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Evaluation of Seed Priming and Culture Media to Improve the Germination Performance and Quality of Sweet Pepper and Eggplant Seedlings

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ABSTRACT

Seed priming is an established approach to the aim of accelerating germination and increasing germination percentage, which can be followed by high-quality seedlings and optimal plant growth. Culture media can influence the growth and nutritional status of seedlings at the nursery stage. In order to study the impact of seed priming and culture medium on germination performance and seedling growth, two separate laboratory and greenhouse experiments were planned in which the seeds and seedlings of sweet pepper and eggplant were subjected to various chemicals (i.e. growth regulators and nutrients) in the culture media. The results showed that the chemicals had a significant effect on seed priming by improving seed germination and root length in both plants. While putrescine improved seed germination, the highest germination percentage and root growth of both plants were observed in the salicylic acid treatment. Seed priming by humic acid was more effective than ZnSO4 and KNO3 in encouraging seed germination. The application of peat moss (solely or in combination with other culture media such as cocopeat and perlite) improved the growth parameters and nutritional status of commercially ready seedlings. The highest shoot weight (fresh and dry) in both plants were observed in seedlings grown on peat moss. Apart from improvements in vegetative features, peat moss enhanced the uptake and accumulation of nutrients such as N, P, K, Ca, and Mg, compared to cocopeat and perlite. In general, the results indicated that salicylic acid was the best priming treatment and peat moss was the best culture medium for the commercial production of eggplant and sweet pepper seedlings.

Abbreviations

C: Cocopeat, Pe: Perlite, PM: Peat moss, P: Phosphorus, N: Nitrogen, Mg: Magnesium, K: Potassium, Ca: Calcium, SA: Salicylic acid, HA: Humic acid, GP: Germination percentage, Put: Putrescine, KNO3: Potassium nitrate, $ZnSO_4$: Zinc sulfate, DW: Distilled water, PAs: Polyamines, GAs: Gibberellins, ABA: Abscisic Acid, SA: Salicylic acid.

Introduction

Seed priming is a technique that allows seeds to readily absorb water without root growth and helps them germinate at an early stage. In other words, primed seeds reach the second stage of water absorption without entering the third stage (Nawaz et al., 2013). Seed priming is considered a common technique to increase germination percentage, particularly by confronting the conditions that negatively impact germination (Hosseini and Koocheki, 2007). Furthermore, as water absorption takes time, physiological heterogeneity in seed mass is observed after planting (Tombegavani et al., 2020). The germination period can be reduced by seed pretreatment. This will result in earlier germination and, consequently, stronger growth (Hosseini and Koocheki, 2007). It has been reported that improving seed performance by priming can decrease lipid degradation and increase antioxidant activity. Besides, physiological changes that occur during priming affect the synthesis and activity of proteins, enzymes, DNA, and RNA (Moradi and Younesi, 2009; Hadi et al., 2012).

Although there are several ways to hasten seed germination, the most convenient method is the application of plant growth regulators (Sappalani et al., 2021). Seeds soaking in appropriate concentrations of plant growth regulators is effectively used for improving germination and seedling growth. Subsequently, this can increase yield under regular and abiotic stress conditions (Tombegavani et al., 2020).

Plant growth regulators, which are normally used for seed priming, include auxins (IBA and NAA), GAs, ABA, SA, and PAs. Some osmotic protectants, such as glycine betaine, are also applied in the priming procedure along with growth hormones (Ashraf and Foolad, 2005). As a growth regulator, salicylic acid plays an essential role in regulating physiological processes such as growth, ion absorption, photosynthesis and germination, depending on its concentration, plant species, growth stage, and environmental conditions (Yazdanpanah et al., 2011). Under normal conditions and dehydration stress, Vigna unguiculata L. seeds were pretreated with salicylic acid at a concentration of 2700 μM, which indicated a favorable condition in terms of morphological and physiological traits (Shekari et al., 2011).

Polyamines (PAs) are important plant growth regulators that possess diverse roles in various plant physiological reactions, ranging from flower induction to development and, finally, senescence. Polyamines are also effective in cell division, embryogenesis, flowering, fruit maturity, seed development, and delayed aging (Liu et al., 2006). The role of putrescine in increasing plant growth in non-stress conditions may correlate with its antioxidant effect, cation-anion balance, or its possible role as a nitrogen source (Tang and Newton, 2004; Hosseini Farahi and Zadehbagheri,2017).

Nutrition priming is another priming type in which seeds are treated with solutions containing nitrogen, phosphorus, potassium, and trace elements that increase seed germination (Ajouri et al., 2004; Souri and Hatamian, 2019). In this method, it is crucial to know the physical properties of the substrates before using them in hydroponic systems and adjusting the solutions.

In recent years, the application of soilless culture systems has expanded to produce various crops and vegetables. Soilless culture has gained attention from horticultural producers due to its several advantages, such as facilitating plant nutrition regulation, increasing the planting density, and improving crop quantity/quality, compared to soil cultivation, as well as its effects on reducing disease and pest incidents (Tüzel et al., 2002). In these systems, different materials are employed as planting media, while each has its own unique characteristics (Albaho et al., 2009). In general, these materials require a high-water holding capacity, adequate ventilation, good drainage, and high cation exchange capacity, and they are supposed to have no adverse effects on plants (Shabani et al., 2011).

Culture media that contain specific materials can influence plant growth and development directly or indirectly. Thus, it is crucial to select a suitable culture medium. The substrates that are commonly applied are, namely, organic (i.e. peat moss, wood residues, coconut fiber, sugarcane pulp, leaf litter, and rice husk) and mineral types (i.e. vermiculite, perlite, rock wool, polyester foam, and sand) (Albaho et al., 2009; Najarian and Souri, 2020).

Since seeds of Solanaceae vegetables germinate slowly, and while priming has a useful, effective role in increasing the germination rate and seedling vigor, the present study aimed at evaluating the effects of seed priming, culture media, several growth regulators and nutritional treatments on the production of sweet pepper and eggplant seedlings.

Materials and Methods

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Plant materials and treatments
The seeds of sweet pepper (*Capsicum annuum* cv. 'California Wonder 301', Seminis, Thailand) and eggplant (*Solanum melongena* cv. 'Chantale', Seminis, Thailand) were subjected to various culture media in two separate experiments conducted in the Seed Science laboratory of Islamic Azad University, Yasuj Branch, Yasuj, Iran. The first experiment focused on studying priming media and the second experiment on studying culture media.

First experiment
Initially, the seeds of sweet pepper and eggplant were disinfected with 2% NaClO (sodium hypochlorite) solution for one minute and rinsed three times with sterilized distilled water. Then, the washed seeds were primed by subjecting them to DW (H_2O), 0.2 mM SA, 0.2 mM Put, 1.5% HA, 0.03% ZnSO4, and 0.2 mM KNO3 as priming treatments. All applied chemicals were supplied from Merck, Germany in a completely randomized design with three replications and then dried at room temperature for 24 h. Each replication consisted of three observations in which thirty seeds were individually placed in sterilized plastic Petri dishes containing 6 mL distilled water and were transferred to a growth chamber (Noor-Sanat Co., Ferdows, Iran). The growth chamber conditions were set to 16/8 h of lightness/darkness at 25°C and 70% relative humidity as recommended by Safarizadeh-Sani et al. (2020). Germination percentage (GP) was measured on the seventh and eighth day from the onset of germination by Equation 1, according to Aboutalebi Jahromi and Hosseini Farahi (2016). At the end of the germination period, root length was also measured with a ruler.

Eq. 1. GP % = (No. of germinated seeds / No. of sown seeds)/100

Second experiment
In the second experiment, the germinated seeds of sweet pepper and eggplant were cultured in 6 different culture media including cocopeat (C), perlite (Pe), peat moss (PM), 50% C + 50% Pe, 50% C + 50% PM, and 50% Pe + 50% PM in a completely randomized design with three replications. Compacted peat blocks were soaked in water before use to make other media fully open and bulk up. The established seedlings were grown in a greenhouse with an average day/night temperature of 25/18 $\pm$ 3°C, day/night periods of 14/10 h, and relative humidity of 70-80%. When the seedlings reached the 8-leaf stage and were ready for commercial sale, parameters such as root dry weight, shoot dry weight, stem diameter, leaf chlorophyll index and mineral contents were measured. Seedling stem diameter was measured with a digital caliper. The chlorophyll index was measured with a chlorophyll meter (SPAD 502, Konica Minolta, Japan).

Assessment of mineral elements
In order to evaluate leaf mineral contents, comprising N, P, K, Ca, and Mg, plant leaf samples were collected and rinsed with distilled water. They were incubated in an oven (at 70°C) to reach a constant weight, and were then powdered using an electric mill. The N content was measured by the Kjeldahl method (Abdipour et al., 2019) at four stages, including sample preparation, digestion, distillation, and titration. In the first step, two grams of each replication were weighed and placed on filter paper. Then, they were transferred to an Erlenmeyer. At the digestion stage, 20 mL of the concentrated H2SO4 (94 to 98%) and 3 grams of SeS2 catalyst were added to the samples, and the machine's time and temperature were set at 30 min and 180°C, respectively. After cooling the samples and reaching room temperature, the Erlenmeyer that contained the sample was placed in a distillation apparatus, and the distilled solution was collected and prepared for titration with H2SO4 (0.1 N) after 15 min. Titration was continued to reach a stabilized purple color. Nitrogen content was calculated using the following equation (No. 2):

Eq. 2. $$N\% = \frac{14 \times N \times V}{W \times 1000} \times 100$$

where N is the normality of NaOH, V is the volume of HCl, and W is the sample weight (g).
To measure leaf K and P contents, leaf samples were dried in an oven at 48°C for 48 h. Phosphorus was analyzed by the calorimetric method (Molybdate-Vanadate yellow color) using a spectrophotometer P 80 Plus (PG Instruments, UK).
Ca and Mg analysis was carried out by placing one gram of dried leaf in an oven at 500°C for 5 h to obtain ash. Then, the ash was placed on a heater after adding 5 mL of 2 N HCl. Following the boiling procedure, the solution was passed through a filter paper using double distilled water to reach 100 mL of volume. Then, the K amount was calculated by the flame method (mg/g), whereas the spectrophotometric evaluations were adjusted by comparing the wavelengths with the diagrams obtained from standard samples (Patterson et al., 1984). Ca and Mg contents were measured by the flame atomic absorption

technique through an atomic absorption apparatus (Atomic-Absorption-Spectrometer FMD4, Analytik Jena, Germany).

Statistical analysis

Data were analyzed using one-way ANOVA by SAS (v. 9.2). Mean values were compared at probability levels of 1% and 5% using Duncan's multiple range test (DMRT).

Results

First experiment

Based on the results, priming significantly affected seed germination in both sweet peppers and eggplants (Table 1). Among the applied treatments, SA, Put, and HA significantly increased seed germination, respectively. In both plants, the highest seed germination was recorded in the SA treatment. These treatments were more effective in improving germination in the eggplants than in the sweet peppers. In the eggplants, SA increased seed germination by 18.8% and reached a total value of 92.2%, whereas the increase in sweet peppers was 18.7% and reached 85.7%. Eggplant seed germination became 87.5% as a result of Put application, which meant an increase of 16.3% compared to the initial condition. In the sweet peppers, Put increased germination by 16.2%, compared to the control, and made total germination reach 85.0% (Fig. 1). Although HA significantly increased germination percentage compared to the control, this priming treatment only led to an increase of 7.0% and 6.9% in the germination of eggplants and sweet peppers, respectively, whereas KNO3 and ZnSO4 did not have a significant impact on seed germination in either plant. The seeds treated with KNO3 showed a germination percentage of 74.3% and 69.1% in the eggplants and sweet peppers, respectively (Fig.1.A,B).

Similar to the germination percentage, root length was also significantly affected by different priming treatments (Table 1). The root length values were significantly higher in different priming treatments compared to the control (DW). As shown in Fig. 1.C, the highest and lowest root lengths in the eggplant seeds were recorded in the SA and DW treatments with values of 10.3 and 2 mm, respectively. It was found that the SA, Put, HA, KNO_3, and $ZnSO_4$ treatments increased the root length of the eggplants by 80.5%, 71.4%, 65.5%, 47.3%, and 45.9%, respectively. In the sweet peppers, the same response was recorded in priming. As seen in Fig. 1D, the SA, Put, HA, $ZnSO_4$, and KNO_3 treatments increased the sweet pepper's root length by 76.1%, 63.6%, 55.5%, 37.5%, and 28.5%, respectively. In general, the SA treatment, which was the best priming treatment in both plants, increased root length by more than three-fold, compared to DW. It should be noted that the KNO3 and ZnSO4 treatments can be ignored due to their weak effects on root length.

Table 1. ANOVA of sweet pepper and eggplant seed germination and root length as affected by different priming treatments.

Plant	Source of variations	df	Seed germination (%)	Root length (cm)
Sweet pepper	Treatment	5	150.77 **	16.06**
	Error	12	4.00	0.04
	CV (%)	-	2.64	5.28
Eggplant	Treatment	5	174.36 **	26.50**
	Error	12	4.36	0.08
	CV (%)	-	2.64	5.28

**: significant at the 1% probability level.

Second experiment

Vegetative characteristics

The vegetative characteristics of seedlings were affected by the different culture media. Based on the results, the sweet pepper vegetative characteristics such as seedling length, stem diameter, root and shoot dry weights were significantly affected by culture media at the 1% probability level (Table 2). The vegetative characteristics of eggplants were also similarly affected by culture media. In the eggplants, the highest and lowest root dry weights were observed in PM and Pe treatments (0.71 and 0.03 g), respectively (Table 3). The application of PM culture media increased root dry weight by up to 23-fold, compared to Pe. The combination of PM with other culture media also improved root length. Its combination with C increased root dry weight by up to 15-fold, compared to the effect of Pe. The PM combination with Pe also improved root dry weight significantly by up to 13-fold (Table 3).

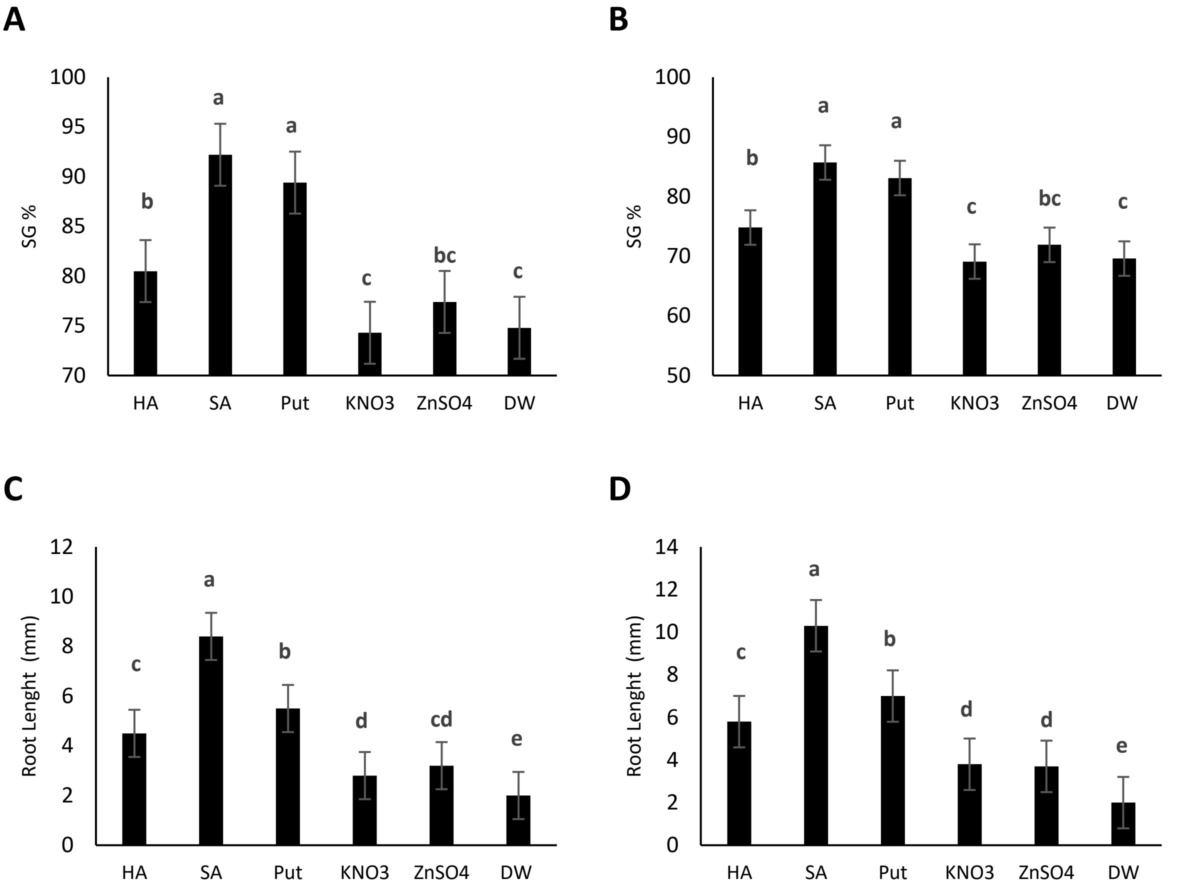

Figure 1. The effects of different priming treatments on seed germination percentage (A: sweet pepper, B: eggplant) and root length (C: sweet pepper, D: eggplant). Mean values with similar letters in each figure are not significantly different at the 5% level of probability using Duncan's Multiple Range Test (DMRT).

Table 2. ANOVA of vegetative traits, measured in sweet pepper and eggplant seedlings, as affected by different culture media

Plant	Source of variations	df	Root dry weight (g)	Shoot dry weight (g)	Stem diameter (cm)	Seedling length (cm)	SPAD index
Sweet pepper	Treatment	5	0.073**	0.906**	0.02**	19.24**	20.17**
	Error	12	0.0001	0.001	0.001	0.08	2.03
	CV (%)	-	5.02	2.72	4.04	2.50	4.54
Eggplant	Treatment	5	0.164**	1.38**	0.045**	21.31**	19**
	Error	12	0.0001	0.002	0.004	0.07	1.58
	CV (%)	-	3.68	3.69	4.24	2.22	4.05

**: significant at the 1% probability level.

The C treatment increased the root dry weight compared to the effect of the Pe medium. Similar results were observed in the case of sweet peppers. In sweet pepper seedlings, the highest and lowest root dry weights were observed in the PM and Pe treatments (0.47 and 0.02 g), respectively (Table 2). The root dry weight of the sweet pepper seedlings was heavier in the PM culture medium, compared to those cultured in Pe and C. The values of increase in the root dry weight of the sweet pepper seedlings that were cultured on PM and C+PM were 23- and 15-fold, respectively. The sweet pepper seedlings cultured on C also showed a higher root dry weight than those cultured on Pe.

A comparable approach can be taken to the increasing trend which was observed in shoot dry weight. The shoot dry weight was increased by PM and C usage. As seen in Table 3, the highest and lowest shoot dry weight of the eggplant seedlings were observed in the PM and Pe culture media (2.32 and 0.53 g), respectively. The increase in shoot dry weight was more than 4-fold, compared to the effect of Pe. Moreover, the application of PM in combination with C or Pe increased shoot dry weight by more than 3-fold. The application of PM medium increased shoot dry weight by up to 32.7%, compared to the C medium. Correspondingly, the cultivation of the eggplant seedlings in C led to an increase in shoot dry weight, compared to the Pe medium. Similar findings were observed in sweet peppers. In the sweet pepper seedlings, shoot dry weight in the PM and Pe treatments were 1.88 and 0.32 g, respectively. The application of PM solely increased shoot dry weight by more than 4-fold, while its application in combination with C or Pe increased the shoot dry weight by more than 3-fold (Table 3). Compared to C, the application of PM medium increased shoot dry weight by up to 33.5%, whereas the C medium increased the shoot dry weight by up to 65.6%, compared to the Pe medium.

Stem diameter was also affected by culture media. PM had a positive effect on stem diameter while Pe had a negative effect. The singularity of PM or its combination with other media increased stem diameter by up to almost 1.5 and 2 fold in the eggplants and sweet peppers, respectively. The highest stem diameter (0.68 mm) was obtained in the eggplant seedlings when they were cultured in PM, while the lowest value (0.36 mm) was observed in eggplants cultured in C and 50% C + 50% Pe media. The application of the PM medium increased the eggplants' stem diameter by up to 47.0%, compared to the effect of C (Table 3). Although stem diameter in the sweet peppers was lower than that of the eggplants, similar findings were observed in this regard. The highest and lowest stem diameters were 0.45 and 0.24 cm as a result of the PM and C or C+Pe treatments, respectively.

Like other vegetative characteristics, seedling length was also affected by culture media in both plants. In the eggplants, the application of PM solely or in combination with other media increased seedling length. The highest eggplant seedling height (16.4 cm) was obtained from the PM medium while the eggplant seedlings were the shortest (8.9 cm) in the Pe culture medium (Table 3). The application of Pe alone or in combination with C or PM decreased seedling lengths. The application of Pe along with PM reduced seedling length by more than 23%. Compared to C, PM increased plant height by up to 31.0%. A similar trend was observed in the sweet peppers. The highest and lowest plant height of the sweet peppers were observed in the PM and Pe media (15.4 and 8.3 cm), respectively (Table 3). Similarly, the application of the PM medium to the sweet pepper seedlings increased plant height by up to 31.1%, compared to their cultivation in C. However, the application of Pe in combination with PM reduced seedling height by up to 22%. In fact, PM increased seedling height by up to 1.85 and 1.84-fold in sweet peppers and eggplants, respectively.

Table 3. Effects of different culture media on the studied vegetative traits of the eggplant and sweet pepper seedlings.

Plant	Media culture	Root dry weight (g)	Shoot dry weight (g)	Stem diameter (cm)	Seedling length (cm)	SPAD index
Eggplant	C	0.33d*	1.56c	0.36e	11.3d	31.0bc
	Pe	0.03f	0.53e	0.42d	8.9f	26.7d
	PM	0.71a	2.32a	0.68a	16.4a	34.1a
	C + Pe	0.18e	0.77d	0.36e	10.3e	30.0c
	C + PM	0.45b	1.80b	0.54b	13.7b	33.0ab
	Pe + PM	0.39c	1.81b	0.50c	12.5c	31.2bc
Sweet pepper	C	0.21d	1.25c	0.24e	10.6d	31.4d
	Pe	0.02f	0.43e	0.28d	8.3f	27.0f
	PM	0.47a	1.88a	0.45a	15.4a	34.5a
	C + Pe	0.12e	0.62d	0.24e	9.5e	30.3c
	C + PM	0.30b	1.44b	0.36b	12.8b	33.3ab
	Pe + PM	0.26c	1.44b	0.33c	11.9c	31.6bc

* Mean values with similar letters in each plant and in each column are not significantly different at the 5% probability level using DMRT.

SPAD index

In general, using the PM culture medium caused a significant increase in the SPAD value of seedlings in both plants. A similar trend of increase was observed in the SPAD index by the application of PM, whereas the application of Pe reduced it. The decreasing percentage by Pe application was 21 for both sweet peppers and eggplants. The application of PM in combination with Pe increased the SPAD value of the eggplant and sweet pepper seedlings by 16% and 17%, respectively. In eggplant seedlings, the highest SPAD value (34.1) was observed in the PM medium, while the lowest value (26.7) was observed in the Pe medium (Table 3). Likewise, in sweet pepper seedlings, the highest SPAD value was observed in PM (34.5), while the lowest value (27.0) was observed in seedlings cultured on Pe (Table 3). These results indicated that the seedlings grown on PM had the highest chlorophyll content, since the SPAD index had a direct correlation with chlorophyll content

(Shaghaghy et al., 2019). This was also observed in the combined culture media, as the combination with PM resulted in a higher SPAD value compared to the combination with Pe. The higher SPAD (chlorophyll content) could be due to a higher rate of the absorption of nutrients such as N and Mg in the PM-cultured seedlings (as reported by Malassiotis et al., 2006) (Fig. 2). Similarly, C application as the culture medium increased the SPAD value as their leaves had higher Mg content (Fig.2).

Leaf element content

Sweet pepper

Culture media had a significant impact on leaf N, P, K, Ca, and Mg contents in sweet peppers (Table 4). The highest and lowest leaf N contents were observed in the PM and C treatments with values of 1.35 and 0.79 mg.kg^{-1} FW, respectively. Among the applied media mixtures, Pe+C resulted in a significantly lower N content in the leaf. However, the application of PM as the culture medium in combination with C and Pe increased leaf N content (Fig. 2A). The PM application increased leaf N content in the sweet peppers by up to 1.7-fold and 42.7%. The combination of PM with Pe or C increased leaf N content by 17.5% and 26.8%, respectively.

Likewise, leaf P and K contents were affected by the culture medium. In the sweet pepper seedlings, using the PM resulted in the highest P and K content versus the other culture media. The PM application increased leaf P content by 40%, compared to the Pe culture medium. Adding PM to C and Pe culture media also increased leaf P content by 10.9% and 35.7%, respectively. The highest and lowest leaf P contents (0.61 and 0.36 mg.kg^{-1} FW) were observed in the PM and Pe treatments, respectively.

Furthermore, the highest and lowest leaf K contents (1.49 and 0.63 mg.kg^{-1} FW) were observed in the PM and Pe treatments, respectively. Leaf K content in the sweet peppers increased by 2.3-fold when cultured on PM, compared to the Pe culture medium. The seedlings cultured in Pe had the lowest P content. As seen in Figures 2B and 2C, the application of PM as the culture medium in combination with C and Pe increased P and K contents similarly. Adding PM to the Pe culture medium increased leaf K content by 47.5%.

Shoot Ca content was also affected by the culture medium. The seedlings planted in the PM culture medium had the highest Ca content (1.3 mg.kg-1 FW), compared to those planted in the other culture media. The application of PM increased leaf Ca content by more than 2-fold compared to the Pe medium. Likewise, the C culture medium increased the Ca content. The application of PM in combination with C and Pe consecutively increased Ca absorption and accumulation in the shoots of the sweet peppers. The increase was 44.6% when it was added to the Pe culture medium. On the other hand, the Pe-cultured seedlings had the lowest Ca content (0.63 mg.kg^{-1} FW) (Fig. 2D).

The type of culture medium also had an impact on the Mg content that was absorbed in the shoots (Fig. 2E). Among all culture media, the sweet pepper seedlings on PM showed the highest Mg content (0.27 mg.kg^{-1} FW). The application of PM increased sweet pepper leaf Mg content by 63%, compared to the Pe culture medium. Although the seedlings planted in PM and C + PM showed a significantly high amount of Mg content in sweet peppers, the lowest amount of Mg uptake was observed as a result of the Pe culture medium. The PM combination with other culture media also increased leaf Mg content. The leaf Mg content of the sweet pepper seedlings cultured in the Pe medium increased by 47.3% when Pe was used in combination with PM.

Table 4. ANOVA of the sweet pepper and eggplant seedlings, considering their mineral contents as affected by different culture media

Plant	Source of variations	df	Mineral content				
			N	P	K	Ca	Mg
Sweet pepper	Treatment	5	0.122**	0.0282**	0.247**	0.225**	0.0116*
	Error	12	0.003	0.005	0.001	0.0009	0.0009
	CV (%)	-	5.61	4.55	2.96	2.77	5.05
Eggplant	Treatment	5	0.119**	0.0269**	0.233**	0.2064**	0.0107**
	Error	12	0.003	0.002	0.0006	0.0009	0.0008
	CV (%)	-	5.62	3.41	2.31	2.94	4.93

* and **: significant at the 5% and 1% probability levels, respectively.

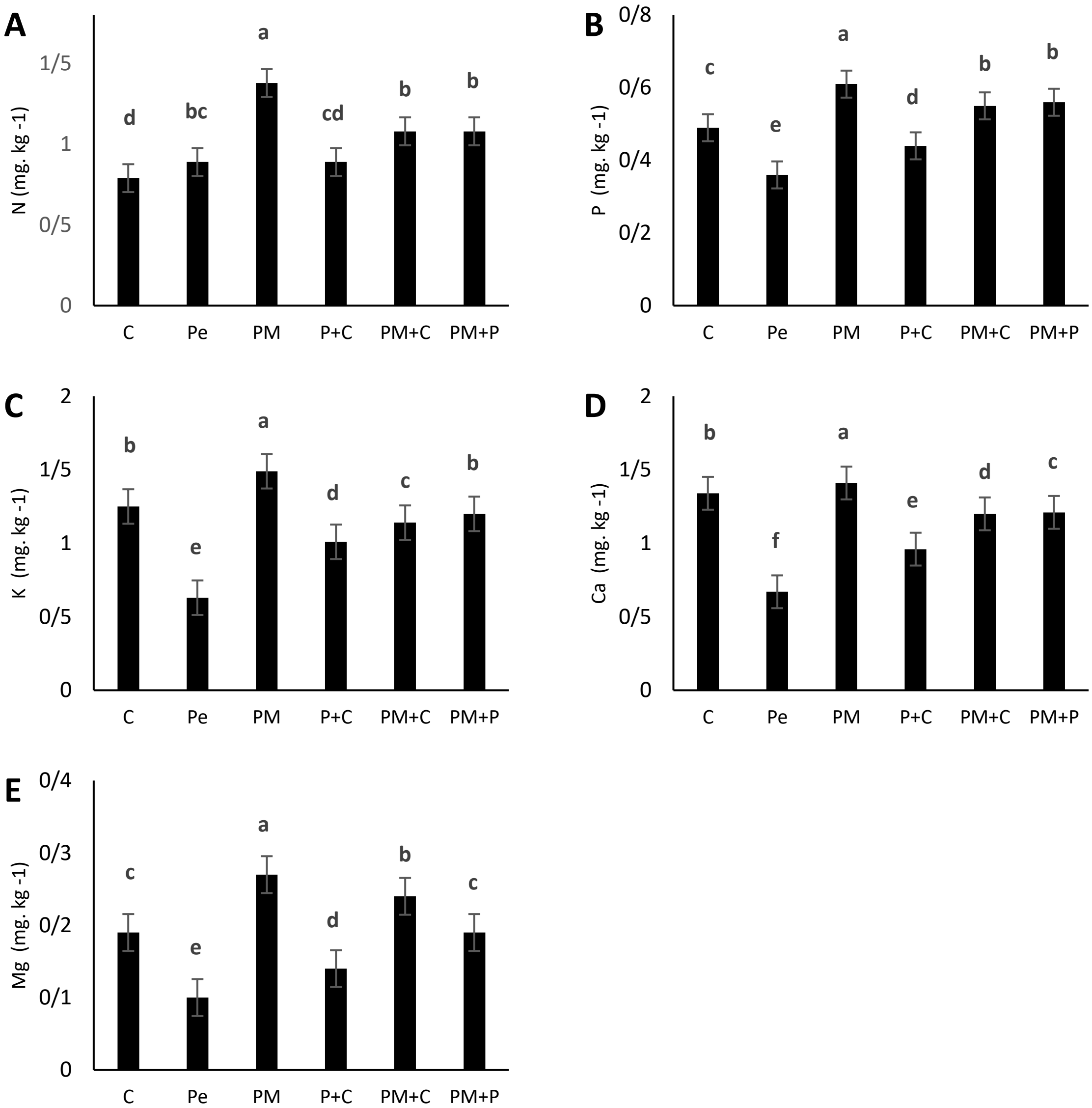

Fig. 2. The effect of different culture media on leaf mineral contents of the sweet pepper seedlings: nitrogen (A), phosphorus (B), potassium (C), calcium (D), and magnesium (E). (Mean values with different letters in A, B, C, and D are significantly different at the 1% level of probability using DMRT. Mean values with different letters in part E are significantly different at the 5% level of probability using DMRT.)

Eggplant

The type of culture media had a significant impact ($p \leq 1\%$) on leaf N, P, K, Ca, and Mg contents in eggplant seedlings (Table 4). The seedlings that were cultured in PM had the highest leaf N content, while the seedlings cultured in C had the lowest content. Generally, the application of PM increased leaf N content in the eggplants by 1.7 fold.

The application of PM, combined with C and Pe media, increased the N content. This increase was 9.3% and 25.4% in response to Pe and C media, respectively (Fig. 3A). As is evident in Figures 3B and 3C, leaf P and K absorption and content were also affected by the culture medium. The eggplant seedlings planted in PM had the highest P and K contents, compared to the other media. This increase was also observed when PM was applied in combination with C and Pe, so that the application of PM in combination with C and Pe increased the P and K contents. The lowest P content in the seedlings was observed in the Pe medium. The increase in leaf P of eggplants by the PM application was 45% in comparison with the Pe treatment. Leaf P content increased (40%) by adding PM to the Pe culture medium. The combination of PM with C increased leaf P content by 11%. A similar trend was observed in the case of leaf K content. The application of PM increased leaf K content by 2.3 fold, compared to the Pe treatment. Adding PM to the Pe culture medium improved leaf K content by 47%. The results confirmed that the Ca content in the shoots of the eggplants was affected by the culture medium. Compared to the other culture media, eggplant seedlings in the PM medium had the highest leaf Ca content. In addition, PM and C culture media increased the Ca content. The mixture of PM with C and Pe also increased Ca absorption and accumulation in eggplant shoots, whereas seedlings in Pe showed the lowest leaf Ca content (Fig. 3D). Compared to Pe, the leaf Ca content increased 2-fold by the effect of PM, and its combination with Pe also improved leaf Ca content by 56.4%.

As shown in Figure 3E, leaf Mg content was also affected by the culture medium. As a result, the eggplant seedlings grown in PM had the highest leaf Mg content among all the culture media. The C + PM culture medium caused the highest Mg content in the eggplant seedlings, whereas the lowest amount was observed in the Pe medium. The application of PM increased the leaf Mg content by 2.6 fold, compared to the leaves of the eggplant seedlings in Pe. The addition of PM and its mixture with Pe increased leaf Mg content by 44.4%, while its addition to C increased leaf Mg content by 21.7%.

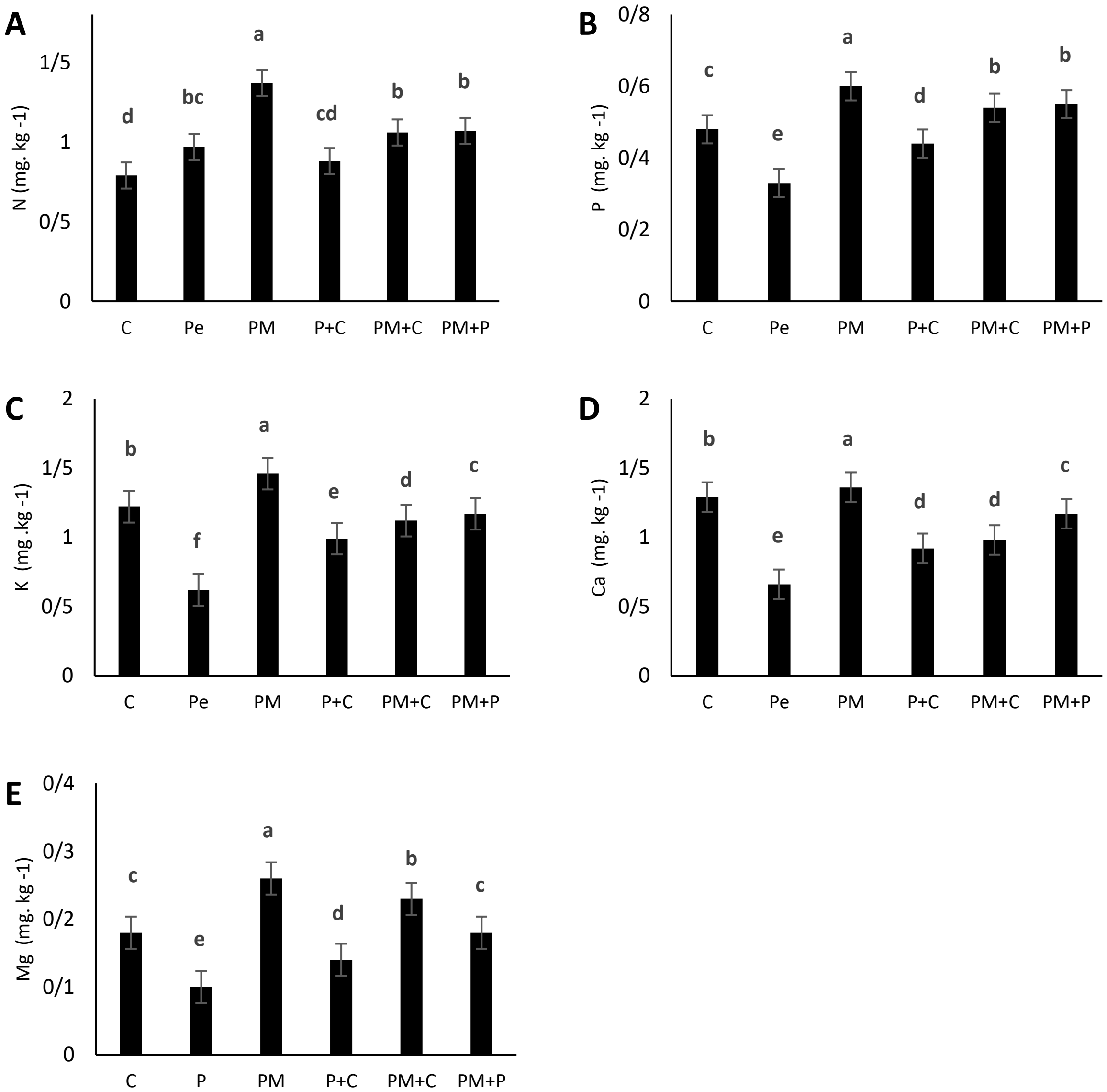

Fig. 3. The effect of different culture media on leaf mineral contents of eggplant seedlings, including nitrogen (A), phosphorus (B), potassium (C), calcium (D), and magnesium (E).
(Mean values with different letters are significantly different at the 1% level of probability using DMRT.)

Discussion

Effect of different priming treatments on seed germination

In this study, pepper and eggplant seed germinations were affected by the applied treatments. According to the results, the highest seed germination percentage of the eggplants and sweet peppers were observed in response to the SA and Put treatments after 8 days (from the germination onset), whereas the lowest germination in both plants was observed in seeds primed with KNO3 and DW. Although germination is an important and sensitive stage in the plant life cycle and is a key process in seedling emergence, the time between planting and seedling establishment usually has a significant effect on yields. Therefore, rapid and uniform germination is essential to increase the yield and quality of transplanted vegetables (Zhang et al., 2012).

Previous research has shown that priming with SA can remove dormancy from fresh seeds, thereby improving germination and relevant features. SA also causes rapid and uniform germination in seeds by increasing their metabolic activity (Karami et al., 2020). It has been suggested that SA increases cell division in roots and stem meristems by maintaining auxin and cytokinin levels in these tissues (Sakhabutdinova et al., 2003).

Seed pretreatment causes physiological changes such as changes in the amount of sugar, organic compounds, and ions accumulated in the seeds, roots, and finally the leaves of the seedlings. This leads to an increased germination rate and greater resistance to adverse conditions in the established seedlings. An increase in germination percentage of bean seeds under salinity stress has been reported by the application of SA (Anaya et al., 2018). It has been reported that SA increases seed germination by organizing antioxidant defense mechanisms, increasing plant growth regulators such as auxins and cytokines, and enhancing proline accumulation (Tabatabaei and Ansari, 2016). In a study, the highest germination percentage, germination rate, natural seedling percentage, seedling length, and seed vigor were obtained in response to the SA treatment (Tabatabaei and Ansari, 2016). The application of SA in pre-treated seeds of tomatoes (Moazen et al., 2021; Szepesi et al., 2005), borages (Shekari et al., 2011), and fennels (Kabiri et al., 2014) increased germination percentage.

SA priming of the seeds of some plants such as tomato (Szepesi et al., 2005), canola (Miar et al., 2011), black bean (Heidarian and Roshandel., 2021), and fennel (Kabiri et al., 2014) reportedly increased seed germination rate and percentage. HA priming after the application of growth regulators enhanced seed germination. Similar to our findings, it has been reported that HA treatment increased the germination percentage of sesame seeds (Nouriyani, 2019). Furthermore, Miar et al. (2011) reported that the application of SA increased the root length of canola. Furthermore, SA pretreatment (300 mg.l-1) enhanced seed germination and initial growth of woolly seedlings, while improving their germination percentage, germination rate, root length, and shoot length (Tavili et al., 2013). Moreover, the SA treatment increased root length by promoting cell division in the root tip (Shakirova et al., 2003).

The application of Put as a growth regulator resulted in the second-longest root length after SA compared to the other studied treatments. The positive effect of Put in increasing root length is related to its role in enhancing cell division in the root tip and also its role in increasing other plant hormones such as auxin and Gas, while reducing ABA content (Hussein et al., 2006). As a small group of molecules, Pedraza et al. (2007) mentioned a wide range of contributions to physiological processes such as embryogenesis, cell division, root and leaf development, and cell proliferation as the effects of PAs. Liu et al. (2016) reported the role of PAs in the seed germination of plants. They reported that exogenous PAs significantly affected seed hormone content (GA, IAA, and Zeatin +Zeatin riboside) during seed germination. The application of putrescine as a seed priming pretreatment improved the germination characteristics and seedling growth of medicinal pumpkin under salinity stress (Farsaraei et al., 2021). There are reports as to the beneficial effects of PA application on the seed germination of other plants, such as tomato (Moazen et al., 2021), hot pepper (Khan et al., 2012), *Ocotea catharinensis* (Dias et al., 2009), and wheat (Liu et al., 2016).

It has been shown that different nitrogenous compounds including inorganic and organic compounds have bio-stimulation effects on various plant growth features (Aslani and Souri, 2018; Aghaye Noroozlo et al., 2019; Mohammadipour and Souri, 2019). Improving seed germination and growth features of peppers by plant hormones has been reported by Tombegavani et al. (2020). As previously described, HA increases root length compared to the $ZnSO_4$ and KNO_3 priming treatments. Moreover, applying SA and spermine on primrose seeds increased the rate and percentage of germination and root growth (Darvizheh et al., 2018). Seed pretreatment elevates growth and improves germination features by enhancing the consumption of seed storage resources. Reports have revealed that seed treatment increases the transfer of seed storage resources to embryonic axis and also activates growth regulation, leading to more growth in the embryonic axis and, consequently, an increase in germination, germination rate, and seedling length (Ansari et al., 2012).

Effect of different culture media on seedling vegetative traits

The results showed that different culture media had a significant effect on the vegetative characteristics of the pepper and eggplant seedlings. The highest and lowest root and shoot dry weight, stem diameter, seedling length, and chlorophyll content of the sweet peppers and eggplants were obtained in the PM and C+Pe treatments, respectively. Previous studies have also mentioned the importance of culture media and their great impact on plant growth, as well as crop yields and quality (Najarian and Souri, 2020; Souri et al., 2019 a, b). It has been suggested that peat moss increases plant growth and seedling height due to the presence of nutrients, especially N, P, and K. By studying the effects of culture media on the growth of tomato seedlings, Mazari et al. (2016) stated that the highest shoot and root dry weights and stem diameter were reached in the combined PM and C culture media, whereas the lowest values were observed in Pe and vermiculite. Shabani et al. (2011) studied the effect of culture media on three sweet pepper cultivars and demonstrated that the use of C and PM in soilless cultivation increased quantitative and qualitative characteristics of sweet peppers. The positive effects of PM on increasing seed germination and growth of oil palm hybrid seeds have been reported by Murugesan et al. (2008). Tomato seedlings grown in a mixture of perlite, vermiculite, and cocopeat with peat substrate had higher root weight, stem diameter, and leaf area than peat substrate per se (Arenas et al., 2002).

Effect of different culture media on leaf chlorophyll index (SPAD)

The results showed that different culture media had a significant effect on leaf chlorophyll index (SPAD) of the pepper and eggplant seedlings. Our results revealed that the highest and lowest SPAD indices were obtained in the seedlings that had been cultivated in the PM and Pe culture media, respectively. Also, the PM medium was more effective than the C medium in increasing leaf SPAD index and chlorophyll content. Leaf greenness is mainly a sign of nitrogen nutrition status and it is associated with chlorophyll content (Klaring and Zude, 2009), taking into account that the leaf color, which is closely correlated with chlorophyll content, is influenced by various factors such as plant growth stage, cultivar, leaf thickness, plant density, and other climatic factors (Molassiotis et al., 2006). In the present study, PM also increased leaf nutrient contents besides their greenness. Similar to our findings, Moazen et al. (2021) reported an increase in the chlorophyll content of tomato leaves in peat moss media due to the enhanced uptake of N, P, K, and Mg.

Effect of different culture media on leaf mineral content

The influence of different culture media was significant on the N, P, K, Ca, and Mg contents in the leaf of sweet peppers and eggplants. The highest and lowest N, P, K, Ca, and Mg content in both plants were observed in the PM and Pe treatments, respectively. The physical and chemical properties of culture media directly or indirectly affected crop yields and quality. The utilization of suitable organic and inorganic substrates allowed plants to grow, spread, and better absorb nutrients. An appropriate culture medium should have a high water-holding capacity and good aeration. It should provide the root system with nutrients in a proper way; therefore, the selection of the best culture medium among different materials is essential in crop production (Aghwani Shajari et al., 2012). In a research study, Saberi et al. (2013) observed that the highest K and Mg concentration in tomato shoots were gained in the cocopeat treatment, while the highest Ca concentration was obtained in the vermiculite medium. In general, they observed that the highest nutrient uptake was achieved by cherry tomatoes in a substrate containing a mixture of perlite and vermiculite. They concluded that it is probably due to optimal root growth conditions, particularly high porosity, water, and nutrient retention capacity of the substrate (Saberi et al., 2013). Due to its spongy structure and high porosity (about 74%), peat moss absorbs a lot of water (it can absorb up to nine times its own weight). Also, due to its cationic capacity, low EC, and low pH, PM is capable of absorbing some elements more efficiently. Besides, the possibility of pathogen proliferation and growth in peat moss is much less. Thus, it will result in a better and faster growth of seedlings and plants (Mofidpoor et al., 2009).

Conclusion

The first experiment demonstrated the importance of seed priming and that plant growth regulators are more efficient in increasing seed germination and germination features, which in turn results in a higher quality of sweet pepper and eggplant seeding at the future stages. As a result, the application of SA and Put can be generally recommended in commercial seedling production of peppers and eggplants in nurseries. The second experiment clearly showed the important role of growth media besides seed priming for further development and growth of seedlings. The highest vegetative quality characteristics were caused by PM in the sweet pepper and eggplant seedlings. These enhanced characteristics were seedling height, root length, stem diameter, and leaf SPAD value. Considering the fact that PM also improved the nutritional status of the seedlings (such as mineral contents of N, P, K, Ca and Mg), the present study recommends the application of PM as a culture substrate in seedling production for peppers and eggplants.

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Conflict of interest
The authors indicate no conflict of interest for the present research.

References

Abdipour M, Hosseinifarahi M, Najafian S. 2019. Effects of Humic Acid and cow manure biochar (cmb) in culture medium on growth and mineral concentrations of basil plant. International Journal of Horticultural Science and Technology 6(1), 27-38. doi: 10.22059/ijhst.2019.279022.287

Aboutalebi Jahromi A., Hosseini Farahi M. 2016. Seed germination, vegetative growth and concentration of some elements in French marigold (*Tageta patula*) as influenced by salinity and ammonium nitrate. International Journal of Horticultural Science and Technology 3(2), 199-209. doi: 10.22059/ijhst.2017.212510.145.

Aghaye Noroozlo Y, Souri MK. Delshad M. 2019. Effects of foliar application of glycine and glutamine amino acids on growth and quality of sweet basil. Advances in Horticultural Science 33(4), 495-501.

Aghwani Shajari M, Nemati, S.H., Mehrbakhsh, MM Fallahi, J., Haghighi Tajour F. 2012. Evaluation of the effects of medium culture and irrigation intervals on seedling growth indices of tomato cultivars under greenhouse conditions. Journal of Horticultural Sciences 26 (1), 87-95. doi: 10.22067 / jhorts4.v0i0.12898

Ajouri A, Asgedom H, Becker M. 2004. Seed priming enhances germination and seedling growth of barley under conditions of P and Zn deficiency. Journal of Plant Nutrition and Soil Science 167, 630–636.

Albaho M, Bhat N, Abo-Rezq H, Thomas B. 2009. Effect of three different substrates on growth and yield of two cultivars of *Capsicum annuum*. European Journal of Scientific Research 28(2), 227-233.

Anaya F., Fghire R., Wahbi, S., and Loutfi K. 2018. Influence of salicylic acid on seed germination of *Vicia faba* L. under salt stress. Journal of the Saudi Society of Agricultural Sciences 17(1), 1-8. http://dx.doi.org/10.1016/j.jssas.2015.10.002

Ansari O, Chogazardi H, Sharifzadeh F, Nazarli H. 2012. Seed reserve utilization and seedling growth of treated seeds of mountain rye (*Secale montanum*) as affected by drought stress. Cercetari Agronomice in Moldova 45, 43–48.

Arenas M, Vavrina CS, Cornell JA, Hanlon EA, Hochmuth GJ. 2002. Coir as an alternative to peat in media for tomato transplant production. HortScience 37, 309–312.

Ashraf M, Foolad MR. 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.

Aslani M and Souri MK. 2018. Growth and quality of green bean (*Phaseolus vulgaris* L.) under foliar application of organic chelate fertilizers. Open Agriculture 3, 146–154.

Darvizheh H, Zahedi M, Abbaszadeh B, Razmjoo J. 2018. Effects of foliar application of salicylic acid and spermine on maternal plant under drought stress on germination indices of purple coneflower (*Echinacea purpurea*). Iranian Journal of Seed Research 5, 1–19.

Dias LLC, Santa-Catarina C, Silveira V, Pieruzzi F P, Floh E I S. 2009. Polyamines, amino acids, IAA and ABA contents during Ocotea catharinensis seed germination. Seed Science and Technology 37, 42–51.

Farsaraei S., Mehdizadeh L. and Moghaddam M. 2021. Seed priming with putrescine alleviated salinity stress during germination and seedling growth of medicinal pumpkin. Journal of Soil Science and Plant Nutrition 1-11. Doi: https://doi.org/10.1007/s42729-021-00479-z

Hadi N, Souri MK., Omidbaigi, R. 2012. The effect of cold stratification and acid gibberllic pre-treatments on seed germination of *Angelica archangelica*, *Tanacetum cinerariaefolium* and *Chelidonium majus*. Agricultural Science and Technology 25 (4): 397-403.

Heidarian F., Roshandel P. 2021. Salicylic acid improves tolerance against salt stress through boosting antioxidant defense system in black bean. International Journal of Horticultural Science and Technology 8(2), 175-189. doi: 10.22059/ijhst.2020.297885.345.

Hosseini A, Koocheki A. 2007. The effect of different priming treatments on germination percent and mean germination time of four varieties of sugar beet. Journal of Agronomic Research 5, 69–76.

Hosseini Farahi M, Zadehbagheri M. 2017. Effect of foliar application of polyamines on growth properties, vase life and endogenous plant growth regulators contents of cut rose flower (*Rosa hybrida* cv. Dolcvita). Iranian Journal of Horticultural Science 47, 717–729.

Hussein MM, Nadia EL, Gereadly HM, El-Desuki M. 2006. Role of putrescine in resistance to salinity of pea plants (*Pisum sativum* L.). Journal of Applied Sciences Research 2, 598–604.

Kabiri R, Hatami A, Naghizadeh M. 2014. Effect of drought stress and its interaction with salicylic acid on fennel (*Foeniculum vulgare Mill.*) germination and early seedling growth. Journal of Medicinal Plants and By-Product 2, 107-116.

Karami L, Hedayat M, Farahbakhsh S. 2020 Effect of salicylic acid priming on seed germination and morphophysiological and biochemical characteristics of tomato seedling (*Lycopersicom esculentun*). Iranian Journal of Seed Research 7 (1) :165-180

Khan H A, Ziaf K, Amjad M, Iqbal Q. 2012. Exogenous application of polyamines improves germination and early seedling growth of hot pepper. Chilean Journal of Agricultural Research 72, 429–433.

Klaring HP, Zude M. 2009. Sensing of tomato plant response to hypoxia in the root environment. Scientia Horticulturae 122, 17–25.

Liu J, Yu B, Liu Y. 2006. Effects of spermidine and spermine levels on salt tolerance associated with tonoplast H+-ATPase and H+-PPase activities in barley roots. Plant Growth Regulation 49, 119–126.

Liu Y., Xu H., Wen X. Xia Liao, Y. Cheng, 2016. Effect of polyamine on seed germination of wheat under drought stress is related to changes in hormones and carbohydrates. Journal of Integrative Agriculture 15, 2759. https://doi.org/10.1016/S2095-3119(16)61366-7

Malassiotis A., Tanou, G, Diamantidis G., Patakas A. and Therios L. 2006. Effects of 4-month Fe deficiency exposure on Fe reduction mechanism, photosynthetic gas exchange, chlorophyll fluorescence and antioxidant defense in two peach rootstocks differing in Fe deficiency tolerance. Journal of Plant Physiology 163, 176-185.
https://doi.org/10.1016/j.jplph.2004.11.016.

Mazari H., Delshad M., Kashi A. 2016. Study of the effect of substrates with different effective air-filled pore space on greenhouse tomato transplant growth. Iranian Journal of Horticultural Science 47(3), 407–419.

Miar Sadegi S., Shekari F., Fotovat R. and Zangani E. 2011. The effect of priming by salicylic acid on vigor and seedling growth of canola (*Brassica napus*) under water deficit condition. Journal of Plant Biology 55-70.

Moazen H., Hosseinifarahi M and Amiri A. 2021. The effect of seed priming and media culture on germination characteristics and quality of tomato seedlings (*Lycopersicon esculentum* L.). Iranian Journal of seed Research 8(2):

Mofidpoor M., Krzic M. and Principe L. 2009. Effects of peat source and length of storage time in bales on selected properties of Sphagnum peat. Canadian Journal of Soil Science 89(5), 635-644.

Mohammadipour N, Souri MK. 2019. Effects of different levels of glycine in the nutrient solution on the growth, nutrient composition and antioxidant activity of coriander (*Coriandrum sativum* L.). Acta Agrobotanica 72(1), 1-9.

Molassiotis A, Tanou G, Diamantidis G, Patakas A, Therios I. 2006. Effects of 4-month Fe deficiency exposure on Fe reduction mechanism, photosynthetic gas exchange, chlorophyll fluorescence and antioxidant defense in two peach rootstocks differing in Fe deficiency tolerance. Journal of Plant Physiology 163, 176–185.

Moradi A, Younesi O. 2009. Effects of osmo-and hydro-priming on seed parameters of grain sorghum (*Sorghum bicolor* L.). Australian Journal of Basic and Applied Sciences 3, 1696–1700.

Murugesan P., Bijimol, G. and Haseela H. 2008. Effect of different substrates on growth of germinated oil palmhybrid seeds. Indian Journal of Horticulture 65(4), 477-480.

Najarian A, Souri M.K, 2020. Influence of sugar cane compost as potting media on vegetative growth, and some biochemical parameters of *Pelargonium× hortorum*. Journal of Plant Nutrition 43(17): 2680-2684.

Nawaz J, Hussain M, Jabbar A, Nadeem GA, Sajid M, Subtain M, Shabbir I. 2013. Seed priming a technique. International Journal of Agriculture and Crop Sciences 6(20), 1373-1381.

Nouriyani H. 2019. Effect of seed priming on germination characteristics, biochemical changes and early seedling growth of sesame (*Sesamum indicum*). Iranian Journal of Seed Research 5, 43–58.

Patterson BD, MacRae EA, Ferguson IB. 1984. Estimation of hydrogen peroxide in plant extracts using titanium (IV). Analytical Biochemistry 139, 487–492.

Pedraza RO, Motok J, Tortora ML, Salazar SM, Diaz-Ricci JC. 2007. Natural occurrence of Azospirillum brasilense in strawberry plants. Plant and Soil 295, 169–178.

Saberi Z, Khoshgoftarmanesh AH, Kalbasi M, Mobli M, Haghighi M. 2013. The effect of different soilless media on macro-and micronutrients uptake by cherry tomato. Journal of Science and Technology of Greenhouse Culture 4, 77–87.

Safarizadeh-Sani A, Hossein B, Goldani M, Gholizadeh M. 2020. Evaluation of the effects of seed priming on growth properties of sweet pepper under irrigation with magnetized water. Iranian Journal of Irrigation and Drainage 14(2), 436-445.

Sakhabutdinova AR, Fatkhutdinova DR, Bezrukova MV, Shakirova FM. 2003. Salicylic acid prevents the damaging action of stress factors on wheat plants. Bulgarian Journal of Plant Physiology 21: 314-319.

Sappalani G., Cabahug L., Valleser V. 2021. Impact of gibberellic acid and organic growth media on seed germination and seedling development of rubber (*Hevea brasiliensis*). International Journal of Horticultural Science and Technology 8(2), 165-174. doi: 10.22059/ijhst.2020.309296.385.

Shabani T, Peyvast G, Olfati J. 2011. Effect of different substrates on quantitative and qualitative traits of three pepper cultivars in soilless culture. Journal of Science and Technology of Greenhouse Culture 2, 11–21.

Shaghaghy A., M.M. Jowkar A. Alirezalu and M. Omidi Ghaleh Mohammadi. 2019. Impact of saline water irrigation on some physiological and biochemical features of *Rosa chinensis* cv 'Old Blush'. Iranian Journal of Horticultural Science and Technology 19 (3), 325-340.

Shakirova FM, Sakhabutdinova RA, Bezrukova MV, Fatkhutdinova RA, Fatkhutdinova DR. 2003. Changes in the hormonal status of wheat seedlings induced by salicylic acid and salinity. Plant Science 164: 317- 322. https://doi.org/10.1016/S0168-9452(02)00415-6.

Shekari F, Pakmehr A, Rastgoo M, Vazayefi M, Ghoreyshi Nasab MJ. 2011. Effect of seed priming with Salicylic Acid on some of physiological traits in *Vigna unguiculata* L. under drought stress. Journal of Agriculture Science 4 (13), 13-29.

Souri MK, Hatamian M, Tesfamariam T.. 2019a. Plant growth stage influences heavy metal accumulation in leafy vegetables of garden cress and sweet basil. Chemical and Biological Technologies in Agriculture 6(1), 1-7.

Souri MK, Hatamian M. 2019. Aminochelates in plant nutrition; a review. Journal of Plant Nutrition 42 (1), 67-78.

Souri MK, Naiji M, Kianmehr MH. 2019b. Nitrogen release dynamics of a slow release urea pellet and its effect on growth, yield, and nutrient uptake of sweet basil (*Ocimum basilicum* L.). Journal of Plant Nutrition 42(6), 604-614.

Szepesi A, Csiszár J, Bajkán S, Gémes K. and Horváth F. 2005. Role of salicylic acid pre-treatment on the acclimation of tomato plants to salt- and osmotic stress. Acta Biologica Szegediensis 49, 123-125.

Tabatabaei SA, Ansari O. 2016. Effect of cu (SO4) stress and plant growth regulators on germination characteristics and biochemical changes of Brassica napus. Iranian Journal of Seed Research 3 (1), 109-121.

Tang W, Newton RJ. 2004. Increase of polyphenol oxidase and decrease of polyamines correlate with tissue browning in Virginia pine (*Pinus virginiana* Mill.). Plant Science 167, 621–628.

Tavili A, Saberi M, Shahriari A, Heidari M. 2013. Salicylic acid effect on Bromus tomentellus germination and initial growth properties under cadmium stress. Journal of Plant Research 26(2), 208-216.

Tombegavani S, Zahedi B, Mousavi Fard S, Ahmadpour A. 2020. Response of germination and seedling growth of pepper cultivars to seed priming by plant growth regulators. International Journal of Horticultural Science and Technology 7(1), 59-68. doi: 10.22059/ijhst.2020.274293.275

Tüzel Y, Tüzel İH, Gül A, Eltez RZ. 2002. Comparison of open and closed systems on yield and quality of greenhouse grown tomatoes. Acta Horticulturae, 579, 585-590.

Yazdanpanah S, Baghizadeh A, Abbassi F. 2011. The interaction between drought stress and salicylic and ascorbic acids on some biochemical characteristics of Satureja hortensis. African Journal of Agricultural Research 6, 798–807.

Zhang M, Wang Z, Yuan L, Yin C, Cheng J, Wang L, Zhang H. 2012. Osmopriming improves tomato seed vigor under aging and salinity stress. African Journal of Biotechnology 11(23), 6305-6311. https://doi.org/10.5897/AJB11.3740.