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Effect of seed priming on germination and seedling vigor indices of maize seed under environmental stress conditions

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Abstract

This study was aimed to evaluating the influence of seed priming treatments on germination and seedling vigor of maize seed. The experiment was laid in a Completely Randomized Block Design with three replicates, in the preservation laboratory of Seed Technology Research Department, Mansoura Unit, Dakahlia Governorate, Egypt. Seeds were soaked in distilled Water (DW), $CaCl_2$ (3%), Kh_2Po_4 (3%), [$(NH_4)2MoO_4$ (3%)] and Vitavax fungicide (2%), along with dry seed as a control treatment, under environmental stress conditions (three germination temperatures conditions *i.e*., 20°C, 25°C and 30°C and three water potentials (ψ) *i.e*., -0.2, 0.-0.4 and -0.6 MPa during 2019 and 2020 seasons. The results illustrated that, factors treatments *i.e*., 30°C and -0.2 MPa significantly recorded the optimum mean values of germination percentage (G%), germination energy (GE%), germination velocity Index (GVI), mean germination time (MGT, day), seedling length (SL, cm), seedling fresh and dry weights (SFW & SDW, gm), and seedling vigor index (SVI-I), while compared to the other treatments. Additionally, all seed priming treatments recorded the highest mean values in contrast to the control treatment. Moreover, treated seeds with ($Cacl_2$ 3%) critically exceed the other seed priming treatments under all stresses conditions, with respect to all germination and seedling vigor parameters.

Keywords: Maize; Seed priming; Temperature; Water potential; Germination Indices

Full length article **Corresponding Author*, e-mail: medhat.eldrenyl@arc.sci.eg

1. Introduction

Maize (*Zea mays* L.*)* crop is ranked the third important grain under global cultivation after wheat and rice crops. Maize crop performance a substantial function in the world economy and is valuable ingredient in produced items, that effectiveness a large attribution of the world population Maize grain contains starch (72%), protein (10%), oil (4.8%), fiber (5.8%), sugar (3.0%), and ash (1.7%) [1]. Under field conditions, the optimal maize seed germination temperature is between 25°C and 28°C. Sub-optimal temperature has deleterious effects on seedling emergence and stand establishment, reduces seedling growth, relative water content, amylase activity and soluble sugars [2]. [3] Studied the effects of early (mid-March), normal (mid-April) and late (mid-May) sowing date (SD) over a three-year period in irrigated maize under Mediterranean conditions. Early SD increased the number of days from sowing to plant emergence. Eight different temperature levels were examined, 5, 10, 15, 20, 25, 30, 35, and 40 °C, it was being found that 20 °C was less than 30°C of germination occurred [4]. Water availability and movement into the seeds are very important to promote germination, initial root enhancement and shoot elongation. Therefore, Seed germination and seedling establishment are potentially the most critical stages for water stress. In general, seed water content of cereal crops must reach at least 35 to 45% of seed dry mass to occur the germination process. Lack of water caused a decrease in germination percentage in maize [5]. The highly negative osmotic potential may affect the seeds water uptake, making germination not possible [6]**.** In addition, Maize is relatively susceptible to drought. Indeed, [7] showed that the osmotic potential of -1.2 MPa reduced the seed germination and shoot length of maize seedlings at 71 and 90%, respectively, when compared to the control (0 MPa). Seed priming is one of the physiological methods that improves seed performance and provides faster and synchronized germination, [8] evaluated the influence of seed priming on physiological parameters of fresh and aged seeds of maize hybrid COH M5. Seeds were soaked in water, 1% KH2PO4, 3% KNO_3 and 2% $CaCl_2$ solution for 6 hrs. The result revealed that seed priming with 1% KH_2PO_4 for 6 hrs showed an increased physiological performance in fresh and aged seeds of UMI 285, UMI 61 and COH M5. The increased physiological performance was observed in terms of increased germination percentage, shoot length, root length, dry matter production and vigor index; accompanied with earlier germination in terms of days to 50% germination and days to maximum germination. Increased field emergence potential was also observed in the seeds primed with 1% KH_2PO_4 for 6 hrs. However, more pronounced effect of seed priming with 1% KH2PO4 for 6 hours was observed in aged seeds than in fresh seeds. [9] Found that, maize seed priming with $Cacl_2$ reduced mean germination time and increased germination percentage, emergence and seedling length. Therefore, this study aimed to evaluate the influence of seed priming technique on maize seed under different temperatures and water potentials conditions.

2. Materials and Methods

Laboratory experiment was carried out at the Laboratory of Seed Technology Research Unit, Mansoura during two summer seasons 2019 and 2020 to evaluate the effect of seed priming, (Distilled Water, Calcium chloride (3%), Potassium dehydrogenate phosphate (3%), Ammonium molybdate (3%) and Vitavax fungicide (2%), under three germination temperature based on growth chamber conditions i.e., 20°C, 25°C and 30°C and three water potentials (ψ) induced by Polyethylene Glycol 6000 in laboratory which were -0.2 , 0.-4 and -0.6 MPa [10]**.** In the present study, seed samples of maize (hybrid Giza 10) were obtained from Field Crops Research Institute, Agricultural Research Center, Giza, Egypt.

2.1. Seed priming procedure

Seed samples of maize, were treated with 0.1% mercuric chloride solution for two minutes and then rinsed three times with autoclaved distilled water. Distilled water beside chemical solutions *i.e*., Calcium chloride ($CaCl_2$, 3%), Potassium dehydrogenate phosphate (Kh_2Po_4, 3%), Ammonium molybdate ($(NH_4)_2MoO_4$, 3%) and Vitavax fungicide (2%), along with un-primed seeds which was served as a control treatment, were prepared separately. The ratio of seed weight to solution volume was 1:5 (g ml^{-1}), obtained by soaking 200 g of seeds in 1000 mL of freshly respective chemical solution for three hours for maize seeds, while soaking in vitavax solution was 30 mints for maize seeds. Every three hours, air blower to prevent smothering of the seeds in the solution blew the selective chemical solutions containing immersed seeds. Then, seeds were dried back to the original seed moisture content at the room temperature under shade [11].

2.2. Water potential treatments

To stimulate drought stress conditions, three grades of water potential treatments were induced by Poly Ethylene Glycol (PEG-6000), [10] which were; -0.2 (MPa) induced by 120 gm of PEG-6000 dissolved in one litter of water at 20°C. -0.4 (MPa) induced by 180 g PEG-600 1 L water/25° C. -0.6 (MPa) induced by 180 g PEG-6000/1L water/5°C (Table, 1). Then after, the germination paper substrates of each treatment were immersed in different PEG solutions in a volume equivalent to 2.5 times the mass of dry paper. Then after, germination papers were covered to maintain relative humidity, before imposing germination procedure.

2.3. Standard germination test

Standard laboratory germination test is the most common and practical seed viability and vigor test, according to International Seed Testing Association roles [12]. One hundred seeds per each treatment were tested between two moistened filter papers located in sterilized Petri-dishes (14 cm diameter). Each Petri-dish contain 25 seed, every four Petri-dishes were preserved close together and considered as though they were one replication. Then, dishes were placed in incubator chamber at 25 °C and 80% RH under the dark conditions. Filter papers were moistened with 10 ml of autoclaved distilled water when necessary to avoid seed drying. Daily observation for seed germination indices continued for seven days after germination to measure physiological seed quality indices as follow;

2.4. Physiological seed quality indices

2.4.1. Germination percentage (G%)

At the end of the test state, the number of germinated seeds was recorded after seven days from testing as final germination percent [12];

$$G\% = (\text{Total No. of germinated seeds} / \text{Total No. of seeds evaluated}) \times 100$$

2.4.2. Germination Energy (GE%)

It was determined on the 4^{th} day of seed sowing as recorded**,** as follow [13];

$$GE\% = (\text{Germination percentage after four days} / \text{total No. of tested seed}) \times 100$$

2.4.3. Germination Velocity Index (GVI)

Germination velocity index was calculated according to by the following formula [14];

$$GVI= G1/N1 + G2/N2 +\cdots+ Gn/Nn$$

Where G1, G2 and Gn the number of germinated seeds in first second….and last count. N1, N2 and Nn were the number of sowing days at the first, second…….and last count.

2.4.4. Mean Germination Time (MGT day)

It was calculated by the following formula [15], as follow;

$$MGT = \sum (D \times n) / \sum n$$

Where n, is the number of seeds germinated on day D and n is the number of days counted from the beginning of the test.

2.4.5. Seedling length (cm)

Ten seedlings were taken randomly per each replicate to measure seedling length expressed in cm at the end of standard germination test [16].

2.4.6. Seedling fresh and dry weights (g)

Ten seedlings were taken to estimate seedlings fresh weight, then oven-dried at 70ºC until constant weight was reached to estimate the seedling dry weights, [17].

2.4.7. Seedling vigor index (SVI-I)

They were calculated using the following equations, [18], as follow;

$$\text{SVI-I} = \text{Seedling length (cm)} \times \text{Germination \%}$$

2.5. Experimental design

Three experiments of maize seed germination were conducted based on three constant temperatures beneath growth chamber conditions i.e., 20°C, 25°C, and 30°C. Each of germination experiments was laid in a Completely Randomized Block Design (CRBD) according to analysis of variance (ANOVA) technique. Each experiment included two factors and replicated four times with combinations of 72 treatments (3 water potential × 6 seed priming treatments × 4 replicates), then combined analysis was conducted between germination temperatures [19]. The least significant deference's (LSD at 0.05%) was used to detect the significance among means of different treatments [20].

3. Results and discussion

Results in Table (2 & 3) presented germination percentage (G%), germination energy (GE%), speed germination index (SGI), mean germination time (MGT day), seedling length (SL cm), seedling fresh weight (SFW g), seedling dry weight (SDW g), and seedling vigor index (SVI) as affected by germination temperature, water potential, and seed priming treatments, and their interactions on maize seed germination and seedling vigor indices.

3.1. Germination temperature effects

Presented data (Table 2), indicated highly significant variation (LSD at 0.05%) under various germination temperatures. The germination indices of G (%), GE (%), and SGI, recorded the highest mean values and the lowest mean values of MGT (day) under 30 °C of growth chamber temperature, followed by germination temperatures of 25 ºC and 20 ºC, respectively. In addition, exposing maize seed to 30 °C recorded the highest mean values *i.e*., 84.85% of G%, 17.23% of GE%, 72.5 of SGI, and the lowest mean germination time of 5.04 day. Maize seeds generally require a warm temperature range of 25 to 30 °C for optimal germination. Within this range, the metabolic processes within the seed are activated, facilitating efficient water uptake and enzymatic activities necessary for germination. Deviating from this temperature range can result in delayed or inhibited germination. More, the low temperature causing lower mitochondrial respiratory activity, electron transport, and ATPase activity [21]. More, the temperature is a necessary factor for seed germination. Moderate temperatures around 26–29 °C are required for a maize seed to germinate. Maize cannot germinate when the temperature is too high (>45 °C) or too low (<6.2 °C), [22]. [23] showed that the cell energy status and the activity of some enzymes *i.e*., lipase, alanine aminotransferase, aspartate aminotransferase, and especially ribonuclease changed as the temperature increased from 23 °C to 41 °C. At the early stage of seed germination, the ATP content significantly increased with increased temperature from 28 °C to 41 °C. More, protein synthesis was severely reduced at high temperatures (>37 °C) in contrast to 28 °C. The change in temperature strongly affected respiration and sugar metabolism during germination, and led to the abnormal respiration interferes with the homeostasis of reactive oxygen species (ROS), which is critical for seed germination. Similar results were found [23,4]. Exhibited data (Table 3), revealed highly significant variation rates (LSD at 0.05%) on SL (cm), SFW (g), SDW (g), and SVI indices, due to applying germination temperature treatment levels on maize seed. More, a germination temperature of 30 ºC was the superior treatment followed by 25 ºC and 20 ºC, respectively. In addition, applied 30 ºC treatment resulted in the highest mean values of all seedling vigor indices, which were 16.35 cm of SL, 11.30 g of SFW, 6.34 g of SDW, and 1257.7 of SVI, as shown in Table (3).

3.2. Water potential effects

Various concentrations of water potential induced by Polyethylene Glycol (PGA-6000), as declared in Table (2) showed significant differences. According to combined analysis results, the superiority level of PGA1 (-0.2 MPa) recorded the highest mean values *i.e*., 86.17% of G%, 15.74% of GE%, and 73.97 of SGI, and the lowest mean values of MGT of 4.67 day. Moreover, applied water potential levels of PGA2 (-0.4 MPa) and PGA3 (-0.6 MPa) came in second and third place, respectively. The most common responses of plants to the reduction of osmotic potential are a delay in initial germination and a reduction in the rate and total germination. Decreased germination parameters with declined osmotic potential could be explained by lack of imbibition water uptake which the principal factor is starting the germination process, promoting cell respiration, DNA synthesis and growth [24 & 25]. Likewise, [26] revealed that, under water deficient conditions, root-induced signaling pathways to the shoot via the xylem induce physiological alterations to adapt under low water potential. Under these conditions, the O_2 supply around the root zone is depleted due to reduction in photorespiration, which affects the ATP production and eventually declining the ATP/ADP ratio. Likewise, data presented in Table (3) indicated significant variation rates (LSD at 0.05%) on seedling vigor indices *i.e*., SL (cm), SFW (g), SDW (g) and SVI, due to sowing maize seeds under some variation levels of water potential treatment.

Table 1. Equivalents among Poly Ethylene Glycol solution concentrations (gram PEG-6000 / liter of water) and water potentials (MPa) for temperatures according to the equation of Michel and Kaufmann (1973)

Concentrations (g PEG/ l liter water)	Temperature (°C)	Water Potential (MPa)
120	20	-0.2
180	25	-0.4
180	5	-0.6

Table 2. Germination percentage (G%), germination energy (GE), speed germination index (SGI) and mean germination time (MGT) as affected by temperatures, water potential and maize seed priming (combined over two seasons)

Treatments / Traits	G (%)	GE (%)	GVI	MGT (day)
(A): Germination temperature				
20 °C	72.49c	11.43c	62.29c	5.71a
25 °C	78.19b	14.92b	67.79b	5.40b
30 °C	84.85a	17.23a	72.51a	5.04c
F test	**	**	**	**
(B): Water potential (ψ)				
PGA_1 (-0.2 MPa)	86.17a	15.74a	73.97a	4.67c
PGA_2 (-0.4 MPa)	78.68b	14.18b	67.70b	5.46b
PGA_3 (-0.6 MPa)	70.69c	13.26c	60.92c	5.95a
F test	**	**	**	**
(C): Seed priming				
Dry seed (Cont.)	65.56f	11.69f	56.31f	6.15a
Distilled water	72.82e	12.43e	62.59e	5.64b
$CaCl_2$ (3%)	87.66a	19.22a	75.38a	4.66f
Kh_2Po_4 (3%)	82.92c	14.43c	71.02c	5.29d
$(NH_4)2MoO_4$ (3%)	78.46d	13.41d	67.45d	5.54c
Vitavax (2%)	83.71b	15.98b	72.44b	4.82e
F test	**	**	**	**
(D): Interactions				
A x B	**	NS	**	**
A x C	**	NS	**	**
B x C	*	**	**	**
A x B x C	**	NS	*	*

PGA1 = -0.2 MPa, PGA2 = -0.4 MPa and PGA3 = -0.6 MPa.

Table 3. Seedling length (SL cm), seedling fresh weight (SFW), seedling dry weight (SDW) and seedling vigor index as affected by temperatures, water potential and maize seed priming of combined two seasons

Treatments / Traits	SL (cm)	SFW (g)	SDW (g)	SVI
(A): Germination temperature				
20 °C	13.72c	8.12c	3.77c	1051.61c
25 °C	15.52b	9.41b	5.63b	1241.12b
30 °C	16.35a	11.30a	6.34a	1257.72a
F test	**	**	**	**
(B): Water potential (ψ)				
PGA_1 (-0.2 MPa)	17.72a	12.05a	6.44a	1505.31a
PGA_2 (-0.4 MPa)	15.19b	9.92b	5.16b	1176.32b
PGA_3 (-0.6 MPa)	12.62c	7.97c	4.15c	868.71c
F test	**	**	**	**
(C): Seed priming				
Dry seed (Cont.)	12.74f	6.44f	3.53f	866.42f
Distilled water	13.44e	8.32e	3.94e	1019.45e
$CaCl_2$ (3%)	17.88a	13.69a	7.33a	1508.12a
Kh_2Po_4 (3%)	16.15c	9.94c	5.61c	1273.21c
$(NH_4)2MoO_4$ (3%)	14.47d	9.26d	4.55d	1109.365d
Vitavax (2%)	16.41b	12.18b	6.87b	1325.51b
F test	**	**	**	**
(D): Interactions				
A x B	**	NS	**	**
A x C	**	NS	**	**
B x C	*	**	**	**
A x B x C	**	NS	*	*

PGA1 = -0.2 MPa, PGA2 = -0.4 MPa and PGA3 = -0.6 MPa.

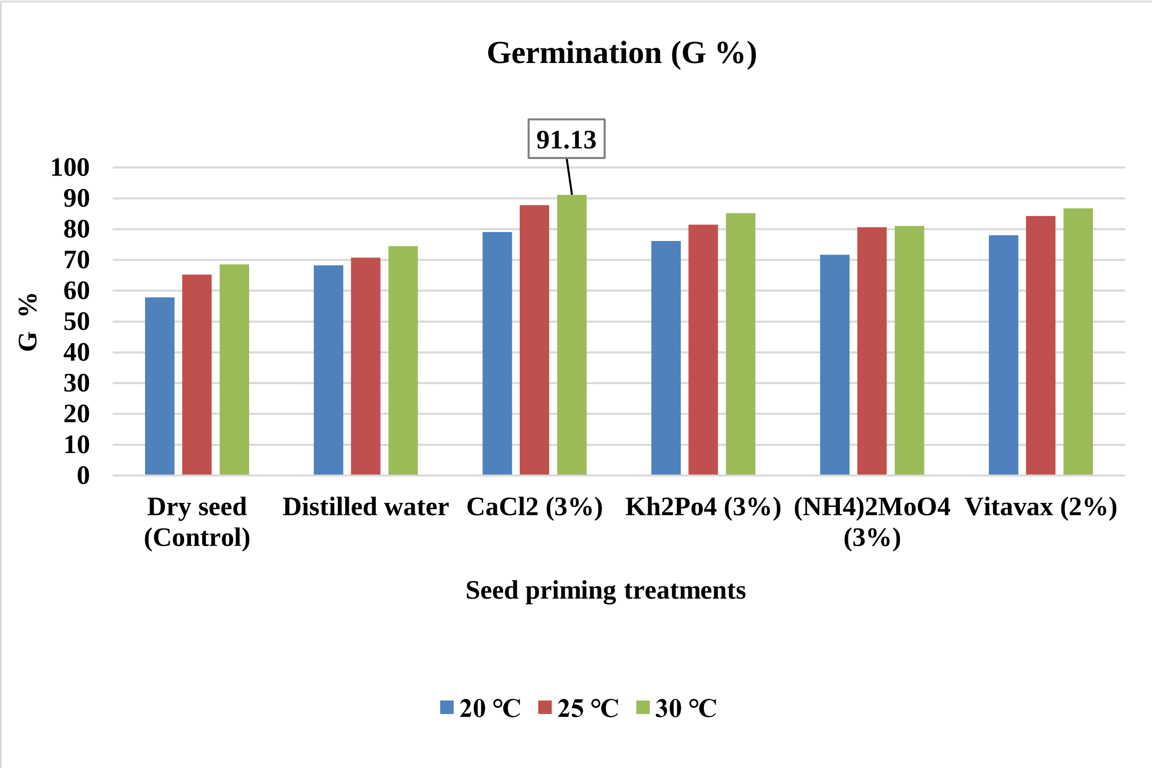


Figure 1. Means of germination percentage (G %) as affected by the interaction between germination temperature levels and seed priming treatments on maize seed.

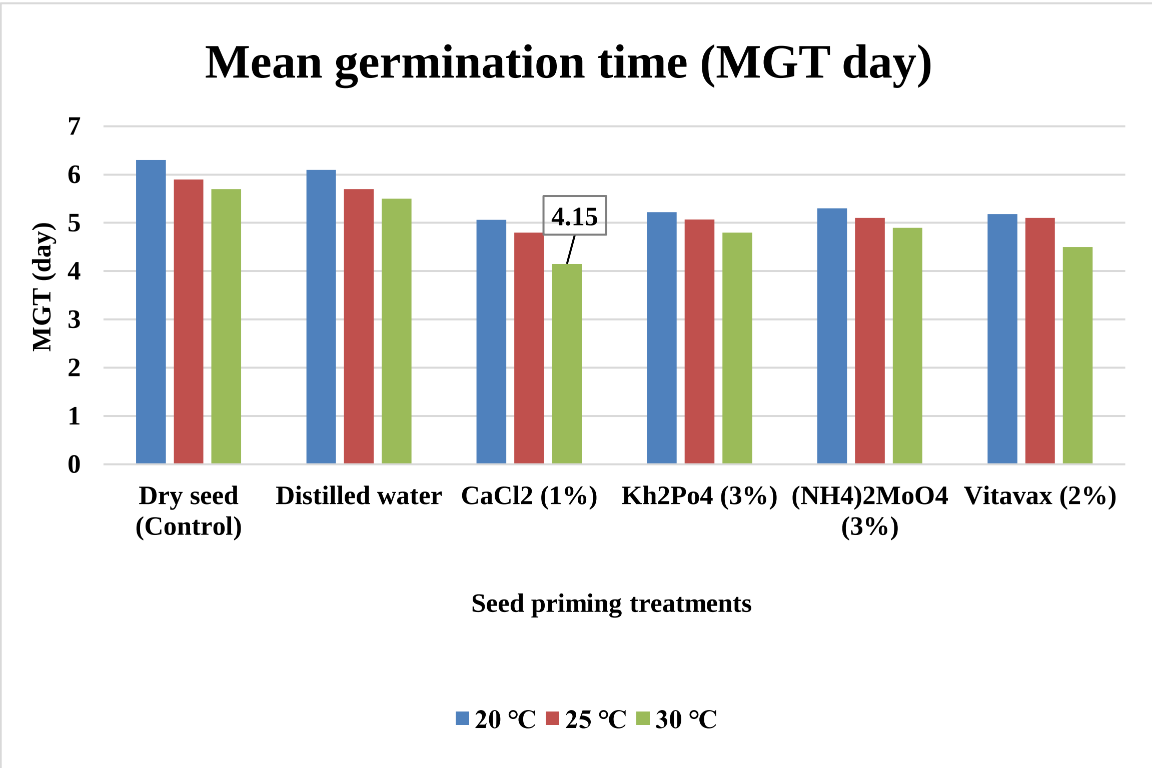
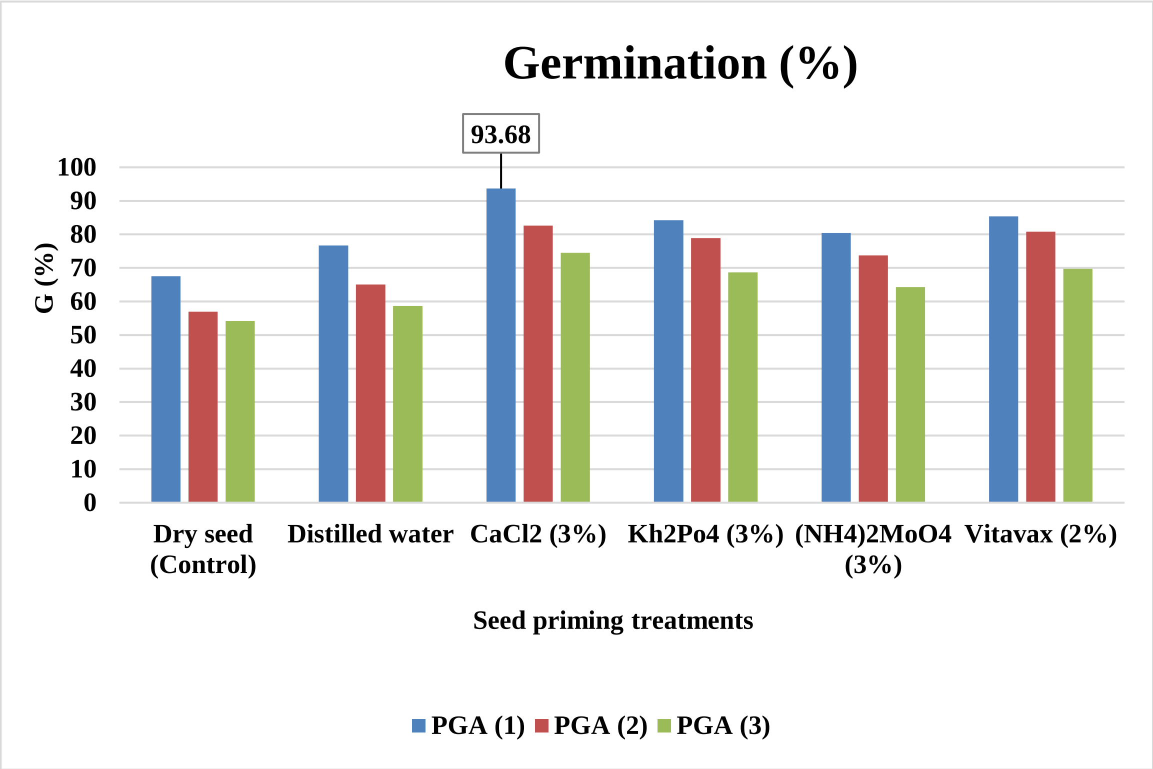
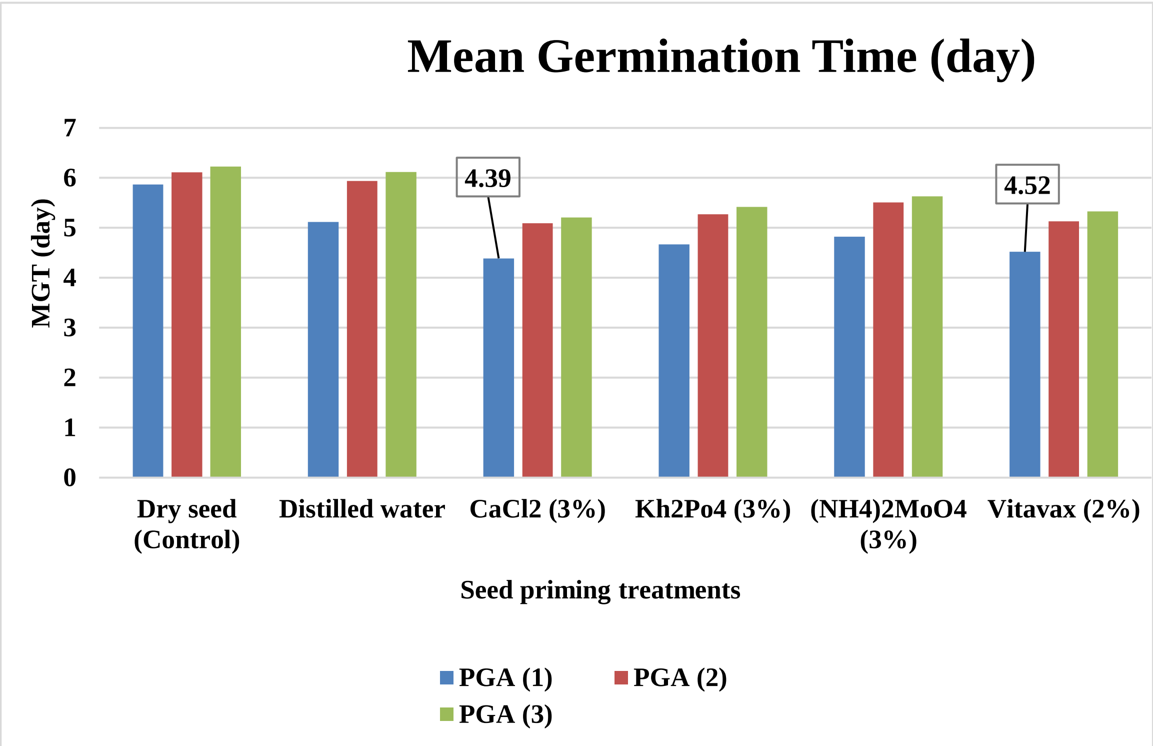


Figure 2. Means of mean germination time (MGT day) as affected by the interaction between germination temperature levels and seed priming treatments on maize seed.



PGA1 = -0.2 MPa, PGA2 = -0.4 MPa and PGA3 = -0.6 MPa.

Figure 3. Means of germination percentage (G %) as affected by the interaction between water potential (ψ) levels and seed priming treatments on maize seed.



PGA1 = -0.2 MPa, PGA2 = -0.4 MPa and PGA3 = -0.6 MPa.

Figure 4. Means of mean germination time (MGT day) as affected by the interaction between water potential (ψ) levels and seed priming treatments on maize seed.

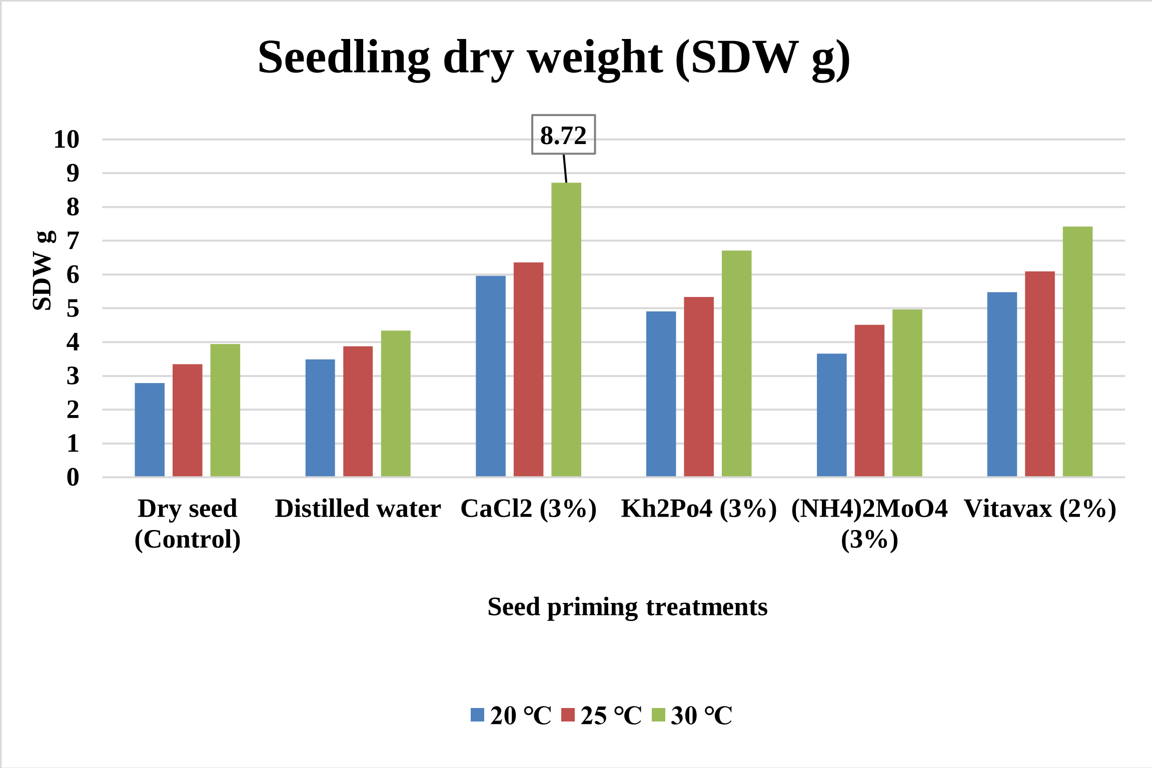


Figure 5. Means of seedling dry weight (g) as affected by the interaction between germination temperature levels and seed priming treatments on maize seed.

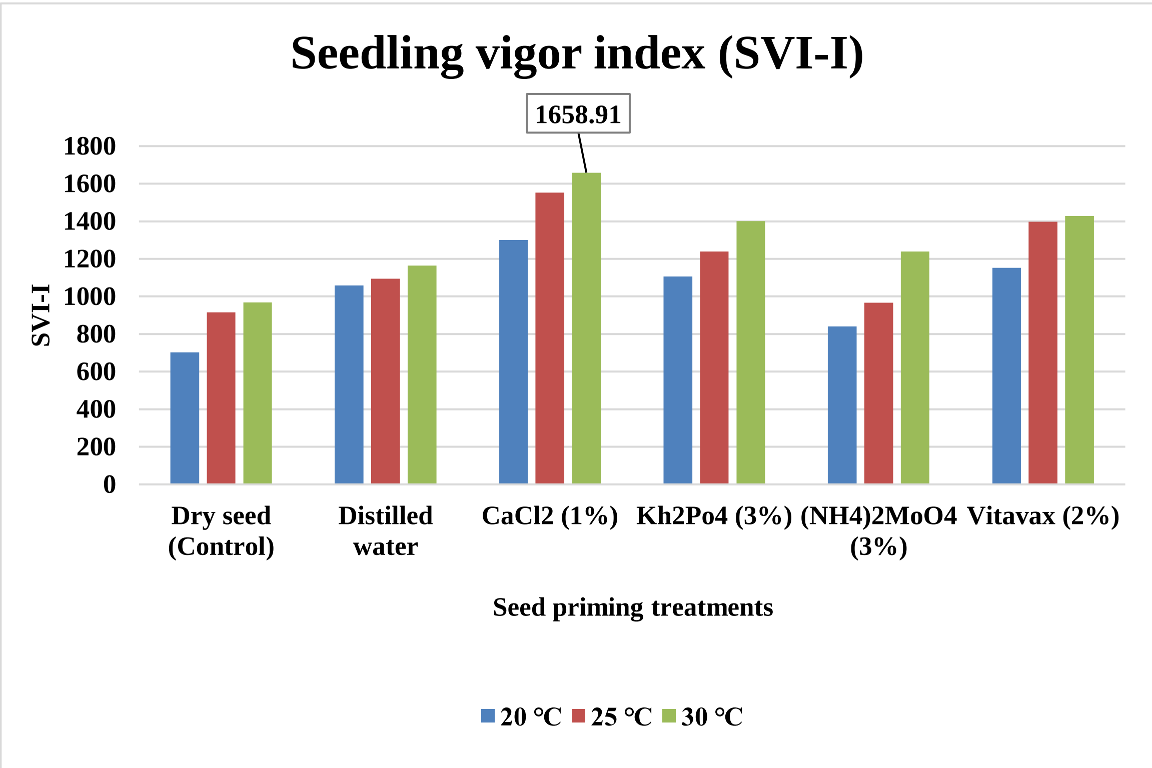
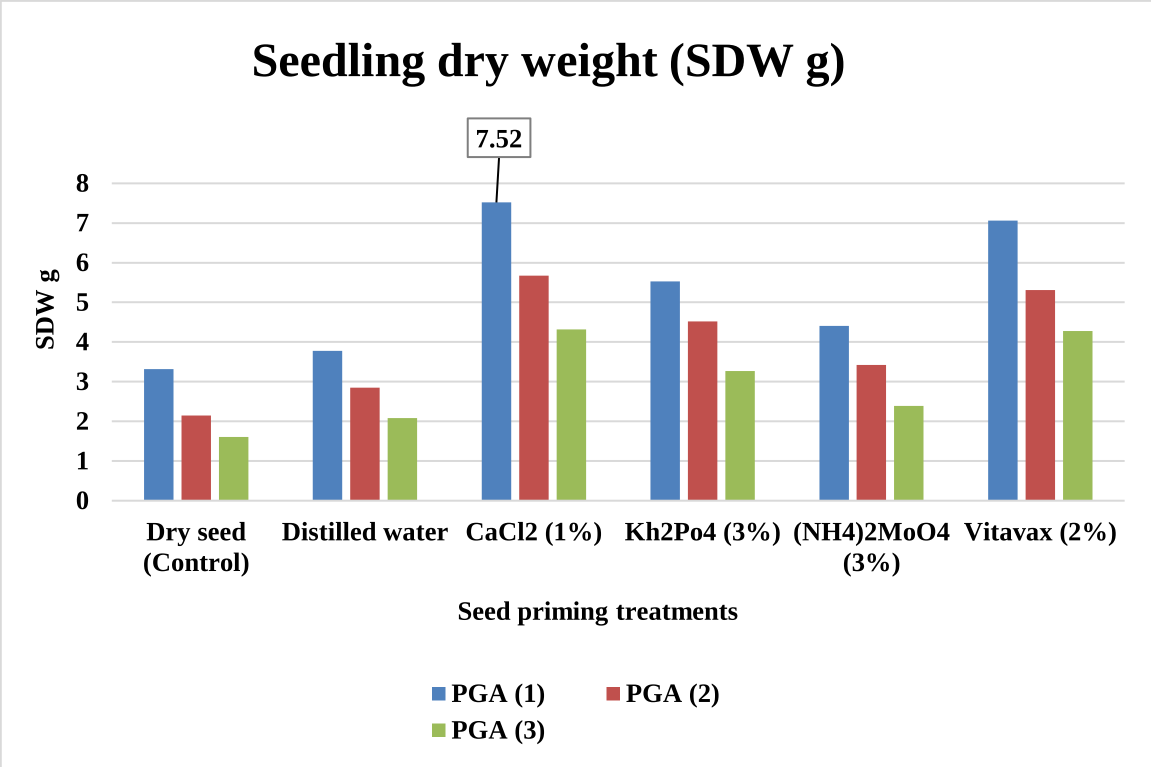
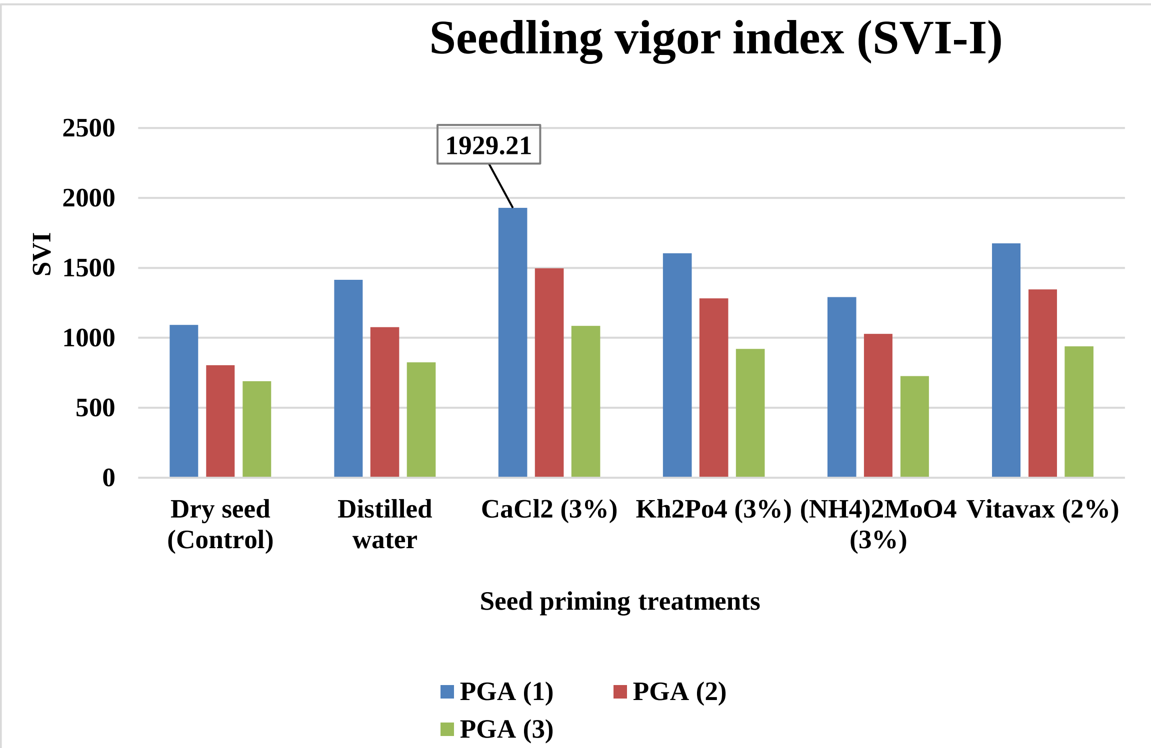


Figure 6. Means of seedling vigor index (SVI) as affected by the interaction between germination temperature levels and seed priming treatments on maize seed.



PGA1 = -0.2 MPa, PGA2 = -0.4 MPa and PGA3 = -0.6 MPa.

Figure 7. Means of seedling dry weight (g) as affected by the interaction between water potential (ψ) levels and seed priming treatments on maize seed



PGA1 = -0.2 MPa, PGA2 = -0.4 MPa and PGA3 = -0.6 MPa

Figure 8. Means of seedling vigor index (SVI-I) as affected by the interaction between water potential (ψ) levels and seed priming treatments on maize seed.

More, applying treatment of PGA1 (-0.2 MPa) significantly surpass the other treatments of PGA2 (-0.4 MPa) and PGA3 (-0.6 MPa), respectively. The highest mean values recorded by PGA1 -0.2 MPa) were, 17.72 cm of SL, 12.05 g of SFW, 6.44 g of SDW and 1505.3 of SVI, as shown in Table (3). Water stress induced lowers enzymatic activity, which decreases carbohydrate metabolism, water potential and soluble calcium and potassium, and alters the hormones of seeds. Also, maize seeds and seedling vigor are described as being low in moisture and metabolically dormant in their quiescence state [27]. Similar results obtained by [28], they evaluated maize seed germination and seedling vigor under water potentials; 0, -0.01, -0.09, -0.6 MPa by Polyethylene glycol 6000. They found that, the level of water potential -0.6 MPa caused negative effect and reduced germination (%), seedling length (cm), and seedling dry weight (g).

3.3. Seed priming effect

Effective and significant impact of the seed priming treatments on seed germination indices were appreciable in Table (2). All seed priming treatments significantly (LSD at 0.05%) increased all germination indices of maize seed, while compared to the unprimed seed (Control treatment). In addition, seed priming treatment of calcium chloride ($CaCl_{2,}$ 3%) was the superior treatment, followed by Vitavax (2%), Kh_2Po_4 (3%), $(NH_4)2MoO_4$ (3%), and hydro priming with distilled water treatments, respectively, compared to the unprimed seed (Cont.) The highest mean values of all germination indices recorded by $CaCl_2$ (3%), were 87.66% of G%, 19.22% of GE%, 75.38 of GVI, and the lowest mean values of MGT of 4.66 days to germinated seed. Seed priming can increase antioxidant enzymes activities such as catalase, peroxidase, superoxide dismutase and osmoprotectants compound such as proline, soluble sugar and soluble protein, likewise decrease lipid peroxidation during seed germination [29]. Seed priming can improve drought stress tolerance by enhanced seed germination. Primed seeds can retain the memory of previous stress and enable protection against oxidative stress through earlier activation of the cellular defense mechanism, reduced imbibition's time, and adapting germination promoters and osmotic regulation. Also, priming significantly enhanced the amount of mitochondria and cell division. Through seed priming, rehydration brings major cellular changes in seeds such as synthesis of nucleic acids and proteins; ATP production, activation of sterols and phospholipids, and repairing DNA damaged during threshing [30]. The positive effect of seed priming with Cacl2, may be due to the influence of Ca+2 on membranes and enhanced antioxidant proteins like SOD enzyme [31]. Furthermore, recorded data in Table (3) presented significant variation rates of seedling vigor indices induced by applying seed priming treatments on maize seeds. All seed priming treatments significantly increased all seedling vigor indices compared to the unprimed seed (Cont.). More, applying CaCl2 (3%) treatment, recorded the highest mean values which were, 17.88 cm of SL, 13.69 g of SFW, 7.33 g of SDW and 15.8.12 of SVI. [32] investigated that, seed priming is an effective seed invigoration tool to increase the rate and uniformity of emergence and crop establishments. Seed priming is a controlled hydration process that involves exposing seeds to low water potentials, which led to restrict germination process, but permits pre-germinative physiological and biochemical changes to occur upon rehydration. Also, primed seeds may exhibit faster rates of germination, more uniform emergence, greater tolerance to environmental stress, and reduced dormancy in many species.

3.4. Interaction effects

Regarding to the two-way interactions between factors under study, results indicated a significant (LSD at 0.05%) effect on G (%), GVI and MGT (day), while GE (%) did not affect by the interaction between (A × B and A × C) factors, as shown in Table (2). Regarding to the three-way interaction, data presented a significant effect on all germination indices, except GE (%), Table (2). In addition, the combined interaction treatment (30 ºC × $CaCl_{2,}$ 3%) achieved the highest means of G% (91.13%) and the lowest means of MGT (4.15 day), as shown in Fig (1&2), respectively. Moreover, the combined interaction treatment (PGA1, -0.2 MPa × $CaCl_{2,}$ 3%) recorded the highest means of G% (93.68%) and the lowest means of MGT (4.39 day), as shown in Fig (3&4), respectively. Likewise, regarding the two-way combined interactions, as shown in Table (3), results cleared a significant (LSD at 0.05%) effect on SL (cm), SFW (g), SDW (g), and SVI, while SFW (g) was not affected by the interaction between (A × B and A × C) factors. In addition, three-way combined interaction presented a significant effect on all seedling vigor indices, except SFW (g). Furthermore, the combined interaction treatment (30 ºC × $CaCl_{2,}$ 3%) obtained the highest means of SDW by 8.72 g and SVI by 1658,9 while compared to the other interaction treatments, as shown in Fig (5&6). Likewise, the combined interaction treatment (PGA1, -0.2 MPa × $CaCl_{2,}$ 3%) significantly obtained the highest mean values of SDW and SVI, which were 7.52 g and 1929.2, respectively, compared to the other interaction treatments, as shown in Fig (7&8). Moreover, all the significant interactions recorded the same trend for the aforementioned studied germination and vigor indices. Seed priming increases the rate of hydration, which helps to combat the drought stress during germination, emergence and growth of maize varieties [33]. These results agreed with [34], they declared that, the positive role of $CaCl_2$, where in, Ca in the form of calcium pectate, act as a cementing agent for adhering cell walls of plants and regulates new tissue formation; root tips, young leaves, and shoot tips avoids distorted growth from improper cell wall formation. Further, Calcium ion (Ca^{+2}) second messenger regulates cell cycle and gene expression which is crucial for plant growth and development particularly so against stresses.

4. Conclusion

This study indicates the importance of seed priming technology in encourage or maintain seed germination and seedling vigor indices while exposing maize seed to the unsuitable environmental conditions, such as unsuitable temperatures temperature and drought stresses. Seed priming with presented chemical proposed materials significantly surpass the unprimed seed. In addition, the best treatment was calcium chloride 3%. It is worth noting that, all the proposed materials succeeded in converging the values of the traits under study reach the highest values under the conditions of environmental stress studied. In conclusion, optimizing the germination temperature, maintaining a favorable water potential, and utilizing seed priming techniques are all essential factors in ensuring successful germination and early growth of maize seeds. By providing the ideal conditions for germination, farmers and gardeners can maximize the potential of maize seeds, leading to healthier and more vigorous plants.

References

[1] M.B. Alvi, M. Rafique, M.S. Tariq, A. Hussain, T. Mahmood, M. Sarwar. (2003). Character association and path coefficient analysis of grain yield and yield components maize (Zea mays L.). Pakistan Journal of Biological Sciences (Pakistan). 6 (2).

[2] A. Wahid, S. Sehar, M. Perveen, S. Gelani, S.M.A. Basra, M. Farooq. (2008). Seed pretreatment with hydrogen peroxide improves heat tolerance in maize at germination and seedling growth stages. Seed Science and Technology. 36 (3) 633-645.

[3] A. Maresma, A. Ballesta, F. Santiveri, J. Lloveras. (2019). Sowing date affects maize development and yield in irrigated mediterranean environments. Agriculture. 9 (3) 67.

[4] H. Khaeim, Z. Kende, M. Jolánkai, G.P. Kovács, C. Gyuricza, Á. Tarnawa. (2022). Impact of temperature and water on seed germination and seedling growth of maize (Zea mays L.). Agronomy. 12 (2) 397.

[5] E.A. Abdelraouf, I.N. Nassar, A.M. Shoman. (2022). Impacts of successive accumulation of salinity, drought, and potassium on Maize (Zea mays L.) germination and growth. Assiut Journal of Agricultural Sciences. 53 (2) 101-117.

[6] C.H.S.G. Meneses, R.D.L.A. Bruno, P.D. Fernandes, W.E. Pereira, L.H.G.D.M. Lima, M.M.D.A. Lima, M.S. Vidal. (2011). Germination of cotton cultivar seeds under water stress induced by polyethyleneglycol-6000. Scientia Agricola. 68 131-138.

[7] Z. Khodarahmpour. (2011). Effect of drought stress induced by polyethylene glycol (PEG) on germination indices in corn (Zea mays L.) hybrids. African Journal of Biotechnology. 10 (79) 18222-18227.

[8] S. Sathish, S. Sundareswaran, N. Ganesan. (2011). Influence of seed priming on physiological performance of fresh and aged seeds of maize hybrid [COH (M) 5] and it's parental lines. ARPN Journal of Agricultural and Biological Science. 6 (3) 12-17.

[9] H. ur Rehman, H. Iqbal, S.M. Basra, I. Afzal, M. Farooq, A. Wakeel, W.A.N.G. Ning. (2015). Seed priming improves early seedling vigor, growth and productivity of spring maize. Journal of Integrative Agriculture. 14 (9) 1745-1754.

[10] B.E. Michel, M.R. Kaufmann. (1973). The osmotic potential of polyethylene glycol 6000. Plant physiology. 51 (5) 914-916.

[11] A.S. Basra, M. Farooq, I. Afza, M. Hussain. (2006). Influence of osmopriming on the germination and early seedling growth of coarse and fine rice. International Journal of Agriculture and Biology. 8 (1) 19-22.

[12] Z. ISTA. (1999). International rules for seed testing. Seed Sci Technol. 27 (Supplement) 333.

[13] S. Ruan, Q. Xue, K. Tylkowska. (2002). The influence of priming on germination of rice (Oryza sativa L.) seeds and seedling emergence and performance in flooded soil.

[14] J.D. Maguire. (1962). Speed of germination-aid in selection and evaluation for seedling emergence and vigor.

[15] R.H. Ellis, E.H. Roberts. (1981). The quantification of ageing and survival in orthodox seeds. Seed Science and Technology (Netherlands). 9 (2).

[16] V. Krishnasamy, D.V. Seshu. (1990). Phosphine fumigation influence on rice seed germination and vigor. Crop science. 30 (1) 82-85.

[17] P.K. Agrawal. (1986). Seed vigor: Concepts and measurement.

[18] A.A. Abdul-Baki, J.D. Anderson. (1970). Viability and Leaching of Sugars from Germinating Barley 1. Crop science. 10 (1) 31-34.

[19] K.A. Gomez, A.A. Gomez. (1984). Statistical procedures for agricultural research. John wiley & sons.

[20] G.W. Snedecor, W.G. Cochran. (1980). Statistical methods. 7th. Iowa State University USA. 80-86.

[21] T.K. Prasad, M.D. Anderson, C.R. Stewart. (1994). Acclimation, hydrogen peroxide, and abscisic acid protect mitochondria against irreversible chilling injury in maize seedlings. Plant Physiology. 105 (2) 619-627.

[22] B. Sánchez, A. Rasmussen, J.R. Porter. (2014). Temperatures and the growth and development of maize and rice: a review. Global change biology. 20 (2) 408-417.

[23] K. Oracz, S. Karpiński. (2016). Phytohormones signaling pathways and ROS involvement in seed germination. Frontiers in plant science. 7 864.

[24] M. Liu, M. Li, K. Liu, N. Sui. (2015). Effects of drought stress on seed germination and seedling growth of different maize varieties. Journal of Agricultural Science. 7 (5) 231.

[25] J.D. Bewley, K.J. Bradford, H.W. Hilhorst, H. Nonogaki, J.D. Bewley, K.J. Bradford, H. Nonogaki. (2013). Germination. Seeds: Physiology of Development, Germination and Dormancy. 3rd Edition 133-181.

[26] M.D.J. Moreno Roblero, J. Pineda Pineda, M.T. Colinas León, J. Sahagún Castellanos. (2020). Oxygen in the root zone and its effect on plants. Revista mexicana de ciencias agrícolas. 11 (4) 931-943.

[27] H. Karimmojeni, H. Rahimian, H. Alizadeh, A.R. Yousefi, J.L. Gonzalez-Andujar, E.M. Sweeney, A. Mastinu. (2021). Competitive ability effects of Datura stramonium L. and Xanthium strumarium L. on the development of maize (Zea mays) seeds. Plants. 10 (9) 1922.

[28] H. Heidari, D. Kahrizi. (2018). Effect of water stress and contaminated water on seed germination traits and early growth in maize (Zea mays). Environmental Engineering and Management Journal. 17 (1) 35-42.
[29] K.C. Jisha, K. Vijayakumari, J.T. Puthur. (2013). Seed priming for abiotic stress tolerance: an overview. Acta Physiologiae Plantarum. 35 1381-1396.
[30] V. Marthandan, R. Geetha, K. Kumutha, V.G. Renganathan, A. Karthikeyan, J. Ramalingam. (2020). Seed priming: a feasible strategy to enhance drought tolerance in crop plants. International journal of molecular sciences. 21 (21) 8258.
[31] M. Abbas, H. Abdel-Lattif, M. Shahba. (2021). Ameliorative effects of calcium sprays on yield and grain nutritional composition of maize (Zea mays L.) cultivars under drought stress. Agriculture. 11 (4) 285.
[32] M. Ashraf, M.R. Foolad. (2005). Pre-sowing seed treatment—A shotgun approach to improve germination, plant growth, and crop yield under saline and non-saline conditions. Advances in agronomy. 88 223-271.
[33] Y. Tian, B. Guan, D. Zhou, J. Yu, G. Li, Y. Lou. (2014). Responses of seed germination, seedling growth, and seed yield traits to seed pretreatment in maize (Zea mays L.). The Scientific World Journal, 2014.
[34] S.C. Byatnalli, M.M. Dhanoji, M.K. Meena. (2018). Influence of seed priming techniques on growth and yield parameters of maize (Zea mays L.). Journal of Pharmacognosy and Phytochemistry. 7 (5) 2248-2250.