associated with interaction between thiamine and Inqath, which had a significant superiority compared with others, while interaction between KCl and Kafier gave the lowest average of germination percentage at cold test (10.5%).

Table 9. Percentage of germination at cold test (%) was affected by seed priming, cultivars of sorghum and their interaction in laboratory experiment

Seed priming	Cultivars of sorghum			Average
	Inqath	Kafier	Rabeh	
Non-primed seed	23.2	24	25.3	24.2
Distilled water	25.2	26.2	28.2	26.5
GA3 (300 mg*L^{-1})	37.5	17.4	40.5	31.8
KCl (40 mg*L^{-1})	28.2	10.5	52.5	30.4
Thiamine (30 mg*L^{-1})	55	16.1	48.6	39.9
Average	33.8	18.8	39	

LSD 5% for seed priming, cultivars of sorghum and their interaction were 0.5, 0.4 and 0.9, respectively.

Test of electrical conductivity (µS*cm^{-1}*g^{-1})

Results in table 10 showed a significant superiority of non-primed seed compared with others and gave the lowest average of electrical conductivity (7.19 µS*cm^{-1}*g^{-1}), while seed priming with KCl gave the highest average (25.04 µS*cm^{-1}*g^{-1}). Rabeh had a significant difference compared with others and gave the lowest average of electrical conductivity (11.19 µS*cm^{-1}*g^{-1}), while Kafier gave the highest average (15.77 µS*cm^{-1}*g^{-1}). The lowest averages of electrical conductivity were related with interaction between non-primed seed and each one of Rabeh, Inqath and Kafier cultivars (7.03, 7.2 and 7.33 µS*cm^{-1}*g^{-1}), respectively. They had a significant superiority compared with others, but they had not significant differences between of them. Interaction between KCl and Kafier gave the highest average of electrical conductivity (31.87 µS*cm^{-1}*g^{-1}).

Table 10. Test of electrical conductivity ($\mu S*cm^{-1}*g^{-1}$) was affected by seed priming, cultivars of sorghum and their interaction in laboratory experiment

Seed priming	Cultivars of sorghum			Average
	Inqath	Kafier	Rabeh	
Non-primed seed	7.2	7.33	7.03	7.19
Distilled water	8.17	8.5	8.37	8.34
GA3 (300 $mg*L^{-1}$)	14.3	18	12.17	14.82
KCl (40 $mg*L^{-1}$)	26.2	31.87	17.07	25.04
Thiamine (30 $mg*L^{-1}$)	12	13.13	11.3	12.14
Average	13.57	15.77	11.19	

LSD 5% for seed priming, cultivars of sorghum and their interaction were 0.17, 0.13 and 0.3, respectively.

Percentage of field emergence (%)

In spring season: results in table 11 showed a significant superiority of KCl compared with others and gave 70.2% as average of field emergence percentage, while non-primed seed gave 48.7%. Rabeh had a significant difference with kafier, but it had not significant difference with Inqath and gave 62.5% as average of field emergence percentage, while Kafier gave 56.5%. The highest average of field emergence percentage (72.2%) associated with interaction between thiamine and Rabeh, which had a significant superiority compared with others, except for interaction between KCL and Inqath, the difference was insignificant. Interaction between non-primed seed and Kafier gave the lowest average of field emergence percentage (40.1%).

In fall season: results in table 11 showed a significant superiority of KCl compared with others and gave 70% as average of field emergence percentage, while non-primed seed gave 56.2%. Rabeh had a significant difference with others and gave 64.6% as average of field emergence percentage, while Inqath gave 62.8%. The highest average of field emergence percentage (71.3%) associated with interaction between thiamine and Rabeh, which had a significant superiority compared with others, except for interactions between KCL and Inqath or KCl and Kafier, the difference was insignificant. Interaction between non-primed seed and Kafier gave the lowest average of field emergence percentage (55.3%).

Table 11. Percentage of field emergence (%) was affected by seed priming, cultivars of sorghum and their interaction during spring and fall seasons of 2015 at field experiments

Seed priming	Spring season of 2015				Fall season of 2015			
	Cultivars of sorghum			Average	Cultivars of sorghum			Average
	Inqath	Kafier	Rabeh		Inqath	Kafier	Rabeh	
Non-primed seed	53.5	40.1	52.4	48.7	56.3	55.3	56.9	56.2
Distilled water	58	58.3	55.4	57.2	60.8	61.4	61.2	61.2
GA3 (300 mg*L^{-1})	63.3	55.4	64.1	60.9	61.2	63.8	65.7	63.6
KCl (40 mg*L^{-1})	71.9	70.5	68.3	70.2	71	71	68	70
Thiamine (30 mg*L^{-1})	65	58	72.2	65.1	64.5	62.9	71.3	66.2
Average	62.3	56.5	62.5		62.8	62.9	64.6	

LSD 5% for seed priming, cultivars of sorghum and their interaction were 0.3, 0.3 and 0.6, respectively, at spring season, and 0.7, 0.5 and 1.2, respectively, at fall season.

Weight of grain (mg)

In spring season: results in table 12 showed a significant superiority of KCl compared with others and gave 30.83 mg as average of grain weight, while non-primed seed gave 25.89 mg. Inqath had a significant difference with others and gave 29.61 mg as average of grain weight, while Kafier gave 27.75 mg. The highest average of grain weight (31.47 mg) associated with interaction between KCl and Inqath, which had a significant superiority compared with others, except for interaction between GA3 and Inqath, the difference was insignificant. Interaction between non-primed seed and Rabeh gave 25.23 mg as average of grain weight.

In fall season: results in table 12 showed 33.26, 33.18 and 33.17 mg as averages of grain weight were related with thiamine, GA3 and KCl, respectively. They had a significant superiority compared with others, but they had not significant differences between of them, while non-primed seed gave 28.21 mg. Rabeh had a significant difference with others and gave 35.03 mg as average of grain weight, while Kafier gave 30.21 mg. The highest average of grain weight (35.18 mg) associated with interaction between KCl and Inqath, which had a significant superiority compared with others, except for interactions between GA3 and Rabeh or thiamine and Rabeh, the difference was insignificant. Interaction between non-primed seed and Kafier gave 27.23 mg as average of grain weight.

Table 12. Weight of grain (mg) was affected by seed priming, cultivars of sorghum and their interaction during spring and fall seasons of 2015 at field experiments

Seed priming	Spring season of 2015				Fall season of 2015			
	Cultivars of sorghum			Average	Cultivars of sorghum			Average
	Inqath	Kafier	Rabeh		Inqath	Kafier	Rabeh	
Non-primed seed	27.07	25.37	25.23	25.89	28	27.23	29.4	28.21
Distilled water	27.77	27.13	27.43	27.44	30.4	29.4	31.13	30.31
GA3 (300 mg*L^{-1})	31.2	28.47	29.33	29.67	32.2	32.17	35.17	33.18
KCl (40 mg*L^{-1})	31.47	30.43	30.6	30.83	35.17	30	34.33	33.17
Thiamine (30 mg*L^{-1})	30.57	27.33	28.9	28.93	32.4	32.23	35.13	33.26
Average	29.61	27.75	28.3		31.63	30.21	33.03	

LSD 5% for seed priming, cultivars of sorghum and their interaction were 0.27, 0.21 and 0.46, respectively, at spring season, and 0.31, 0.24 and 0.53, respectively, at fall season.

Number of grain per plant

In spring season: results in table 13 showed that highest average of grain number per plant (1,905.5) associated with GA3 and had a significant superiority compared with others, but it had not significant difference with thiamine, while non-primed seed gave 1,504.1 as average. Rabeh had a significant difference with others and gave 1,907.9 as average of grain number per plant, while Inqath gave 1,632.6 as average. Interaction between GA3 and Rabeh had a significant superiority compared with others and gave the highest average (2,262.8), while interaction between non-primed seed and Inqath gave 1,462.5 as average of grain number per plant.

In fall season: results in table 13 showed thiamine had a significant superiority compared with others and gave 2,352.1 as average of grain number per plant, while non-primed seed gave 1,828.7 as average. Inqath had a significant difference with others and gave 2,219.8 as average of grain number per plant, while Kafier gave 1,903.4 as average. Interaction between thiamine and Inqath had a significant superiority compared with others and gave the highest average (2,609.3), while interaction between non-primed seed and Rabeh gave 1,765.2 as average of grain number per plant.

Table 13. Number of grain per plant was affected by seed priming, cultivars of sorghum and their interaction during spring and fall seasons of 2015 at field experiments

Seed priming	Spring season of 2015				Fall season of 2015			
	Cultivars of sorghum			Average	Cultivars of sorghum			Average
	Inqath	Kafier	Rabeh		Inqath	Kafier	Rabeh	
Non-primed seed	1,462.5	1,532.9	1,517.1	1,504.1	1,865.2	1,855.8	1,765.2	1,828.7
Distilled water	1,623.9	1,601.2	1,690.9	1,638.7	2,045.8	1,959.3	1,955.4	1,986.8
GA3 (300 mg*L^{-1})	1,699.6	1,754.1	2,262.8	1,905.5	2,181.3	1,811.1	2,134.2	2,042.2
KCl (40 mg*L^{-1})	1,676.1	1,623.7	2,001.4	1,767.1	2,397.7	1,724.4	1,947.9	2,023.3
Thiamine (30 mg*L^{-1})	1,701	1,860.3	2,067	1,876.1	2,609.3	2,166.3	2,280.6	2,352.1
Average	1,632.6	1,674.4	1,907.9		2,219.8	1,903.4	2,016.7	

LSD 5% for seed priming, cultivars of sorghum and their interaction were 75.5, 58.5 and 130.8, respectively, at spring season, and 25.9, 20.1 and 44.9, respectively, at fall season.

Yield of grain per plant (g)

In spring season: results in table 14 showed GA3 gave 56.43 g as average of grain yield per plant and had a significant superiority compared with others, except KCl, the difference was insignificant, while non-primed seed gave 38.93 g. Rabeh had a significant difference with others and gave 54.39 g as average of grain yield per plant, while Kafier gave 46.51 g. Interaction between GA3 and Rabeh had a significant superiority compared with others and gave the highest average of grain yield per plant (66.33 g), while interaction between non-primed seed and Rabeh gave 38.28 g.

In fall season: results in table 14 showed thiamine had a significant superiority compared with others and gave 78.17 g as average of grain yield per plant, while non-primed seed gave 51.57 g. Inqath had a significant difference with others and gave 70.7 g as average of grain yield per plant, while Kafier gave 57.6 g. The highest

average of grain yield per plant (84.54 g) associated with interaction between thiamine and Inqath, which had a significant superiority compared with others, except for interaction between KCl and Inqath, the difference was insignificant. Interaction between non-primed seed and Kafier gave the lowest average of grain yield per plant (50.56 g).

Table 14. Yield of grain per plant (g) was affected by seed priming, cultivars of sorghum and their interaction during spring and fall seasons of 2015 at field experiments

Seed priming	Spring season of 2015				Fall season of 2015			
	Cultivars of sorghum			Average	Cultivars of sorghum			Average
	Inqath	Kafier	Rabeh		Inqath	Kafier	Rabeh	
Non-primed seed	39.61	38.9	38.28	38.93	52.23	50.56	51.91	51.57
Distilled water	45.1	43.44	46.39	44.98	62.2	57.61	60.88	60.23
GA3 (300 mg*L^{-1})	53.03	49.93	66.33	56.43	70.23	58.26	75.05	67.85
KCl (40 mg*L^{-1})	52.74	49.43	61.25	54.47	84.32	51.71	66.89	67.64
Thiamine (30 mg*L^{-1})	52	50.85	59.72	54.19	84.54	69.83	80.13	78.17
Average	48.49	46.51	54.39		70.7	57.6	66.97	

LSD 5% for seed priming, cultivars of sorghum and their interaction were 2.09, 1.62 and 3.62, respectively, at spring season, and 1, 0.77 and 1.73, respectively, at fall season.

Total grain yield (ton*ha^{-1})

In spring season: results in table 15 showed KCl had a significant superiority compared with others and gave the highest average of total grain yield (3.396 ton*ha^{-1}), while non-primed seed gave 1.685 ton*ha^{-1}. Rabeh had a significant difference with others and gave the highest average of total grain yield (3.084 ton*ha^{-1}), while Kafier gave the lowest average (2.363 ton*ha^{-1}). The highest average of total grain yield (3.833 ton*ha^{-1}) associated with interaction between thiamine and Rabeh, which had a significant superiority compared with others, except for interactions between GA3 and Rabeh or KCl and Rabeh, the difference was insignificant. Interaction between non-primed seed and Kafier gave the lowest average of total grain yield (1.387 ton*ha^{-1}).

In fall season: results in table 15 showed thiamine had a significant superiority compared with others and gave the highest average of total grain yield (4.611 ton*ha^{-1}), while non-primed seed gave 2.576 ton*ha^{-1}. Inqath had a significant

difference with others and gave the highest average of total grain yield (3.992 ton*ha^{-1}), while Kafier gave the lowest average (3.222 ton*ha^{-1}). Interaction between KCl and Inqath had a significant superiority compared with others and gave the highest average of total grain yield (5.319 ton*ha^{-1}), while interaction between non-primed seed and Kafier gave the lowest average of total grain yield (2.488 ton*ha^{-1}).

Table 15. Total grain yield (ton*ha^{-1}) was affected by seed priming, cultivars of sorghum and their interaction during spring and fall seasons of 2015 at field experiments

Seed priming	Spring season of 2015				Fall season of 2015			
	Cultivars of sorghum			Average	Cultivars of sorghum			Average
	Inqath	Kafier	Rabeh		Inqath	Kafier	Rabeh	
Non-primed seed	1.883	1.387	1.785	1.685	2.614	2.488	2.625	2.576
Distilled water	2.327	2.25	2.304	2.294	3.361	3.147	3.314	3.274
GA3 (300 mg*L^{-1})	2.982	2.457	3.782	3.074	3.819	3.306	4.383	3.836
KCl (40 mg*L^{-1})	3.371	3.099	3.717	3.396	5.319	3.264	4.044	4.209
Thiamine (30 mg*L^{-1})	3.004	2.623	3.833	3.153	4.847	3.904	5.082	4.611
Average	2.713	2.363	3.084		3.992	3.222	3.89	

LSD 5% for seed priming, cultivars of sorghum and their interaction were 0.125, 0.097 and 0.216, respectively, at spring season, and 0.074, 0.057 and 0.127, respectively, at fall season.

Discussion

Seed priming technique is effective to improve traits studied in comparison with non-primed seed. This is consistent with what mentioned by Ashraf and Foolad (2005) and Moradi and Younesi (2009).

Gibberellins play an important role in activity of metabolic that occurs during the process of germination and this may lead to improve growth and grain yield later. Maybe, That was the reason behind the superiority of GA3 at percentages of germination at first and final counts, weight of grain, number of grain per plant and yield of grain per plant in comparison with other treatments (Tables 3, 4, table 12 in fall season, tables 13 and 14 in spring season, respectively). This result is supported by Richards et al. (2001), Olszewski et al. (2002), Cheyed (2008) and Al-Selawy (2011).

Thiamin had a role in seed priming compared with other treatments, which led to supremacy of lengths of radicle and plumule, dry weight of seedling, index of seedling vigour, percentage of germination at cold test, number of grain per plant, weight of grain, yield of grain per plant and total grain yield (Tables 5, 6, 7, 8, 9, 13, tables 12, 14 and 15 in fall season, respectively). Thiamine plays many roles to improve germination, growth and reproduction through helping to improve construction of root system, and repairs damaged parts especially under environmental stress. Probably this suggests a best way to add thiamine is seed soaking or foliar application at some stage of vegetative growth. Note that, in several previous studies, thiamine was used as a factor to tolerate or reducing injury diseases, insecticides and some environmental stresses through seed soaking or sprayed it on vegetative parts (Rapala-Kozik et al., 2008; Pushpalatha et al., 2011; Hamada and Jonsson, 2013; Balliu et al., 2016).

Potassium chloride (KCl) had a role in priming of seed, because it superiority at percentage of field emergence, weight of grain, yield of grain per plant and total grain yield (Tables 11, 12, tables 14 and 15 in spring season, respectively) compared to other treatments. This is consistent with what mentioned by Fixen (1993), Farooq (2005), Al-Selawy (2011), Badar uz Zaman et al. (2012), Lemrasky and Hosseini (2012) and Dawood (2014).

Priming of seed by thiamine led to improve performance of seed under cold stress compared with non-primed seed (Table 9). Maybe this refers to effectiveness of seed priming technique at enhancing of seed tolerance to environmental stress. It gives an indicator to study the possibility of tolerance to other environmental stresses. This is consistent with what mentioned by Ashraf and Foolad (2005), Rapala-Kozik et al. (2008) Moradi and Younesi (2009) and Balliu et al. (2016).

Results of electrical conductivity test showed seed priming had disadvantages as well when non-primed seed had a performance better than primed seed under this test (Table 10). Logically, proportion of electrolytes that leaks from seed should be higher in primed seed than non-primed. Perhaps it due to an activation of metabolic processes in advance, and demolition of compounds of large molecular weight as a result of pre-activation process. Perhaps, it is an indication shows that primed seed have short storage duration compared with non-primed. This is consistent with what mentioned by Murungu et al. (2004), Ashraf and Foolad (2005), Cheyed (2008), Moradi and Younesi (2009), Al-Selawy (2011) and Nawaz (2013).

Genotype and chemical variations of cultivars could be an enough reason for their different performance regardless if that performance was under narrow or wide range of environmental conditions. Maybe this is the reason behind supremacy of Rabeh in percentage of germination at first count, length of plumule, dry weight of seedling, index of seedling vigour, percentage of germination at cold test, test of electrical conductivity, percentage of field emergence, weight of grain, number of grain per plant, yield of grain per plant and total grain yield (Tables 4, 6, 7, 8, 9, 10, 11, table 12 in fall season, tables 13, 14 and 15 in spring season, respectively). Also, Inqath cultivar had a superiority in percentage of germination at first count, length of radicle, index of seedling vigour, number of grain per plant, yield of grain per plant and total grain yield (Tables 4, 5, 8, table 12 in spring season, tables 13, 14 and 15 in fall season, respectively). Kafier had not superiority at most traits under this study.

Response trend of field emergence during spring and fall seasons (Table 11) was similar to response trend of plumule length, dry weight of seedling and index of seedling vigour (Tables 6, 7 and 8).

Response trend of grain yeild per plant (Table 14) was similar to response trend of grain number per plant and weight of grain (Tables 12 and 13) during both seasons under this study. But highest proportion of influencing on yield of grain per plant was belonging to number of grain per plant in comparison to weight of grain under this study.

Response trend of total grain yield (Table 15) was related or similar to response trend of grain yield per plant and field emergence (Tables 11 and 14) during spring and fall seasons under this study. A highest proportion of influencing on total grain yield was belonging to yield of grain per plant in comparison to percentage of field emergence that reflects field establishment or number of plants per area under this study.

Seed priming technique with GA3, KCl or thiamine with different cultivars of sorghum has led to improve all traits under this study in comparison to non-primed seed. The highest proportion of influencing on most traits under this study was belonging to effect of seed priming in comparison to effect of sorghum cultivars (Tables 1 and 2). Possibly, it due to stability and adaptation of studied sorghum cultivars to grow in same environmental conditions during spring or fall seasons under this study.

Conclusions

Technique of seed priming led to improve all traits under this study in comparison to non-primed seed. A superiority of GA3 or KCl or thiamine was various over most traits. Stabile effect was not recorded for any of these materials on most traits under this study. Cultivars of sorghum had various responses according to existing of priming factor or not. The responding of traits studied to effect of seed priming, cultivars of sorghum and their interaction was not the same under standard growth conditions in laboratory or under growth conditions at field during spring or fall seasons. In general, seed priming led to enhance all traits studied regardless of growth conditions in laboratory or at field. It can be recommended to do more studies about these priming materials as a combination at different concentrations.

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