Vegetable Science (2025) 52(1): 84-91
doi: 10.61180/vegsci.2025.v52.i1.12
ISSN- 0970-6585 (Print), ISSN- 2455-7552 (Online)
www.isvsvegsci.in

RESEARCH ARTICLE

Effect of seed priming on physiological and biochemical parameters of cucumber (*Cucumis sativus* L.) seeds

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Abstract

A study was undertaken to study the effect of different priming treatments on cucumber var. Punjab Naveen. Different concentrations of priming treatments viz. K_2HPO_4, KH_2PO_4, hydroxyurea, GA_3, ethrel, benzyl adenine, mimosine, KNO_3, $ZnSO_4$ and hydro priming were given, and parameters were recorded. Among the treatments, GA_3 150 ppm improved shoot length (14.93 cm), mean seedling length (26.99 cm) and SVI-I (2699) in comparison to the control. Seed treatment with Ethrel 50 ppm gave the highest speed of germination (4.33) with less mean germination time (2.43). The highest mean seedling dry weight (9.36 mg) and SVI-II (927) were reported with $ZnSO_4$ 0.5%. Similarly, total soluble sugars (8.40 mg g^{-1}FW), α-amylase activity (2.49 mg maltose min^{-1} mg^{-1} protein) and dehydrogenase activity (0.544) improved with ethrel 50 ppm while K_2HPO_4 10^{-3}M improved membrane stability index (64.38%) with highest protein content (183.01 mg g^{-1}FW). The activity of antioxidant enzymes like catalase (51.3 µ moles min^{-1} mg^{-1} protein) and peroxidase (3.07 ΔA min^{-1} mg^{-1} protein) was found highest with benzyl adenine 50 ppm along with reduced lipid peroxidation (0.21 µ moles MDA g^{-1}FW). Hydroxyurea 50 mM gave the highest Total phenol content (5.38 mg g^{-1}FW). The results indicated that priming with growth regulators improved various germination and vigor-contributing characters, along with enhanced enzymatic activity and lesser lipid peroxidation.

Keywords: Seed priming, GA_3, Ethrel, Vigor, Biochemical

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Citation: Varinda, & Singh, R. (2025). Effect of seed priming on physiological and biochemical parameters of cucumber (*Cucumis sativus* L.) seeds. Vegetable Science 52 (1): 84-91.

Source of support: Nil

Conflict of interest: None.

Received: 24/10/2024 **Revised:** 20/03/2025 **Accepted:** 02/05/2025

Introduction

Good quality seed is of paramount importance for sustainable agriculture and has the capability to give higher yields under both normal and adverse environmental conditions (Raj & Raj, 2019). To secure a good harvest, modern agriculture, with emphasis on technology and precision, mandates that almost every seed rapidly germinate as well as promote quality seedlings. Seed producers bear a greater responsibility consequently for maintaining and ensuring seed quality and genetic purity from harvest to further sowing (Chormule et al., 2018). Seed quality enhancement techniques are innovative technologies that researchers have created to maintain the farmers' access to high-quality seeds. One of the most effective seed enhancement methods is seed priming, which is now used in many crops to improve their physiological and biochemical characteristics. To influence the growth of seedlings, seed priming is a pre-sowing technique that modifies pre-germination metabolic activity before the emergence of the radicle. This is a simple and low-cost technique and promotes quick, uniform emergence and plant development to provide higher yields.

At the time of priming, seeds enter the metabolic activation stage, but they are desiccated back to their original

moisture content to stop them from starting the radical protrusion stage. This "head-start" enables them to show more homogeneity and germination rates. In early spring, planted cucumber, late and limited seedling emergence is indeed a great obstacle in achieving a uniform and vigorous crop stand that further delays fruit maturity and early marketability of fruits. Priming treatments are known to modify certain physiological and environmental parameters and are regularly observed by many researchers. Primed cucumber seeds were shown to have significantly higher mean seedling length (MSL), initial and final germination counts, rate of germination, mean seedling dry weight (MSDW), seedling vigor index (SVI-I) and SVI-II, along with other seed quality indices (Sowmya et al., 2022, Mombeini et al., 2022, Alam et al., 2023) and other crops like coriander (Bharti et al. 2024). On the flip side, primed cucumber seeds also show improvements in biochemical parameters such as sugar content, electrical conductivity, antioxidant activity, and catalase activity (Shakuntala et al., 2020a, Mombeieni et al., 2022). Therefore, seed priming with various chemicals such as dipotassium hydrogen phosphate, potassium dihydrogen phosphate, gibberellic acid, ethrel, potassium nitrate, zinc sulfate and hydroxyurea is necessary to increase germination and other physiological properties as well as early maturity of fruits. The present investigation was carried out to study the effects of different priming methods on different physiological and biochemical parameters of cucumber seeds.

Materials and Methods

The present investigation was conducted on cucumber variety Punjab Naveen at the Plant physiology laboratory of the Office of Director Seeds, Punjab Agricultural University, Ludhiana during 2020-2022. The experiment was conducted in completely randomized design (CRD) and consisted of 29 treatments *viz*.T_1- K_2HPO_4 10^{-1} M, T_2- K_2HPO_4 10^{-3}M, T_3- K_2HPO_4 10^{-5} M, T_4- Hydroxyurea 10 mM, T_5- Hydroxyurea 25 mM, T_6- Hydroxyurea 50 mM, T_7- $ZnSO_4$ 0.5%, T_8- $ZnSO_4$ 1%, T_9- $ZnSO_4$ 2%, T_{10}- KH_2PO_4 10^{-1}M, T_{11}- KH_2PO_4 10^{-3} M, T_{12}- KH_2PO_4 10^{-5} M, T_{13}- Hydro priming, T_{14}- Benzyl adenine 10 ppm, T_{15}- Benzyl adenine 50 ppm, T_{16}- Benzyl adenine 100 ppm, T_{17}- KNO_3 0.5%, T_{18}- KNO_3 1%, T_{19}- KNO_3 1.5%, T_{20}- Ethrel 10 ppm, T_{21}- Ethrel 50 ppm, T_{22}- Ethrel 100 ppm, T_{23}-Mimosine 100 µM, T_{24}-Mimosine 150 µM, T_{25}-Mimosine 200 µM, T_{26}- GA_3 100 ppm, T_{27}- GA_3 150 ppm, T_{28}- GA_3 200 ppm, T_{29}-Control. The seeds were treated with priming treatments for 6 hours, rinsed with running tap water, and dried back to their original moisture content by air drying for 2 to 3 days and various physiological and biochemical parameters were recorded thereafter.

Seed germination (%) was assessed using the between-paper method as described by ISTA (2008). Ten normal seedlings from each treatment were randomly selected in triplicates at the time of germination count (8th day) and the length of each was measured from the shoot tip to the root tip using a centimeter scale. Root length (from root base to root tip) and shoot length (from tip of shoot to tip of shoot) were both measured individually. Seedlings were bagged, dried in a hot air oven at 70°C for 24 hours and weighed using an electronic balance after cooling. The seedling vigor index-I was calculated as described by Abdul-Baki & Anderson (1973) and the seedling vigor index-II was calculated as described by Bewley & Black (1994). The top of the paper method was used to measure the speed of germination (AOSA, 1983). For eight days, the number of seeds that germinated each day was measured to calculate the mean germination time (Ellis & Roberts, 1981).

The Total soluble sugar content of seeds was estimated by using the phenol-sulphuric acid method as described by Dubois et al. (1956). Total soluble protein content was determined using a method proposed by Lowry et al. (1951) and the total phenol content of seeds was estimated by utilizing the method described by Bray & Thorpe (1954). The method, as described by Murata et al. (1968) and Kittock & Law (1968), was used for the estimation of α-amylase activity and dehydrogenase activity, respectively. The membrane integrity of seeds was determined by the method of Fletcher and Drexler (1980). The enzymatic activity of seeds involving catalase and peroxidase was assessed by following the method elaborated by Aebi (1984) and Claiborne & Fridovich (1979) respectively. The method described by Heath & Packer (1968) was used to assess lipid peroxidation. The data obtained from different physiological and biochemical parameters with different treatments was subjected to analysis of variance using OP STAT software. The critical difference values were calculated at 5% (p = 0.05) probability level.

Results and Discussion

Physiological Parameters

The primary requirement for all seeds is the germination potential and seed vigor and these should always be considered together while evaluating the seed. In the present study, all the priming treatments except K_2HPO_4 10^{-1}M (T_1), benzyl adenine 10 ppm (T_{14}) and hydro priming (T_{13}) reported 100% germination (Table 1a). When compared to hydro priming, chemical priming of seeds using K_2HPO_4, KH_2PO_4, hydroxy urea, ethrel and gibberelic acid appears to be advantageous for increasing the percentage of germination and vigor of the seed (Mombeini et al., 2022). Similar results were reported in seeds of cucumber (Shakuntala et al., 2020b).

The highest shoot length (14.93 cm) was observed with T_{27} and the lowest shoot length (4.59 cm) with T_{16} (Table 1a). The increased shoot length due to priming with gibberlic acid 150 ppm might be due to its role in enhanced growth of meristematic portion, cell elongation and a greater rate of

Table 1a: Effect of various priming treatments on germination percentage, shoot length, root length seedling length and seedling vigor index-I of seeds of *Cucumis sativus* L.

Treatment	*Germination (%)*	*Shoot length (cm)*	*Root length (cm)*	*Mean Seedling length (cm)*	*Seedling vigor index-I*
Di potassium hydrogen phosphate 10^{-1}M	97.00 ± 1.73	13.30 ± 0.35	12.87 ± 0.03	26.17 ± 0.38	2540 ± 79.85
Di potassium hydrogen phosphate 10^{-3}M	100.00 ± 0.00	11.87 ± 0.14	11.46 ± 0.25	23.33 ± 0.17	2333 ± 16.91
Di potassium hydrogen phosphate 10^{-5}M	98.00 ± 1.16	12.63 ± 0.12	12.41 ± 0.02	25.05 ± 0.11	2455 ± 25.44
Hydroxyurea10mM	100.00 ± 0.00	12.76 ± 0.20	12.04 ± 0.06	24.80 ± 0.15	2480 ± 14.57
Hydroxyurea 25 mM	100.00 ± 0.00	12.49 ± 0.08	11.66 ± 0.05	24.15 ± 0.09	2415 ± 8.98
Hydroxyurea 50 mM	100.00 ± 0.00	12.47 ± 0.12	10.89 ± 0.06	23.36 ± 0.12	2336 ± 12.12
Zinc sulfate 0.5%	99.00 ± 0.58	11.97 ± 0.04	11.39 ± 0.06	23.37 ± 0.10	2313 ± 18.50
Zinc sulfate 1%	100.00 ± 0.00	12.58 ± 0.19	11.94 ± 0.11	24.53 ± 0.27	2453 ± 26.64
Zinc sulfate 2%	100.00 ± 0.00	12.64 ± 0.17	11.39 ± 0.07	24.03 ± 0.22	2403 ± 21.66
Potassium dihydrogen phosphate 10^{-1} M	100.00 ± 0.00	13.35 ± 0.25	12.18 ± 0.12	25.53 ± 0.38	2553 ± 37.60
Potassium dihydrogen phosphate 10^{-3}M	99.00 ± 0.58	12.35 ± 0.32	12.34 ± 0.09	24.69 ± 0.40	2444 ± 50.50
Potassium dihydrogen phosphate 10^{-5}M	100.00 ± 0.00	13.25 ± 0.02	12.64 ± 0.12	25.89 ± 0.11	2589 ± 10.97
Hydro priming	97.00 ± 1.73	13.17 ± 0.19	12.84 ± 0.21	26.01 ± 0.39	2523 ± 72.57
Benzyl adenine 10 ppm	97.00 ± 0.58	14.14 ± 0.14	10.90 ± 0.14	25.04 ± 0.21	2429 ± 25.01
Benzyl adenine 50 ppm	100.00 ± 0.00	6.70 ± 0.19	5.10 ± 0.04	11.80 ± 0.17	1180 ± 17.40
Benzyl adenine 100 ppm	99.00 ± 0.58	4.59 ± 0.13	2.01 ± 0.19	6.62 ± 0.31	656 ± 34.59
Potassium nitrate 0.5 %	100.00 ± 0.00	13.19 ± 0.05	10.07 ± 0.12	23.26 ± 0.16	2326 ± 16.00
Potassium nitrate 1%	100.00 ± 0.00	13.93 ± 0.01	11.76 ± 0.14	25.69 ± 0.15	2569 ± 15.03
Potassium nitrate 1.5%	100.00 ± 0.00	13.85 ± 0.12	11.77 ± 0.25	25.62 ± 0.38	2562 ± 37.72
Ethrel 10ppm	100.00 ± 0.00	13.15 ± 0.08	10.27 ± 0.06	23.42 ± 0.13	2342 ± 12.84
Ethrel 50ppm	98.00 ± 1.16	13.13 ± 0.20	10.84 ± 0.15	23.97 ± 0.16	2348 ± 15.86
Ethrel 100ppm	100.00 ± 0.00	13.73 ± 0.16	10.91 ± 0.08	24.64 ± 0.24	2464 ± 23.83
Mimosine 100µM	100.00 ± 0.00	14.41 ± 0.10	10.66 ± 0.02	25.07 ± 0.08	2507 ± 8.08
Mimosine 150µM	100.00 ± 0.00	13.23 ± 0.00	10.88 ± 0.06	24.12 ± 0.06	2412 ± 5.77
Mimosine 200µM	100.00 ± 0.00	13.14 ± 0.08	10.63 ± 0.08	23.77 ± 0.16	2377 ± 15.52
Gibbrellic acid 100ppm	100.00 ± 0.00	14.14 ± 0.10	11.67 ± 0.08	25.80 ± 0.17	2580 ± 17.14
Gibbrellic acid 150ppm	100.00 ± 0.00	14.93 ± 0.04	12.06 ± 0.12	26.99 ± 0.16	2699 ± 16.04
Gibbrellic acid 200ppm	100.00 ± 0.00	14.01 ± 0.26	12.09 ± 0.11	26.10 ± 0.28	2610 ± 27.50
Control	100.00 ± 0.00	12.59 ± 0.07	11.89 ± 0.10	24.48 ± 0.05	2448 ± 5.35
C.D.	1.67	0.45	0.32	0.63	83.85
C.V.	1.02	2.19	1.75	1.63	2.17

cell division. The lowest shoot length of priming treatment benzyl adenine 50 and 100 ppm might be due to toxicity of the chemical with its higher concentration and it restricts the polar movement of auxin in plants that further inhibits the upward growth of seedlings and contributes towards the thickening of seedlings. On the other hand, the highest root length (12.87 cm) was observed with treatment T_1 and the lowest root length (2.0 cm) with treatment T_{16} (Table 1a). The reduced gap between the emergence of root and imbibition might be the reason for enhanced root length (Shakuntala et al. 2020b).

The highest seedling length was reported to be T_{27} (26.99 cm) and the lowest with T_{16} (6.62 cm) (Table 1a). Enhanced seedling length with T_{27} is positively correlated with increased shoot length. Our results are similar to the findings of Armin et al. (2010) in watermelon. The highest dry weight was produced with T7 (9.36 mg) and lowest in T15 (5.32 mg) (Table 1b). The faster rate of germination in primed

Table 1b: Effect of various priming treatments on dry weight, seedling vigor index-II, speed of germination and mean germination time of seeds of *Cucumis sativus* L.

Treatment	*Mean seedling Dry weight (mg)*	*Seedling vigor index-II*	*Speed of germination*	*Mean germination time*
Di potassium hydrogen phosphate 10^{-1}M	7.40 ± 0.06	718 ± 11.20	3.02 ± 0.02	3.43 ± 0.05
Di potassium hydrogen phosphate 10^{-3}M	8.87 ± 0.15	887 ± 14.53	2.83 ± 0.01	4.10 ± 0.06
Di potassium hydrogen phosphate 10^{-5}M	7.83 ± 0.18	768 ± 24.03	2.82 ± 0.08	4.27 ± 0.03
Hydroxyurea10 mM	8.43 ± 0.09	843 ± 8.82	4.06 ± 0.02	2.57 ± 0.03
Hydroxyurea 25 mM	8.30 ± 0.06	830 ± 5.77	3.05 ± 0.03	3.40 ± 0.06
Hydroxyurea 50 mM	9.03 ± 0.12	903 ± 12.02	3.32 ± 0.02	3.17 ± 0.03
Zinc sulfate 0.5%	9.36 ± 0.05	927 ± 9.70	2.87 ± 0.03	4.03 ± 0.02
Zinc sulfate 1%	8.37 ± 0.07	837 ± 6.67	2.81 ± 0.02	4.43 ± 0.07
Zinc sulfate 2%	8.20 ± 0.03	820 ± 3.33	2.13 ± 0.03	4.93 ± 0.02
Potassium dihydrogen phosphate 10^{-1}M	7.82 ± 0.04	782 ± 4.05	2.96 ± 0.01	3.80 ± 0.02
Potassium dihydrogen phosphate 10^{-3}M	8.25 ± 0.08	817 ± 3.06	2.92 ± 0.02	4.00 ± 0.00
Potassium dihydrogen phosphate 10^{-5}M	8.62 ± 0.01	862 ± 1.46	3.42 ± 0.05	2.98 ± 0.02
Hydro priming	8.61 ± 0.19	835 ± 24.01	3.97 ± 0.03	2.73 ± 0.12
Benzyl adenine 10ppm	8.47 ± 0.01	821 ± 4.06	4.00 ± 0.00	2.63 ± 0.12
Benzyl adenine 50ppm	5.32 ± 0.08	532 ± 8.21	3.84 ± 0.05	2.83 ± 0.07
Benzyl adenine 100ppm	6.90 ± 0.05	683 ± 7.69	3.47 ± 0.04	2.97 ± 0.02
Potassium nitrate 0.5 %	7.72 ± 0.14	772 ± 13.78	3.67 ± 0.04	2.90 ± 0.05
Potassium nitrate 1%	8.29 ± 0.08	829 ± 8.33	4.31 ± 0.02	2.43 ± 0.03
Potassium nitrate 1.5%	8.88 ± 0.09	888 ± 9.33	4.25 ± 0.04	2.47 ± 0.03
Ethrel 10ppm	8.61 ± 0.04	861 ± 4.18	4.06 ± 0.06	2.57 ± 0.03
Ethrel 50ppm	8.18 ± 0.04	802 ± 6.01	4.33 ± 0.04	2.43 ± 0.03
Ethrel 100ppm	8.49 ± 0.04	849 ± 3.93	3.47 ± 0.03	2.97 ± 0.03
Mimosine 100µM	8.41 ± 0.05	841 ± 5.24	4.28 ± 0.13	2.45 ± 0.05
Mimosine 150µM	7.66 ± 0.16	766 ± 16.15	3.89 ± 0.02	2.77 ± 0.06
Mimosine 200µM	8.35 ± 0.08	835 ± 8.37	3.87 ± 0.03	2.78 ± 0.01
Gibbrellic acid 100ppm	8.17 ± 0.03	817 ± 2.67	3.36 ± 0.09	3.13 ± 0.03
Gibbrellic acid 150ppm	8.14 ± 0.10	814 ± 9.56	3.75 ± 0.03	2.89 ± 0.03
Gibbrellic acid 200ppm	8.07 ± 0.07	807 ± 6.67	3.58 ± 0.08	2.93 ± 0.03
Control	9.01 ± 0.03	901 ± 3.34	2.54 ± 0.05	4.51 ± 0.01
C.D.	0.25	28.84	0.13	0.14
C.V.	1.89	2.16	2.35	2.62

seeds led to more time for the development of plumule and radicals that will ultimately contribute towards more dry matter accumulation in seedlings. A decrease in germination time and enhanced cell division in the meristematic cells of seedling shoots and roots during priming treatment led to a rise in plant development, which is indeed the primary cause of the rise in dry matter accumulation (Rehman et al., 2011).

Higher seedling vigor of primed seeds is significantly correlated with higher germination percentage, length and dry weight of seedlings. The highest SVI-I was reported with treatment T_{27} (2699) and the lowest was reported with T_{16} (656) (Table 1a). The highest SVI-II was reported with T_7 (927) and the lowest was reported with treatment T_{15} (532) (Table 1b). For priming treatments, the seedling vigor index increases primarily owing to the shortening of the time required for imbibition and emergence as well as lesser injury to the membranes of the seed along with enhanced activities of enzymes like dehydrogenase

Table 2a: Effect of various priming treatments on total soluble sugars, total protein content, alpha amylase activity, dehydrogenase \ activity and lipid peroxidation of seeds of *Cucumis sativus* L.

Treatment	*Total soluble sugars (mg g^{-1}FW)*	*Total protein (mg g^{-1} FW)*	*Alpha amylase (mg maltose min^{-1} mg^{-1} protein)*	*Dehydrogenase (Absorbance at 485 nm)*	*Lipid peroxidation (µ moles MDA g^{-1} FW)*
Di potassium hydrogen phosphate 10^{-1}M	6.36 ± 0.02	150.62 ± 0.72	1.71 ± 0.00	0.338 ± 0.02	0.35 ± 0.00
Di potassium hydrogen phosphate 10^{-3}M	7.29 ± 0.03	183.01 ± 1.50	2.12 ± 0.00	0.451 ± 0.006	0.31 ± 0.001
Di potassium hydrogen phosphate 10^{-5}M	6.23 ± 0.03	150.82 ± 2.48	1.63 ± 0.02	0.499 ± 0.007	0.29 ± 0.002
Hydroxyurea10mM	6.48 ± 0.04	95.58 ± 0.72	1.72 ± 0.02	0.450 ± 0.006	0.26 ± 0.002
Hydroxyurea 25 mM	6.24 ± 0.02	103.13 ± 0.69	1.72 ± 0.02	0.288 ± 0.009	0.48 ± 0.00
Hydroxyurea 50mM	6.56 ± 0.02	97.17 ± 1.24	1.74 ± 0.02	0.275 ± 0.009	0.29 ± 0.00
Zinc sulfate 0.5%	5.85 ± 0.04	88.51 ± 1.28	1.57 ± 0.02	0.267 ± 0.005	0.40 ± 0.001
Zinc sulfate 1%	5.63 ± 0.23	84.05 ± 1.38	1.46 ± 0.05	0.28 ± 0.012	0.39 ± 0.001
Zinc sulfate 2%	5.68 ± 0.07	81.07 ± 1.58	1.55 ± 0.01	0.287 ± 0.012	0.39 ± 0.00
Potassium dihydrogen phosphate 10^{-1} M	7.12 ± 0.04	75.51 ± 1.70	1.87 ± 0.016	0.439 ± 0.004	0.31 ± 0.00
Potassium dihydrogen phosphate 10^{-3}M	6.56 ± 0.08	103.93 ± 1.39	1.74 ± 0.02	0.334 ± 0.006	0.35 ± 0.003
Potassium dihydrogen phosphate 10^{-5}M	6.58 ± 0.03	121.81 ± 1.55	1.74 ± 0.03	0.344 ± 0.004	0.32 ± 0.002
Hydro priming	5.07 ± 0.57	108.69 ± 1.77	1.40 ± 0.00	0.397 ± 0.005	0.22 ± 0.002
Benzyl adenine 10ppm	5.26 ± 0.38	83.26 ± 0.53	1.43 ± 0.00	0.27 ± 0.008	0.22 ± 0.00
Benzyl adenine 50ppm	4.87 ± 0.31	111.08 ± 1.70	1.36 ± 0.03	0.39 ± 0.01	0.21 ± 0.006
Benzyl adenine 100ppm	5.64 ± 0.07	80.08 ± 0.87	1.52 ± 0.13	0.222 ± 0.013	0.24 ± 0.002
Potassium nitrate 0.5 %	7.53 ± 0.02	145.65 ± 1.05	2.21 ± 0.01	0.312 ± 0.008	0.39 ± 0.001
Potassium nitrate 1%	6.16 ± 0.05	127.77 ± 1.39	1.60 ± 0.01	0.40 ± 0.008	0.40 ± 0.002
Potassium nitrate 1.5%	6.84 ± 0.11	131.94 ± 1.21	1.77 ± 0.00	0.504 ± 0.00	0.47 ± 0.004
Ethrel 10ppm	8.30 ± 0.08	87.63 ± 1.24	2.20 ± 0.03	0.539 ± 0.001	0.41 ± 0.010
Ethrel 50ppm	8.43 ± 0.01	82.66 ± 1.11	2.49 ± 0.05	0.544 ± 0.01	0.32 ± 0.00
Ethrel 100ppm	8.19 ± 0.07	100.55 ± 1.21	2.11 ± 0.03	0.409 ± 0.009	0.23 ± 0.008
Mimosine 100µM	8.09 ± 0.03	64.38 ± 1.82	2.22 ± 0.01	0.394 ± 0.011	0.25 ± 0.002
Mimosine 150µM	7.73 ± 0.18	73.72 ± 1.43	2.37 ± 0.03	0.454 ± 0.008	0.25 ± 0.001
Mimosine 200µM	8.21 ± 0.21	122.80 ± 0.91	2.01 ± 0.03	0.449 ± 0.006	0.26 ± 0.003
Gibbrellic acid 100ppm	7.42 ± 0.11	88.62 ± 1.21	2.15 ± 0.02	0.393 ± 0.004	0.29 ± 0.002
Gibbrellic acid 150ppm	6.75 ± 0.12	91.61 ± 1.30	1.76 ± 0.00	0.504 ± 0.006	0.39 ± 0.005
Gibbrellic acid 200ppm	7.17 ± 0.10	119.82 ± 0.34	1.92 ± 0.01	0.497 ± 0.004	0.25 ± 0.020
Control	5.97 ± 0.07	82.66 ± 1.21	1.59 ± 0.00	0.372 ± 0.006	0.69 ± 0.004
C.D.	0.47	3.78	0.12	0.021	0.01
C.V.	4.26	2.20	4.14	3.34	2.55

Table 2b: Effect of various priming treatments on total phenol, catalase, peroxidase and membrane stability index of seeds of *Cucumis sativus* L.

Treatment	*Total phenol (mg g^{-1} FW)*	*Catalase (μ moles min^{-1} mg^{-1} protein)*	*Peroxidase (ΔA min^{-1} mg^{-1} protein)*	*Membrane stability index (%)*
Di potassium hydrogen phosphate 10^{-1}M	3.03 ± 0.04	19.8 ± 0.03	0.68 ± 0.02	43.22 ± 1.30
Di potassium hydrogen phosphate 10^{-3}M	3.22 ± 0.04	21.6 ± 0.31	0.84 ± 0.00	63.57 ± 0.04
Di potassium hydrogen phosphate 10^{-5}M	5.13 ± 0.05	23.0 ± 0.01	0.98 ± 0.01	64.38 ± 0.62
Hydroxyurea10mM	4.91 ± 0.04	26.6 ± 0.14	1.08 ± 0.02	60.27 ± 0.30
Hydroxyurea 25 mM	5.34 ± 0.05	16.2 ± 0.11	0.39 ± 0.00	65.04 ± 1.10
Hydroxyurea 50 mM	5.38 ± 0.09	23.6 ± 0.29	1.05 ± 0.02	62.40 ± 0.63
Zinc sulfate 0.5%	2.79 ± 0.03	19.3 ± 0.02	0.46 ± 0.02	51.32 ± 0.37
Zinc sulfate 1%	2.64 ± 0.27	19.7 ± 0.02	0.61 ± 0.00	47.67 ± 1.39
Zinc sulfate 2%	2.41 ± 0.02	19.6 ± 0.02	0.54 ± 0.00	39.85 ± 1.39
Potassium dihydrogen phosphate 10^{-1} M	5.37 ± 0.04	21.7 ± 0.08	0.87 ± 0.00	54.95 ± 0.72
Potassium dihydrogen phosphate 10^{-3}M	4.52 ± 0.02	19.8 ± 0.04	0.63 ± 0.01	58.96 ± 0.70
Potassium dihydrogen phosphate 10^{-5}M	3.30 ± 0.03	20.6 ± 0.15	0.73 ± 0.00	64.58 ± 0.59
Hydro priming	4.51 ± 0.04	50.2 ± 0.01	1.80 ± 0.01	59.98 ± 0.31
Benzyl adenine 10ppm	3.87 ± 0.05	51.2 ± 0.02	2.34 ± 0.02	55.78 ± 0.76
Benzyl adenine 50ppm	4.69 ± 0.00	51.3 ± 0.04	3.07 ± 0.01	48.17 ± 1.94
Benzyl adenine 100ppm	3.92 ± 0.02	34.7 ± 0.03	1.45 ± 0.03	47.31 ± 0.41
Potassium nitrate 0.5 %	4.04 ± 0.03	19.5 ± 0.03	0.49 ± 0.01	50.77 ± 0.00
Potassium nitrate 1%	4.05 ± 0.03	19.4 ± 0.01	0.46 ± 0.02	43.53 ± 2.31
Potassium nitrate 1.5%	4.06 ± 0.03	17.6 ± 0.02	0.44 ± 0.00	44.15 ± 0.00
Ethrel 10ppm	3.40 ± 0.03	18.6 ± 0.22	0.45 ± 0.02	56.20 ± 1.87
Ethrel 50ppm	3.92 ± 0.04	20.1 ± 0.04	0.68 ± 0.00	56.44 ± 1.03
Ethrel 100ppm	4.82 ± 0.02	35.0 ± 0.04	1.18 ± 0.02	58.73 ± 1.24
Mimosine 100μM	4.69 ± 0.00	30.6 ± 0.01	1.36 ± 0.02	57.20 ± 4.19
Mimosine 150μM	3.89 ± 0.05	29.9 ± 0.02	1.20 ± 0.03	55.28 ± 1.28
Mimosine 200μM	3.80 ± 0.03	26.9 ± 0.03	1.09 ± 0.02	51.29 ± 1.82
Gibbrellic acid 100ppm	4.80 ± 0.03	21.8 ± 0.03	0.98 ± 0.03	56.12 ± 0.00
Gibbrellic acid 150ppm	3.83 ± 0.05	19.6 ± 0.00	0.49 ± 0.03	60.12 ± 0.02
Gibbrellic acid 200ppm	4.98 ± 0.06	28.9 ± 0.03	1.19 ± 0.01	51.27 ± 1.73
Control	3.59 ± 0.02	15.5 ± 0.06	0.35 ± 0.00	57.60 ± 0.16
C.D.	0.18	0.29	0.05	3.75
C.V.	2.64	0.70	2.93	4.19

and α-amylase activities (Pandey et al., 2017). During seed priming, metabolic activities get accelerated, which allows physiological and biochemical changes to commence in the seed, leading to a higher seedling vigor index (Shakuntala et al., 2020a). Our results are similar to the results of Singh & Bassi (2016) in bitter gourd seeds and Rahman et al. (2020) in okra seeds.

The highest speed of germination was reported with treatment T_{21} (4.33) and the lowest speed of germination was reported with treatment T_9 (2.13) (Table 1b). The possible reason for accelerating the speed of germination with the application of a growth regulator like ethrel might be due to the involvement of plant growth regulator in a breakdown of stored food reserve and increment of activities of enzyme required for mobilization of food reserve that further enhance the speed of germination (Singh & Bassi, 2016). On the other hand, the lowest mean time required for germination is reported with treatment T_{21} (2.43) and the highest mean germination time recorded in treatment T_9 (4.93) (Table 1b). Mean germination time is inversely dependent upon the speed of germination means if the speed of germination is more mean time required for germination will be lesser and vice versa. Shortening the lag phase and the advancement of genetic repair mechanisms

can resume during priming may lead to a considerable decrease in the mean germination time (Krainart et al., 2015).

Biochemical parameters

Priming treatments also had a significant effect on the biochemical characteristics of cucumber seeds and data regarding the biochemical parameters is presented in Tables 2a and 2b. Our data revealed the highest total soluble sugars with treatment T_{23} (8.43 mg g^{-1} FW) and the lowest with treatment T_{15} (4.87 mg g^{-1}FW). A crucial process that begins with priming is the hydrolysis of starch macromolecules into simpler sugars with stimulation of the α-amylase enzyme (Pawar & Laware, 2018). Plant growth regulators involved in the breakdown of food reserve by activation of certain enzymes that are required for their metabolism ultimately enhance the level of energy providing components like sugars in primed seeds. The highest α-amylase activity with treatment T_{21} (2.49 mg maltose min^{-1} mg^{-1}protein) and lowest with treatment T_{15} (1.36 mg maltose min^{-1} mg^{-1} protein). It is possible that appropriate hydration during imbibition, which increased the hydrolysis of starch, contributed to the enhancement of α-amylase activity in primed seeds (Kaur, 2020).

The highest total soluble protein content (183.01 mg g^{-1}FW) was found with treatment T2 and the lowest was found with treatment T23 (64.38 mg g^{-1}FW). Varier et al. (2010) claimed that seed priming increases protein synthesis by enhancing the efficiency of the machinery involved in protein synthesis. A similar result of increased soluble protein content was also reported by Amooaghaie et al. (2010). Dehydrogenase activity was found to be higher with treatment T_{21} (0.544), whereas T_{16} (0.222) gave the lowest value for dehydrogenase activity. Priming helps to initiate certain enzymes that are required for the biosynthesis of macromolecules or metabolization of the food reserve of seed. These enzymes may include α-amylase, dehydrogenase enzymes, lipase enzymes and protease enzymes. Enhanced dehydrogenase enzyme activity may be a signpost for larger levels of cellular biosynthetic processes, including DNA and RNA synthesis, which in turn point to elevated amounts of protein and energy production required for seedling emergence and germination.

The production of ROS (reactive oxygen species) occurs throughout the priming procedure alongside seed imbibition and the ensuing dehydration (Raj & Raj, 2019). Considerable oxidative damage happens when reactive oxygen species (ROS) react with macromolecules. ROS formation during water absorption can be regulated because priming enhances the activity of antioxidant enzymes as well as phenolic compounds and reduction of peroxidation and oxidation of lipid membranes. These antioxidant systems include monodehydroascorbate reductase (DHAR), ascorbate peroxidase (APX), glutathione reductase (GSH), superoxide dismutase (SOD), peroxidase (POD), catalase (CAT), and ascorbate peroxidase (SOD) (Lutts et al., 2016). Treatment T_{15} gave a significantly higher value of catalase (51.3 μ moles min^{-1} mg^{-1} protein), peroxidase (3.07 ΔA min^{-1} mg^{-1} protein) along with reduced lipid peroxidation (0.21 μ moles MDA g^{-1}FW). In contrast, T_{29} gave the lowest activity of catalase (15.5 μ moles min^{-1} mg^{-1} protein), peroxidase (0.35 ΔA min^{-1} mg^{-1} protein) along with the highest lipid peroxidation (0.69 μ moles MDA g^{-1}FW). Similarly, Krainart et al. (2015) reported reduced lipid peroxidation in primed cucumber seeds. Phenolic compounds have strong antioxidant properties and a high capacity for scavenging free radicals and they block the enzymes needed to produce reactive oxygen species (ROS) and to reduce highly oxidized ROS (Acharya et al., 2020). The highest value of total phenol content was found with treatment T_6 (5.38 mg g^{-1}FW) and the lowest was found with treatment T_9 (2.41 mg g^{-1}FW).

Apart from the mobilization of food reserve material and activation of antioxidant enzymes priming also helps in improved repair of cell membranes damaged during seed deterioration. The highest value of membrane stability index was reported with treatment T_5 (65.04%) and the lowest was obtained with priming treatment T_1 (43.22%). All treatments maintained their positive effects and improved the integrity of cellular membranes except the treatment T_1 (43.22%), which gave the lowest value upon comparison with the control. The possible reason for improved membrane stability might be due to the restoration of the integrity of membranes that further controlled the leaching out of electrolytes. A similar result of improved membrane stability was reported by Sowmya (2011) and Shakuntala et al. (2020b) in cucumber seeds.

Conclusion

The germination of cucumber seed along with seedling vigor index was greatly augmented in seeds primed with growth regulators. Ethrel boosted the speed of germination and gibberlic acid improved shoot length along with enzyme activities. Comprehensively, priming treatments alter both physiological and biochemical parameters, fostering spearheading performance of seed.

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सारांश

खीरे की वैरायटी पंजाब नवीन पर विभिन प्राइमिंग उपचारों के प्रभाव का अध्ययन करने के लिए एक अध्ययन किया गया। प्राइमिंग उपचारों की विभिन्न सांद्रताएँ जैसे K_2HPO_4, KH_2PO_4, हाइड्रोक्सीयूरिया, GA_3, एथ्रेल, बेंजाइल एडेनिन, मिमोसिन, KNO_3, $ZnSO_4$ और हाइड्रो प्राइमिंग दी गई और मापदंडों को दर्ज किया गया। प्राइमिंग उपचारों में GA_3 150ppm ने नियंत्रण की तुलना में शूट की लंबाई (14.93 सेमी), औसत अंकुर लंबाई (26.99 सेमी) और अंकुर शक्ति सूचकांक-I (2699) में सुधार किया। एथ्रेल 50 पीपीएम के साथ बीज उपचार से अंकुरण की उच्चतम गति (4.33) के साथ-साथ कम औसत अंकुरण समय (2.43) मिला। उच्चतम औसत अंकुर शुष्क वजन (9.36 मिलीग्राम) और अंकुर शक्ति सूचकांक-II (927) $ZnSO_4$ 0.5% के साथ रिपोर्ट किया गया था। इसी प्रकार, कुल घुलनशील शर्करा (8.40 मिलीग्राम जी-1एफडब्ल्यू), α-एमाइलेज गतिविधि (2.49 मिलीग्राम माल्टोज मिन-1 मिलीग्राम-1 प्रोटीन) और डीहाइड्रोजनेज गतिविधि (0.544) जैसे जैव रासायनिक मापदंडों में इथरेल 50 पीपीएम के साथ इलाज करने पर सुधार हुआ था, जबकि, के2एचपीओ4 10- 3M ने उच्चतम प्रोटीन सामग्री (183.01 mg g-1FW) के साथ झिल्ली स्थिरता सूचकांक (64.38%) में सुधार किया। कैटालेज़ (51.3 μ मोल मिनट-1 mg-1 प्रोटीन) और पेरोक्सीडेज़ (3.07 μA मिनट-1 mg-1 प्रोटीन) जैसे एंटीऑक्सीडेंट एंजाइमों की गतिविधि कम लिपिड पेरोक्सीडेशन (0.21 μ मोल MDA g) के साथ बेंज़िल एडेनिन 50ppm के साथ उच्चतम पाई गई। -1FW). कुल फिनोल सामग्री (5.38 mg g-1FW) हाइड्रोक्सीयूरिया 50mM उपचार के साथ उच्चतम पाई गई। इन परिणामों ने संकेत दिया कि विभिन्न विकास नियामकों के साथ प्राइमिंग ने विभिन्न अंकुरण और शक्ति योगदान देने वाले गुणों में सुधार किया, साथ ही बढ़ी हुई एंजाइमेटिक गतिविधि और कम लिपिड पेरोक्सीडेशन के साथ।