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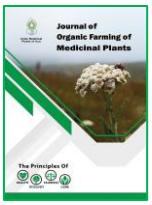

Original Article

The organic priming role in the alleviation of salinity damage on seed germination of cumin (*Cuminum cyminum* L.)

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ABSTRACT

Salinity stress reduces the germination and growth of plants, and organic priming is a suitable way to reduce environmental issues and increase seed germination and plant growth. For this purpose, a study was arranged as a factorial base on a completely randomized design with three replications on cumin seeds. Research treatments included five levels of organic priming (control (no prime), hydropriming, chitosan, humic acid and vermicompost) and four levels of salinity stress (0, 50, 100 and 150 mM NaCl). The results indicated that salinity stress decreased the germination and growth seedling of cumin. Priming with humic acid, chitosan and vermicompost and also hydropriming reduced the negative effects of salinity stress compared to the control (without prime), but the humic acid, chitosan and vermicompost priming action was better than hydropriming. The highest seed germination of cumin was observed in vermicompost priming (98.58 %) in the control condition which had no significant difference with humic acid (98.33 %) and chitosan (98.24 %). The highest proline content (0.86 µmol g^{-1} FW) was related to 150 mM salinity stress without prime, and the lowest (0.29 µmol g^{-1} FW) was observed in humic acid priming, and vermicompost (0.28 µmol g^{-1} FW) in the control condition. The lowest seed germination (54.24 %) was obtained in 150 mM salinity stress. Organic priming increased the germination and growth of cumin seedlings and it is a suitable approach to alleviate salinity stress damage in cumin seedlings.

1. Introduction

Salinity stress is one of the main abiotic stress that decrease germination and growth of plants. Expansion of saline soils and the loss of susceptible lands is one of the problems that agricultures facing with it. Salinity stress cover about 50% of total agricultural land by 2050. Salinity stress produces various detrimental effects on physiological, biochemical, and molecular plants features and also decrease productivity of plants (Verma et al., 2020; Seleiman et al., 2020). Thus, providing solutions such as priming, to deal with salinity stress is very important. Priming is an admirable method that improves the germination of seeds in stress and non-stress conditions and also, causes acceleration and uniformity in germination and improves the growth of plants (Machado et al., 2017). Hydropriming, due to providing enough water for seeds, increases germination, uniform and rapid emergence of seedlings, and increases plant growth under environmental stress conditions (Tania et al., 2020). Results of a study showed that salinity stress in basil (*Ocimum basilicum* L.) seed decreased germination by reducing α-amylase activity (Bahcesular et al., 2020).

Humic acid is one of the main components of humic substances, produced by the biological decomposition of organic matter. Priming seeds with humic acid may increase its beneficial effects to increase crop yield and control environmental stresses (Shen et al., 2020). Humic acid priming increased soybean [*Glycine max* (L.) Merrill.] (Weerasekara et al., 2021), sweet basil (*Ocimum basilicum* L.) (Kalhor Monfared, 2021), and Fenugreek (*Trigonella foenum-graecum*) (Abd Elhakem et al., 2021) seeds germination and growth seedling characteristics of them.

The vermicompost extract is one of the organic fertilizers and also due to the presence of macro and also micro elements such as iron, zinc, copper, and manganese are so important for the growth of plants, especially in the sensitive stage of germination and plant nutrition (Jjagwe et al., 2020). Vermicompost priming improved dill (*Anethum graveolens* L.) growth characteristic and seed quality (Ozden et al., 2017).

Chitosan is a non-toxic, dissoluble and environmentally friendly substance. Chitosan is glucosamine polysaccharide made from chitin. It is very substantial due to its antioxidant activity in dealing with oxidative damages resulting from environmental stresses (especially salinity stress). In environmental stresses, application of chitosan activates some enzymes such as catalase and superoxide dismutase to cope stress (Li et al., 2020; Xiaochen et al., 2020). Researchers suggested that chitosan priming increased germination percentage and seedling growth of broad beans (*Vicia faba* L.) (Abdel Aziz, 2019).

Cumin (*Cuminum cyminum* L.) is one of the considerable medicinal plants of the Appiaceae family with many therapeutic advantages, including rectifying the function of the digestive system. The essential oil of this plant has many uses in the food, cosmetic and health industries (Omidbaigi, 2007). Cultivation of cumin in salinity soil reduces the yield and yield compounds of this plant. It is necessary to use suitable way to improve the germination characteristics of plants and to deal with salinity stress. Therefore, considering the importance of improving the germination and growth of seedlings in salinity stress and the importance of cumin medicinal plant, this experiment aims to investigate the effect of organic priming for reducing the negative effects of salinity stress and extension plant tolerance in environmental stress.

2. Material and Method

2.1 Field experiment

The experiment was conducted as a factorial base on a completely randomized design with three replications, on cumin (*Cuminum cyminum* L.) seeds in the seed technology laboratory of the Islamic Azad University, Karaj branch, in July 2021. The cultivar name of cumin was Rz19. Its origin was from India. Treatments included five levels of organic priming (control (no prime), hydropriming, chitosan, humic acid, vermicompost) as first factor and four levels of salinity stress (0 (control), 50, 100 and 150 mM NaCl) as second factor.

2.2 Seed priming

Before performing the experiment, the papers were sterilized in an autoclave at 100˚C for 20 minutes, and the seeds were sterilized with 3% sodium hypochlorite solution for two minutes and then washed with distilled water. In each experimental unit, 150 seeds of cumin were planted between papers (sandwich method). Sodium chloride was used to apply salinity stress. Before the experiment, vermicompost was sent to the laboratory for chemical analysis (Table 1). To prepare vermicompost extract, first, 100 g of vermicompost was mixed with 400 ml of water and placed on a shaker for 24 hours, then it was passed through a cleaning cloth (Gopal et al., 2010). In this experiment, chitosan concentration of 100 ppm was used. Chitosan was from Sigma-Aldrich, USA. To prepare the chitosan solution, first a 1% acetic acid solution was prepared, then the chitosan solution was stirred in the acid (Khan et al., 2003).

Table 1. Physicochemical properties of the vermicompost

K (%)	P (%)	N (%)	pH	Moisture (%)
0.55	0.52	1.82	7.6	4.39
C/N	O.C (%)	O.M (%)	EC ($ds\ m^{-1}$)	
15.21	26.32	40.73	7.5	

The concentration of humic acid was considered to be 1.5% and the seeds were pre-treated (seed priming) for 24 hours in the treatments of chitosan, humic acid, vermicompost and distilled water at a temperature of 20˚C and then planted in experimental units. 20 ml of salinity stress solution prepared at different levels and added to each experimental unit then kept in the dark place of germinator for 14 days at a temperature of 25˚C and 45% humidity. Traits such as seedling length, germination percentage, seedling vigor, allometric coefficient, proline content, activity of alpha-amylase, catalase and ascorbate peroxidase enzymes were measured.

2.3 Seedling length and germination percentage

The length of seedlings was measured with a ruler. When the root length was 2-3 mm, germination percentage was calculated by Equation 1 (Scott et al., 1984).

$$GP=(S/T)\times 100 \quad \text{(Eq. 1)}$$

Where S and T are the number of germinated seeds and total cultivated seeds, respectively.

2.4 Seedling vigor and allometric coefficient

Seedling vigor was also calculated according to equation 2 and allometric coefficient according to equation 3 (ISTA, 1985).

Seedling vigor= normal germination percentage × seedling length (Eq.2)

Allometric coefficient= root length /stem length (Eq.3)

2.5 Alpha amylase enzyme activity

In order to measure alpha-amylase enzyme activity, 1 g of germination seed tissue was used. To prepare seed tissue extract, first, 5 ml of 60 mM 6.8 phosphate buffer solution was added to the powdered seeds and this solution was centrifuged for 15 minutes at 12,000 rpm. 0.5 ml of 2% starch solution was transferred into the test tube and then 0.5 ml of the extract prepared from above was added to it. After 30 minutes of incubation at 37˚C, the reaction was stopped by 1 ml of 0.1 normal

hydrochloric acid and then 1 ml of iodine reagent (containing 5 mM iodine (I2) and 5 mM of potassium iodide (KI)) was added to it, after that the volume of the contents of the tube was increased to 10 ml with distilled water and finally the light absorption of the solution concentration was measured by a spectrophotometer (PG Instruments Itd VIS/UV+T model) It was recorded with a wavelength of 620 nm and compared with the control sample (Xiao et al., 2006).

2.6 Catalase and Ascorbate peroxidase activity

1500 microliters of 100 mM sodium phosphate buffer containing 2% PVP and 1.3 mM EDTA was added to 350 mg of seedling tissue and after that, the samples for 15 minutes at 15,000 were vortexed. They were centrifuged at 1000 rpm and the light was used to measure the enzyme extract. The reaction mixture contained 30 mM hydrogen peroxide in 50 mM phosphate buffer (pH=7) and 100 microliters of enzyme extract in a final volume of 1000 microliters. The amount of enzyme activity was calculated in terms of each micromole of H_2O_2 decomposed per minute in mg of protein. Absorbance changes at 240 nm were recorded for 3 minutes with a spectrophotometer (PG Instruments Itd VIS/UV+T model (Aebi, 1984). Ascorbate peroxidase enzyme was measured from seedling tissue by spectrophotometric method (PG Instruments Itd VIS/UV+T model) at a temperature of 25°C and finally the enzyme activity was calculated in terms of micromoles of oxidized ascorbate per gram of protein content per minute (Sairam et al., 1998).

2.7 Proline content

The seedlings were dried at a temperature of 25° C for 72 hours, and after grinding, 0.3 g of dry plant material was poured into a mortar and 5 ml of 3% sulphosalicylic acid was added to it, then it was homogenized. The samples were centrifuged for 10 minutes at 4°C at 15000 rpm. 2 ml of ninhydrin acid were added to 2 ml of the resulting clarifier, and then they were mixed well, and solutions of 0, 4, 8, 12, 16, and 20 mg l^{-1} proline standards were used. Then 2 ml of ninhydrin acid and 2 ml of glacial acetic acid were added to them and mixed well. The samples were placed in a hot water bath (bain-marie) for 90 minutes at a temperature of 100° C, and then placed in ice. 4 ml of toluene were added to the solutions and placed in the shaker for 30 minutes, and the absorbance was read using a spectrophotometer (PG Instruments Itd VIS/UV+T model) at a wavelength of 520 nm and compared with a control sample (Bates et al., 1973).

2.8 Statistical analysis

Data analysis was completed using SAS software (Ver. 9.4). The mean values were compared using Duncan's multiple range test at a 5% probability levels.

3. Results

3.1 Seedling length and germination percentage

The results of the ANOVA for seedling length and germination percentage demonstrated that the main effects of priming, salinity stress and also, the interactions between the priming and salinity stress were significant ($p < 0.01$) (Table 2). The mean values showed that chitosan, humic acid and vermicompost priming improved these traits better than hydropriming. Salinity stress decreased seedling length and germination percentage compared to control (no stress). Priming with humic acid, chitosan, vermicompost and hydropriming decreased the negative effects of salinity stress compared to the control. The highest seedling length obtained in chitosan (13.34 cm), vermicompost (13.28 cm) and humic acid (13.06 cm), in control condition (without salinity stress) and the lowest seedling length (6.65 cm) was recorded in 150 mM salinity stress in no prime treatment. In addition, the greatest germination percentage was observed in vermicompost (98.58 %), humic acid (98.33 %) and chitosan (98.24 %), in control seedling (no salinity stress) and the lowest germination percentage (54.24 %), was achieved 150 mM salinity stress in unprimed seeds (Table 3).

3.2 Seedling vigor and allometric coefficient

According to ANOVA results, the main effects of priming, salinity stress, as well as the interactions between the priming and salinity stress were significant on seedling vigor and allometric coefficient (Table 2). The mean values showed that usage of chitosan, humic acid, vermicompost and hydropriming promoted seedling vigor and decreased allometric coefficient compared to control (no prime). Salinity stress reduced seedling vigor but increased allometric coefficient over control (no stress). The highest seedling vigor (1311.24) was achieved in chitosan in control condition (without salinity stress) and the lowest one (361.38) was observed in 150 mM salinity stress in unprimed seeds. In addition, the highest allometric coefficient (1.82) was related to 150 mM salinity stress, and also was achieved in 100 mM salinity stress in unprimed seeds (1.80). The lowest of this trait (0.93), was observed in150 mM salinity stress (Table 3).

3.3 Alpha amylase and catalase activity

ANOVA results for alpha amylase and catalase activity showed the significance of the main effects of priming, salinity stress and also, the interactions between the priming and salinity stress were significant ($p < 0.01$) (Table 2). The mean values showed that utilization of chitosan, humic acid and vermicompost priming increased alpha amylase and catalase activity compared to control (no prime) and salinity stress decreased these traits than control (no stress). The highest alpha amylase

activity was achieved in chitosan (85.24 nmol seed^{-1} minute^{-2}), humic acid 84.98 (nmol seed^{-1} minute^{-2}), vermicompost (85.21 nmol seed^{-1} minute^{-2}) without salinity stress, and the lowest alpha amylase activity was observed in 150 mM salinity stress (27.48 nmol seed^{-1} minute^{-2}). The most catalase activity was observed in chitosan (0.031 µmol Fw minute^{-1}), humic acid (0.029 µmol Fw minute^{-1}), vermicompost (0.030 µmol Fw minute^{-1}) with control condition (no salinity stress) and the lowest catalase activity (0.005 µmol Fw minute^{-1}) was observed in 150 mM salinity stress in unprimed seeds (Table 3).

3.4 Ascorbate peroxidase activity and proline content

ANOVA results presented that the main effects of priming, salinity stress and also the interactions between the priming and salinity stress were significant ($p < 0.01$) on ascorbate peroxidase activity. The main effects of priming, salinity stress was significant ($p < 0.01$), the interactions between the priming and salinity stress were significant ($p < 0.05$) on proline content (Table 2).

The mean values showed that usage of chitosan, humic acid, vermicompost and hydropriming reduced ascorbate peroxidase activity and proline content over control (no prime). Salinity stress increased them over no stress condition. The most ascorbate peroxidase activity (0.212 µmol H_2O_2 min^{-1} mg^{-1} protein) was observed in 150 mM salinity stress, and (0.213 µmol H_2O_2 min^{-1} mg^{-1} protein) was achieved in 100 mM salinity stress without prime. The lowest one was recorded in humic acid priming (0.131 µmol H_2O_2 min^{-1} mg^{-1} protein), and chitosan (0.129 µmol H_2O_2 min^{-1} mg^{-1} protein), in control condition. The highest proline content (0.86 µmol g^{-1} FW) was achieved in 150 mM salinity stress without prime, and the lowest of this trait was observed in humic acid (0.29 µmol g^{-1}FW), and vermicompost (0.28 µmol g^{-1} FW) in control condition (Table 3).

Table 2. Variance analysis of priming and salinity stress effect on germination traits and enzymes activity of cumin

S.O.V	Df	Seedling length	Germination percentage	Seed vigor index	Allometric coefficient	Alpha-Amylase Activity	Catalase Activity	Ascorbate Peroxidase Activity	Proline content
Priming (P)	4	91.24**	428.86**	1925.73**	5.36**	113.65**	0.97**	1.66**	1.18**
Salinity stress (S)	3	46.32**	632.73**	2175.36**	9.54**	125.72**	1.18**	5.14**	2.48**
P×S	12	71.56**	555.84**	4879.45**	10.42**	106.11**	1.09**	10.58**	2.25*
Error	40	19.48	12.68	10.29	2.13	13.73	0.75	3.81	0.97
C.V (%)		9.85	10.24	9.54	8.39	7.65	6.37	5.69	4.28

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

Table 3. Means comparison of priming and salinity stress effect on germination traits and enzymes activity of cumin

Treatments		Seedling length	Germination percentage	Seed vigor index	Allometric coefficient	Alpha-Amylase Activity	Catalase Activity	Ascorbate Peroxidase Activity	Proline content
Priming	Salinity stress (mM)	(cm)	(%)			(nmol seed^{-1}minute^{-2})	(µmol Fw minute^{-1})	(µmol H_2O_2 min^{-1} mg^{-1} protein)	(µmol g^{-1}FW)
Chitosan	Control	13.34^{a}	98.24^{a}	1311.24^{a}	1.11^{e}	85.24^{a}	0.031^{a}	0.129^{f}	0.43^{d}
	50	12.11^{b}	95.75^{b}	1162.24^{c}	1.24^{d}	75.36^{b}	0.020^{b}	0.147^{e}	0.41^{d}
	100	11.05^{c}	90.66^{c}	1001.79^{d}	1.26^{d}	63.89^{c}	0.014^{c}	0.165^{d}	0.55^{c}
	150	9.98^{d}	83.66^{d}	835.21f	1.61^{b}	54.36^{d}	0.015^{c}	0.179^{c}	0.78^{b}
Humic Acid	Control	13.06^{a}	98.33^{a}	1255.04^{b}	1.10^{e}	84.98^{a}	0.029^{a}	0.131^{f}	0.29^{e}
	50	13.11^{b}	95.42^{b}	1243.23^{b}	1.13^{e}	76.48^{b}	0.021^{b}	0.168^{d}	0.42^{d}
	100	11.12^{c}	90.50^{c}	1007.45^{d}	1.26^{d}	62.57^{c}	0.013^{c}	0.165^{d}	0.43^{d}
	150	11.03^{c}	84.66^{d}	934.13^{e}	1.62^{b}	53.36^{d}	0.012^{c}	0.181^{c}	0.54^{c}
Vermicompost	Control	13.28^{a}	98.58^{a}	1308.56^{a}	0.93^{f}	85.21^{a}	0.030^{a}	0.146^{e}	0.28^{e}
	50	12.18^{b}	95.55^{b}	1162.84^{c}	1.12^{e}	75.42^{b}	0.020^{b}	0.167^{d}	0.77^{b}
	100	11.02^{c}	89.93^{c}	990.78^{e}	1.25^{d}	64.73^{c}	0.013^{c}	0.180^{c}	0.53^{c}
	150	11.04^{c}	83.90^{d}	927.56^{e}	1.63^{b}	55.24^{d}	0.014^{c}	0.190^{b}	0.75^{b}
Hydropriming	Control	12.16^{b}	95.11^{b}	1156.42^{c}	1.26^{d}	64.90^{c}	0.022^{b}	0.149^{e}	0.51^{c}
	50	10.07^{d}	83.72^{d}	838.13^{f}	1.48^{c}	54.88^{d}	0.012^{c}	0.165^{d}	0.76^{b}
	100	8.65^{e}	73.23^{e}	634.79^{g}	1.49^{c}	54.91^{d}	0.008^{d}	0.179^{c}	0.78^{b}
	150	7.86^{f}	72.76^{e}	575.86^{gh}	1.62^{b}	38.49^{e}	0.007^{d}	0.188^{b}	0.87^{a}
Control	Control	10.98^{c}	94.67^{b}	1039.75^{d}	1.51^{c}	38.52^{e}	0.013^{c}	0.179^{c}	0.52^{c}
	50	8.57^{e}	73.33^{e}	629.21^{g}	1.64^{b}	37.11^{e}	0.007^{d}	0.189^{b}	0.76^{b}
	100	7.77^{f}	65.90^{f}	513.09^{h}	1.80^{a}	32.69^{f}	0.008^{d}	0.213^{a}	0.77^{b}
	150	6.65^{g}	54.24^{g}	361.38^{i}	1.82^{a}	27.48^{g}	0.005^{e}	0.212^{a}	0.86^{a}

Means in a column and a treatment followed by the same letter are not significantly different at 1% level

4. Discussion

In this study, organic priming could increase germination percentage and other characteristic of cumin seedling. Environmental stress can reduce the percentage of germination, which will have a greater effect on seeds with lower strength, and seed priming can increase the percentage of germination, especially in environmental stresses condition. Organic priming with vermicompost, humic acid and chitosan prepare nutrient and also hormones such as auxin and cytokinin for seeds and increase germination percentage (Jjagwe et al., 2020; Shen et al., 2020). In addition, chitosan like humic acid and vermicompost is full of nitrogen and the role of chitosan is increasing the biosynthesis of auxin hormone. Auxin is one of the reasons for stimulating the growth of seedlings. On the other hand, organic priming by increasing enzyme activity and membrane permeability as well as providing nutrients, especially nitrogen, and due to the presence of nutrients such as fulvic acid, stimulate germination (Shen et al., 2020; Gomes et al., 2021). The results of other study showed that, the application of vermicompost priming increased the germination and growth of onion seeds under salinity stress conditions, which was consistent with the results of the present study (Muhie et al., 2020). Similarly, other researchers suggested that vermicompost application improved seed germination of mung bean (*Vigna radiata* L.) and increased tolerance of seedling in copping salinity stress (Rupani et al., 2018).

One of the reason of increasing seed vigor in organic priming treatments is the increasing germination percentage. Organic priming increased germination percentage due to the improving hormones and organic substances, which increased the total number of germinated seeds (plants produced) and the result is the prompted the seed vigor (Jjagwe, et al., 2020).

One of the parameters that is affected by environmental stress is the allometric coefficient. The allometric coefficient is the result of dividing the root length on the stem length, and increasing this indicates the resistance of the plant to environmental stress such as salinity. The reason for the increase in allometric coefficient in salinity stress is the lack of access to water for the seeds, because the roots have expanded for water. On the other hand, the transfer of nutrients from the cotyledon to the embryo decreased and that is the causes to decrease in the length of the shoot (Muhie et al., 2020).

In this study, with increasing salinity stress, the activity of ascorbate peroxidase increased too. Which can be seen as the response of the plant to deal with salinity stress, and the use of organic priming help seedling to tolerant salinity stress and reduced the activity of ascorbate peroxidase compared to control (without prime). The ascorbate peroxidase enzyme detoxifies the H_2O_2 produced in the chloroplast through the ascorbate-glutathione cycle (Semida et al., 2018).

Hydrolytic enzymes such as alpha-amylase are responsible for the breakdown of seed reserves and energy production in the early stages of growth; therefore, the decrease in growth caused by water stress in the early stages of growth is related to metabolic factors caused by the decrease in water content. The elements and hormones present in the priming of humic acid and vermicompost cause the release of hydrolytic enzymes and breakdown of starch into oligosaccharides. After that, the oligosaccharides are broken down into glucose. This reduces the water potential of the cell and thus facilitates the entry of water into the cell, and following this process, cell growth is stimulated (Abd Elhakem et al., 2021; Liu et al., 2018). Application of organic priming with the access of seeds to high-consumption elements and more nutrients, increase the production of hydrolytic enzymes such as alpha-amylase, because they cause the synthesis of auxin and gibberellin hormones (Abd Elhakem et al., 2021; Liu et al., 2018). Gibberellin is one of the most important hormones affecting the synthesis and activity of alpha-amylase and other hydrolytic enzymes, and auxin is a hormone whose synthesis is influenced by nutrients and increases with the increase of nutrients (Muhie et al., 2021). Therefore, it is possible that the priming of seeds with humic acid, chitosan and vermicompost has increased the synthesis and activity of alpha-amylase enzyme by helping the synthesis of these two hormones. In this regard, it was reported that the use of chitosan increased the activity of alpha-amylase enzyme in maize (*Zea mays* L.) (Gomes et al., 2021).

Humic acid, vermicompost and chitosan priming, created suitable hormonal conditions for the seedling and also provided the elements availability such as nitrogen for seedling. Which is directly related to the synthesis of protein and catalase in the seedling (Voko et al., 2022; Li et al., 2020). Similarly, use of humic acid improved Fenugreek seedling growth characteristics (Abd Elhakem et al., 2021). In addition, other researchers offered that the application of vermicompost can be improve dill growth characteristic in saline condition (Ozden et al., 2017).

The role of proline and its positive effects depend on the structure of the plant, the duration and also intensity of the stress. Actually when content of proline in the plant increases, it indicates the ability of the plant to react to the stress. One of the main causes of increased proline concentration in salinity stress can be changes in the activities of enzymes involved in proline biosynthesis or degradation. Increasing the activity of enzymes involved in proline biosynthesis and decreasing the

activity of its decomposing enzymes such as proline oxidase causes the accumulation of proline in plants. The increase of proline content was considered to the presence of high-energy compounds from photosynthesis. Others stated the regulatory effect of ABA on light processes in proline metabolism is the reason for it. The application of organic priming increased the plant's resistance to salinity stress by increasing the access of seedlings to mineral elements and plant growth regulators (Desoky et al., 2020; Seleiman et al., 2020).

5. Conclusion

Organic priming is suitable technique in order to enhance tolerance levels of plants in response to stress factors. In summary, salinity stress, especially 150 mM salinity caused significant reduction in seed germination and other growth characteristics of cumin. In addition, with enhance the salinity stress, proline content and ascorbate peroxidase enzyme activity increased, which indicates an increase in the plant's tolerance to salinity stress. In increasing germination ability and tolerate with salinity stress, and reduced the negative effects of salinity stress, chitosan, humic acid, and vermicompost priming functions were more effective than hydropriming. Finally, it is recommended to apply chitosan, humic acid or vermicompost priming to deal with and reduce the negative effects of salinity stress on cumin seed germination.

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