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EFFECT OF BIOSTIMULANT TREATMENTS ON SEED QUALITY PARAMETERS OF PEARL MILLET HYBRID HHB 299 AND ITS PARENTAL LINES

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SUMMARY

The study was conducted to analyze the effect of biostimulants treatment on the seed quality parameters of biofortified pearl millet hybrid HHB 299 and its parental lines (A line ICMA04888, B line ICMB04888 and R line H13/0001) at CCS HAU Hisar during 2024. The results revealed that seed treatment with different biostimulants *viz.*, Seaweed extract @ 100ml/kg, Gelatin @ 1%, Chitosan @ 5g/kg and Biomix @ 100ml/kg significantly influenced the germination, seedling length, radicle emergence, seedling dry weight, and vigour indices of HHB 299 and its parental lines over untreated seeds. However, seaweed extract @100 ml/kg resulted in maximum increase in germination percentage along with other seed quality parameters. Priming with Seaweed extract @ 100 ml/kg seeds for 6 hours with one and a half volume of solution at 36° improved the germination of A line by 11.54 %, B line by 7.94%, R line by 10.56% and HHB 299 by 10.00% over unprimed seeds. Hence, seaweed extract @ 100ml/kg is very effective for seed priming in saline-affected areas to ensure better germination and seedling establishment of pearl millet.

Key words: biostimulants, biofortified, pearl millet, priming, seaweed extract, vigour index

The increasing global population has intensified the demand for food, particularly in resource-constrained regions, spurring the cultivation of resilient crops like pearl millet. Pearl millet [*Pennisetum glaucum* (L.) R. Br.] is an annual, diploid, highly allogamous crop with seven chromosome pairs. It is one of the world's hardiest warm-season, coarse grain cereal crop, believed to be originated in West Africa. Today, it is cultivated across more than 30 million hectares over 30 countries, primarily in the arid and semi-arid tropical regions of Asia and Africa. India is the world's largest producer of pearl millet, both in terms of area and production. In 2023-24, pearl millet covered an area of 7.00 million hectares in India, yielding 9.53 million tons with a productivity rate of 1360 kg/ha [Anonymous, 2023]. It is a highly nutritious crop, offering 10.96 g protein, 61.78 g carbohydrate, 11.49 g dietary fiber, 27.35 mg calcium, 6.42 mg iron and 348 kcal of energy per 100 grams [Dayakar *et al.*, 2017; Longvah, 2017]. Its nutrient-rich profile makes it a vital food source, particularly in addressing micronutrient deficiencies in developing countries. Pearl millet exhibits considerable genetic variability in iron (30-140 mg/kg) and zinc (20-90 mg/kg) concentrations which can be exploited to develop high-yielding, nutrient-rich cultivar [Govindaraj *et al.*, 2019]. This potential has been harnessed through biofortification, a sustainable approach to enhance the nutritional quality of staple crops by increasing their micronutrient content through agronomic practices, conventional breeding or modern biotechnology. India pioneered the development of biofortified pearl millet with release of Dhanashakti- an open pollinated variety in 2014 [Rai *et al.*, 2014]. Currently, biofortified pearl millet is cultivated on over 70,000 hectares in India, with several additional cultivars undergoing evaluation in national and international trials for potential release [Govindaraj *et al.*, 2019].

Renowned for its adaptability to harsh climatic conditions, the successful cultivation of pearl millet depends on effective germination and uniform establishment. Germination is the most crucial step of crop's life which involves water imbibition by seed, seed coat rupture and radicle protrusion. Seeds of different crop species exhibit unique germination responses according to their genetic makeup [Nonogaki *et al.*, 2010; Wakjira and Negash, 2013]. Many economically significant crops face challenges such as low germination rates, poor seedling emergence and weak field establishment which adversely affect

their yield potential [Nonogaki *et al*., 2010]. To address these issues, it is essential to develop strategies that enhance and synchronize seed germination while improving crop performance [Rifna *et al.*, 2019; Zulfiqar, 2021]. As a sustainable alternative, researchers have focused on seed soaking and priming with compounds that stimulate germination [Tian *et al*., 2014; Ngoroyemoto *et al*., 2019; Abbasi *et al*., 2021; Mzibra *et al*., 2021]. In particular, seed treatment with biostimulants has emerged as an effective way to enhance germination rates and subsequent seedling establishment [Amirkhani *et al*., 2019; Ma *et al*., 2019; Anjos *et al*., 2020; Dalvi *et al*., 2021; Husseein *et al*., 2021; Costa *et al*., 2024]. Biostimulant is defined as a fertilizing product that stimulates plant nutrition processes regardless of its nutrient content, with the primary aim of enhancing characteristics like nutrient use efficiency, abiotic stress tolerance and soil nutrient availability [European Union, 2019].The beneficial effects of biostimulants can be attributed to polyphenolic compounds, carotenoids, minerals, vitamins, phlorotannins, peptides, tocotrienols, proteins, tocopherols, phytohormones, betaines, amino acids, polyamines and polysaccharides.These bioactive substances can boost yield and fruit quality, enhance photosynthesis, increase carbohydrate levels, promote nodule development and improve the production of secondary metabolites. Moreover, biostimulants are recognized for inducing positive plant responses at lower doses compared to traditional fertilizers [Du Jardin, 2015].

Biostimulants are categorized into major groups such as humic substances, seaweed extracts, protein hydrolysates, biopolymers, inorganic compounds and beneficial microorganisms based on their unique properties and functions. Humic-like biostimulants promote plant growth by regulating membrane permeability [Blomster *et al.,* 2011], boosting chlorophyll content, photosynthetic efficiency [Haghighi *et al.,* 2013] and enhancing carbon and nitrogen metabolism [Jannin *et al.*, 2012]. Additionally, biostimulants containing fulvic acids stimulate cell division, root growth and nutrient uptake under stress conditions [De Pascale *et al.,* 2017; Shah *et al.,* 2018; Qin and Leskovar, 2020]. Seed priming with liquid seaweed extract of *Kappaphycus alvarezii* (K-sap) and *Gracilaria edulis* (G-sap) improved germination percentage, seedling weight, vigour index, prolonged storability and increased fruit yield in *Capsicum frutescens* [Dutta *et al.*, 2019]. Application of seaweed (*Ascophyllum nodosum*) extract has enhanced antioxidant metabolism and improved germination percentage, germination speed and seedling vigour under heat stress conditions [Anjos *et al.*, 2020; Rasul *et al.,* 2021]. Seed encapsulation with gelatin promoted early plant growth and increased fruit production in tomato [Touchette *et al*., 2022]. Seed coating with polymer and different bioagents enhanced seed quality parameters along with increasing oil and protein content in soybean [Dalvi *et al*., 2021]. Moreover, seed treatment with diazotrophic bacteria such as *Pseudomonas fluorescens, Azotobacter chroococcum, Azospirillum lipoferum, Acetobacter diazotrophicus* and the fungus *Trichoderma viride* improved nutrient uptake and enhanced grain yield and quality in pearl millet [Singh *et al.*, 2018]. Different concentrations of biostimulants for seed treatment yield varying outcomes. Both excessively high and low concentrations can adversely affect seed quality enhancement. Therefore, determining an optimal concentration is essential to achieve the desired results. Despite of their potential benefits, limited knowledge exists regarding the role of biostimulants in enhancing seed quality parameters in pearl millet. As an important cereal crop in ensuring both nutritional and financial security across the globe, it is crucial to explore the potential of commercially available biostimulants in improving seed quality parameters in pearl millet. Since germination challenges are observed in pearl millet, especially in inbred lines, the present study was planned to assess the effectiveness of different biostimulants in enhancing seed quality parameters of biofortified hybrid and its parental lines.

MATERIALS AND METHODS

The study was conducted on biofortified pearl millet hybrid HHB 299 and its parental lines *i.e.*, A line ICMA04888, B line ICMB04888 and R line H13/0001 at the Department of Seed Science and Technology, CCS Haryana Agricultural University Hisar during 2024. Seeds of all three parental lines and hybrid were primed with water, Seaweed extract @ 50 and 100 ml/kg, Chitosan @ 5 and 10g/kg, Gelatin @ 0.5 and 1% for 6 hours with one and a half volume of solution at 36? temperature. After drying back to the original moisture content, the seeds were assessed for seed quality parameters in the laboratory. For treatment with Biomix @ 100 ml/kg and Providence spp. with 10^8Cfuml, seeds were evenly coated with jaggery solution (volume half of the seed weight) and then after drying, seeds were treated with one and a half volume of biomix

and providence spp. Four replicates of hundred seeds from each treatment were placed in between two sufficient moistened germination papers, rolled and placed in a seed germinator maintained at 25±2°C temperature and 95±5% relative humidity. Unprimed seeds were treated as control. The final count was taken on the 7th day and only normal seedlings were considered for per cent germination as per International Seed Testing Association, rules [ISTA, 2019]. For estimation of radicle emergence (%), hundred seeds from each treatment in four replications were placed on the top of the moist blotter paper in petri-plates and placed in the seed germinator. Seeds with 2 mm radicle were counted at 24 and 48 hours. Ten normal seedlings were randomly selected from each replication at the final count of standard germination and seedling length was measured using meter scale and expressed in centimeters. The same seedlings were dried in a hot air oven for 48 hours at 70±1°C. The dried seedlings from each replication were weighed and the average seedling dry weight was calculated in milligrams. Vigour indices were estimated by as per the formula suggested by Abdul-Baki and Anderson, 1973.

Vigour index-I = [Standard germination (%) × Average Seedling length (cm)]

Vigour index-II = [Standard germination (%) × Average Seedling dry weight (mg)]

The experiment was conducted in completely randomized design as per standard method suggested by Panse and Sukhatme (1967). The data was analyzed by using the online statistical tool (OPSTAT) developed by Sheoran (2010) and the means were compared at p=0.05.

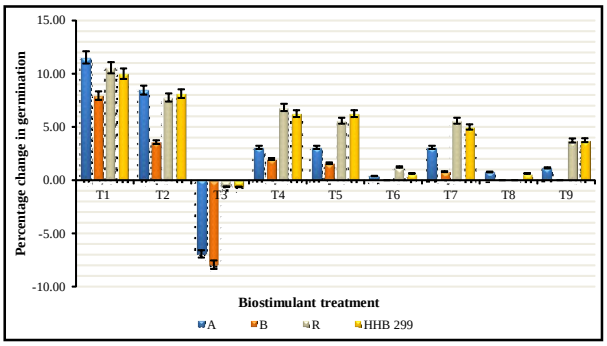
RESULTS AND DISCUSSION

The results revealed that germination of HHB 299 and its parental lines were significantly influenced by seed treatment with biostimulants. Seaweed extract @100ml/kg resulted in maximum germination (79.38%) followed by seaweed extract @ 50ml/kg (77.25%). Also, the germination percentage observed on seed treatment with chitosan @5g/kg (75.56%), gelatin @1% (75.25%), and biomix @100ml/kg (74.88%) were statistically at par with each other. However, seed treatment with chitosan @10g/kg resulted in lowest germination (69.50%) which was even observed lower than control (untreated seed). Among the lines, highest germination was recorded for R line (83.78%) followed by hybrid HHB 299 (83.20%) whereas minimum germination was recorded for the seeds of B line (63.50%) (Table 1). A significant interaction between the treatments and lines was observed. The interaction indicates that the maximum germination was recorded on the seed treatment with seaweed extract @100ml/kg for R line (89.00%) which was statistically at par with HHB 229 (88.00%) and the minimum germination was recorded on the seed treatment with chitosan @10g/kg for B line (58%). Seed treatment with seaweed extract @100ml/kg increased the germination of A line by 11.54%, B line by 7.94%, R line by 10.56% and HHB 299 by 10.00%. However, treatment with chitosan @10g/kg

TABLE 1
Effect of seed treatment with biostimulants on germination (%) and seedling length (cm) of pearl millet hybrid and its parental lines

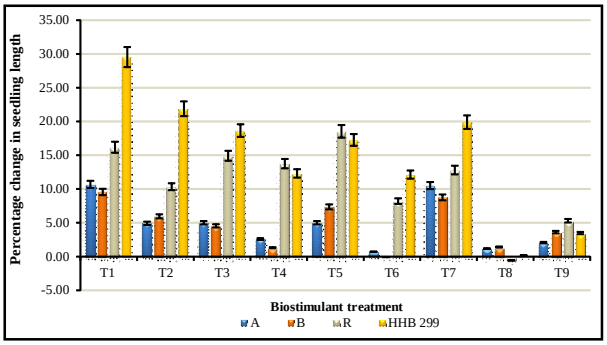
Parameters → / Treatments(T) ↓ Lines(L) →	Germination (%)					Seedling length (cm)				
	A	B	R	HHB 299	Mean	A	B	R	HHB 299	Mean
Seaweed extract @ 100ml/kg	72.50	68.00	89.00	88.00	79.38	31.05	27.28	24.75	39.25	30.58
Seaweed extract @ 50ml/kg	70.50	65.25	86.75	86.50	77.25	29.43	26.38	23.50	36.93	29.06
Chitosan @ 10g/kg	60.50	58.00	80.00	79.50	69.50	29.45	26.03	24.48	35.95	28.98
Chitosan @ 5g/kg	67.00	64.25	86.00	85.00	75.56	28.78	25.23	24.23	34.03	28.06
Gelatin @ 1%	67.00	64.00	85.00	85.00	75.25	29.45	26.73	25.25	35.53	29.24
Gelatin @ 0.5%	65.25	63.00	81.50	80.50	72.56	28.25	24.88	23.05	33.98	27.54
Biomix @ 100ml/kg	67.00	63.50	85.00	84.00	74.88	31.00	27.08	24.03	36.33	29.61
Providence spp. (108Cfu ml)	65.50	63.00	80.50	80.50	72.38	28.38	25.25	21.18	30.35	26.29
Hydropriming	65.75	63.00	83.50	83.00	73.81	28.63	25.80	22.43	31.35	27.05
Control	65.00	63.00	80.50	80.00	72.13	28.05	24.90	21.30	30.30	26.14
Mean	66.60	63.50	83.78	83.20		29.25	25.95	23.42	34.40	
SE±(m)	T=0.32, L=0.20,T×L=0.63					T=0.26, L=0.17,T×L=0.53				
C.D. (P=0.05)	T=0.89, L=0.56,T×L=1.78					T=0.74, L=0.47,T×L=1.48				

reduced the germination of A line by 6.92%, B line by 7.94%, R line by 0.62% and HHB 299 by 0.63% as compared to control [Fig. 1]. Among the different treatments, maximum seedling length was recorded on seed treatment with seaweed extract @ 100ml/kg (30.58cm) followed by biomix @100ml/kg (29.61cm) which was statistically at par with gelatin @1% (29.24cm), seaweed extract @ 50ml/kg (29.06cm) and chitosan @10g/kg (28.98cm). On the other hand, seed treatment with providence spp. (10^8Cfu ml) resulted in the lowest seedling length (26.29cm) which was statistically at par with control (26.14cm). Among the lines, the highest seedling length was recorded for HHB 299 (34.40cm) followed by A line (29.25cm), whereas minimum seedling length was recorded for the seeds of R line (23.42cm). The interaction between the treatments and lines was found to be significant which indicates that the longest seedlings were developed from the seeds of hybrid HHB 299 (39.25cm) on seed treatment with seaweed extract @ 100 ml/kg (Table 1). Seedling length of A line is increased by 10.70%, B line by 9.56%, R line by 16.20% and HHB 299 by 29.54% on treatment with seaweed extract @ 100ml/kg. Also, treatment with biomix @ 100ml/kg increased the seedling length of A, B, R line and HHB 299 by 10.52%, 8.76%, 12.82% and 19.90% respectively. However, little or no improvement was recorded on treatment with providence spp. [Fig. 3]. Maximum radicle emergence at 24h was observed on seed treatment with biomix @100ml/kg (55.13%) succeeded by seaweed extract @ 100ml/kg (52.75%) while minimum radicle



T1: Seaweed extract @ 100ml/kg, T2: Seaweed extract @ 50 ml/kg, T3: Chitosan @ 10g/kg T4: Chitosan @ 5g/kg, T5: Gelatin @ 1%, T6: Gelatin @ 0.5%, T7: Biomix @ 100ml/kg, T8: Providence spp. T9: Hydroprimed seeds.

Fig. 1. Percentage change in germination of pearl millet hybrid and its parental lines through seed treatment with biostimulants.



T1: Seaweed extract @ 100ml/kg, T2: Seaweed extract @ 50 ml/kg, T3: Chitosan @ 10g/kg T4: Chitosan @ 5g/kg, T5: Gelatin @ 1%, T6: Gelatin @ 0.5%, T7: Biomix @ 100ml/kg, T8: Providence spp. T9: Hydroprimed seeds.

Fig. 2. Percentage change in seedling length of pearl millet hybrid and its parental lines through seed treatment with biostimulants.

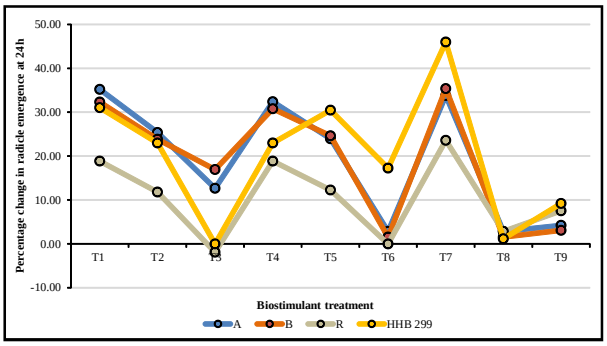
TABLE 2

Effect of seed treatment with different biostimulants on radicle emergence (%) of pearl millet hybrid and its parental lines at 24h and 48 h

Parameters → / Treatments(T) ↓ Lines(L) →	24h					48 h				
	A	B	R	HHB 299	Mean	A	B	R	HHB 299	Mean
Seaweed extract @ 100ml/kg	48.00	43.00	63.00	57.00	52.75	76.50	69.25	90.50	88.75	81.25
Seaweed extract @ 50ml/kg	44.50	40.25	59.25	53.50	49.38	72.75	67.00	87.50	85.75	78.25
Chitosan @ 10g/kg	40.00	38.00	52.00	43.50	43.38	64.00	61.75	83.75	81.00	72.63
Chitosan @ 5g/kg	47.00	42.50	63.00	53.50	51.50	73.00	68.00	91.75	90.00	80.69
Gelatin @ 1%	44.00	40.50	59.50	56.75	50.19	73.00	69.50	91.25	90.00	80.94
Gelatin @ 0.5%	36.50	33.00	53.00	51.00	43.38	69.50	67.25	86.00	85.50	77.06
Biomix @ 100ml/kg	47.50	44.00	65.50	63.50	55.13	74.00	69.75	92.75	90.50	81.75
Providence spp. (108Cfu ml)	36.50	33.00	54.50	44.00	42.00	69.50	67.00	86.00	84.75	76.81
Hydropriming	37.00	33.50	57.00	47.50	43.75	71.00	69.00	86.75	86.00	78.19
Control	35.50	32.50	53.00	43.50	41.13	69.50	67.00	85.75	83.50	76.44
Mean	41.65	38.03	57.98	51.38		71.28	67.55	88.20	86.58	
SE±(m)	T=0.26, L=0.17,T×L=0.52					T=0.23, L=0.15,T×L=0.47				
C.D. (P=0.05)	T=0.73, L=0.46, T×L=1.46					T=0.65, L=0.41, T×L=1.31				

emergence (41.13%) was recorded for control [Table 2]. Among the lines, maximum radicle emergence at 24h was reported for R line (57.98%) followed by HHB 299 (51.38%) whereas minimum radicle emergence was observed for the seeds of B line (38.03%). A significant interaction between the treatments and lines was observed. The interaction indicates that the maximum radicle emergence at 24h was observed on seed treatment with biomix @100ml/kg for R line (65.50%) succeeded by HHB 299 (63.50%) which was statistically at par with the radicle emergence rate on seed treatment with seaweed extract @ 100ml/kg and chitosan @5g/kg for R line (63.00%). Treatment with biomix @100ml/kg increased radicle emergence of A, B, R line and HHB 299 by 33.80%, 35.38%, 23.58% and 45.98% respectively. No improvement or reduced radicle emergence was reported for HHB 299 and R line on treatment with chitosan @10g/kg (Fig. 2).

At 48h, the maximum radicle emergence was observed on seed treatment with biomix @100ml/kg (81.75 %) which was statistically at par with seaweed extract @ 100 ml/kg (81.25%) while the lowest radicle emergence was recorded with chitosan @10g/kg (72.63%). Among the lines, maximum radicle emergence at 48h was reported for R line (88.08%) followed by HHB 299 (86.58%) whereas minimum radicle emergence was observed for the seeds of B line (67.55%). The interaction between the treatments and lines was found to be significant which indicates that the maximum radicle emergence was attained by R line (92.75%) on seed treatment with biomix @100ml/kg which was found to be statistically at par with radicle emergence rate on seed treatment with chitosan @5g/kg for R line (91.75%). However, the lowest radicle emergence was recorded on seed treatment with chitosan @10g/kg for the seeds of B line (61.75%) which was even lower than the control (untreated seed).



T1: Seaweed extract @ 100ml/kg, T2: Seaweed extract @ 50 ml/kg, T3: Chitosan @ 10g/kg T4: Chitosan @ 5g/kg, T5: Gelatin @ 1%, T6: Gelatin @ 0.5%, T7: Biomix @ 100ml/kg, T8: Providence spp. T9: Hydroprimed seeds.

Fig. 3. Percentage change in radicle emergence of pearl millet hybrid and its parental lines through seed treatment with biostimulants.

Seaweed extract @ 100ml/kg resulted in maximum dry weight (92.95 mg) which was statistically at par with gelatin @1% (91.85 mg) followed by chitosan @10g/kg (89.83 mg) which was statistically at par with seaweed extract @ 50ml/kg (89.52 mg). However, the minimum dry weight (77.72 mg) was recorded for control (untreated seed) which was statistically at par with providence spp. (78.09

TABLE 3

Effect of seed treatment with biostimulants on seedling dry weight (mg) and vigour index ? of pearl millet hybrid and its parental lines

Parameters → / Treatments(T) ↓ Lines(L) →	Seedling dry weight (mg)					Vigour index ?				
	A	B	R	HHB 299	Mean	A	B	R	HHB 299	Mean
Seaweed extract @ 100ml/kg	106.03	92.58	59.68	113.53	92.95	2,251	1,854	2,202	3,455	2,440
Seaweed extract @ 50ml/kg	101.10	91.13	54.98	110.90	89.53	2,074	1,720	2,038	3,192	2,256
Chitosan @ 10g/kg	103.43	93.45	54.83	107.60	89.83	1,781	1,509	1,958	2,858	2,027
Chitosan @ 5g/kg	95.33	90.65	52.10	102.05	85.03	1,929	1,621	2,084	2,893	2,132
Gelatin @ 1%	108.30	90.95	59.83	108.33	91.85	1,974	1,710	2,146	3,020	2,212
Gelatin @ 0.5%	104.18	87.18	55.88	104.53	87.94	1,844	1,567	1,879	2,734	2,006
Biomix @ 100ml/kg	95.45	84.48	43.88	99.75	80.89	2,077	1,719	2,042	3,052	2,222
Providence spp. (108Cfu ml)	91.40	80.55	45.33	95.10	78.09	1,859	1,591	1,705	2,443	1,899
Hydropriming	92.45	81.40	46.10	96.25	79.05	1,882	1,624	1,873	2,601	1,995
Control	91.15	80.30	44.83	94.60	77.72	1,824	1,568	1,715	2,424	1,883
Mean	98.88	87.27	51.74	103.26		1,950	1,648	1,964	2,867	
SE±(m)	T=0.54, L=0.34,T×L=1.07					T=21.21, L=13.42,T×L=42.42				
C.D. (P=0.05)	T=1.51, L=0.95, T×L=3.01					T=59.47, L=37.61,T×L=118.93				

mg) and hydroprimed seeds (79.05 mg). Among the lines, maximum dry weight was observed for hybrid HHB 299 (103.26 mg) followed by A line (98.88 mg) whereas the minimum dry weight was recorded for R line (51.74 mg). A significant interaction between the treatments and lines was observed. The interaction indicates that the maximum dry weight was observed for the hybrid HHB 299 (113.53 mg) on seed treatment with seaweed extract @ 100ml/kg which was statistically at par with seaweed extract @ 50ml/kg (110.90 mg) for HHB 299. On the other hand minimum dry weight was recorded for R line (43.88 mg) on seed treatment with biomix @100ml/kg which was statistically at par with R line of control (44.83 mg), providence spp. (45.33 mg) and hydro-primed seeds (46.10 mg).

Highest vigour index-I (2440) was recorded on seed treatment with seaweed extract @ 100 ml/kg followed by seaweed extract @ 50ml/kg (2256) which was statistically at par with biomix @100ml/kg (2222), gelatin @1% (2212) and chitosan @5g/kg (2132). However, control (untreated seed) recorded the lowest value of vigour index-I (1883) which was statistically at par with the value observed on seed treatment with providence spp. (1899). Among the lines, highest value of vigour index-I was observed for the hybrid HHB 299 (2867) followed by R line (1964) which was statistically at par with A line (1950) while B line recorded the lowest value (1648) of vigour index-I. The interaction between the treatments and lines was found to be significant which indicates that the highest vigour index-I was observed for HHB 299 (3455) on seed treatment with seaweed extract @ 100ml/kg succeeded by seaweed extract @ 50 ml/kg (3192). In contrast, B line recorded the lowest vigour index-I on seed treatment with chitosan @ 10g/kg (1509) which was statistically at par with gelatin @ 0.5% (1567) and control (1568).

Highest value of vigour index-II was recorded on seed treatment with seaweed extract @ 100ml/kg (7321) followed by seaweed extract @ 50ml/kg (6860) which was statistically at par with gelatin @1%. However, control (untreated seed) recorded the lowest value (5541) of vigour index-II which was statistically at par with the value observed on seed treatment with providence spp. (5592). Among the lines, HHB 299 recorded the highest value (8603) of vigour index-II followed by A line (6591) whereas the lowest vigour index-II was observed for the seeds of R line (4342). A significant interaction between the treatments and lines was observed. The interaction indicates that the highest value of vigour index-II was recorded on seed treatment of HHB 299 with seaweed extract @ 100 ml/kg (9991) succeeded by seaweed extract @ 50ml/kg (9596) while control (untreated seed) of R line (3608) recorded the lowest vigour index-II which was statistically at par with the value observed on seed treatment of R line with providence spp. (3649), biomix @100ml/kg (3730) and hydroprimed seeds (3849).

In the present study, it is found that priming the three parental lines and hybrid with seaweed extract @100 ml/kg seeds for 6 hours with one and a half volume of solution at 36? resulted in maximum increase in germination percentage as compared to other biostimulants and control. This aligns with the findings of Hernandez-Herrera *et al.,* (2023) who reported that tomato seeds treated with the seaweed extract obtained from *Eisenia arborea*, *Macrocystis pyrifera* and *Padina caulescens* resulted in increase in germination by 29.41%, 23.53% and 11.76% respectively. Similar findings were observed by Elamparithi *et al.,* (2023) in onion, Jumadi *et al.* (2023) in tomato, Mamede *et al.* (2023) in rapeseed, Alaila *et al.* (2022) in barley, Kurakula *et al.* (2021) in chickpea, Thriunavukkarasu *et al.,* (2020) in chilli. Considerable increase in seedling length, seedling dry weight and vigour indices were also obtained on treatment with seaweed extract @100ml/kg, which are in agreement with the findings of Layek *et al.* (2018) who reported that rice seeds soaked with extracts from *Kappaphycus alvarezii* (K sap) and *Gracilaria edulis* (G sap) @ 2.5% and 5% each resulted in increased germination, seedling length and vigour indices over water soaked seeds. These effects can be attributed to the presence of bioactive compounds such aspolyphenolic compounds, carotenoids, minerals, vitamins, proteins, tocopherols, phytohormones, betaines, amino acids, polyamines, and polysaccharides which stimulate growth by inducing multiple physiological processes in plants, even at lower concentrations (Khan *et al.,* 2009; Castellanos-Barriga *et al.,* 2017; Gonzalez-Gonzalez *et al.,* 2020).

Radicle emergence of pearl millet hybrid and its parental lines was significantly enhanced on treatment with biomix @100ml/kg which was statistically at par with seaweed extract @ 100ml/kg. This aligns with the findings of Sunitha and Lakshmi (2018) who observed that priming pearl millet seeds for 30 minutes with biofertilizers ranging from 0.8-4.8 x 10^6 colony forming units (CFUs)/seed increased germination by 30-35% and reduced the time for radical emergence (RT50) by 24 h over non-primed control.

Treatment with chitosan @ 5g/kg seeds

TABLE 4
Effect of seed treatment with different biostimulants on vigour index ? of pearl millet hybrid and its parental lines

Treatments (T) ↓ / Lines →	A	B	R	HHB 299	Mean
Seaweed extract @100ml/kg	7,687	6,295	5,310	9,991	7,321
Seaweed extract @50ml/kg	7,128	5,946	4,769	9,596	6,860
Chitosan @10g/kg	6,260	5,419	4,386	8,553	6,155
Chitosan @5g/kg	6,387	5,824	4,480	8,673	6,341
Gelatin @1%	7,259	5,821	5,085	9,205	6,842
Gelatin @0.5%	6,797	5,491	4,554	8,416	6,315
Biomix @100ml/kg	6,394	5,364	3,730	8,380	5,967
Providence spp. with 108Cfu ml	5,987	5,075	3,649	7,655	5,592
Hydropriming	6,079	5,128	3,849	7,988	5,761
Control	5,926	5,059	3,608	7,569	5,541
Mean	6,591	5,542	4,342	8,603	
SE±(m)		T=50.97, L=32.24,T×L=101.94			
C.D. (P=0.05)		T=142.90, L=90.38,T×L=285.80			

improved the germination and other seed quality parameters substantially. This observation aligns with previous studies where chitosan nanoparticles at lower concentration (5??g/mL) improved seed germination percentage, germination index, vitality index, fresh weight, the ratio of root/shoot and seedling index in wheat [Li *et al.*, 2019]. This is probably due to large surface area and small size of chitosan nanoparticles that contributes to their improved adsorption and utilization by plants [Liang 2017]. However, it was observed that seed treatment with chitosan @ 10g/kg significantly decreased the germination as compared to control. This observation aligns with previous studies where chitosan nanoparticles exhibited negative or no growth effects at high concentrations 100 ?g/mL in wheat [Li*et al.*, 2019]. It was reported that natural oligosaccharides and polysaccharides often show positive physiological activity at lower concentrations but can exhibit inhibitory effects at higher concentrations [Guan *et al.*, 2009; Kananont *et al.*, 2010; Saharan *et al.*, 2016]. This inhibitory effect at high concentrations might be attributed to the induction of cell apoptosis [Wang *et al.*, 2008; Zhang *et al.*, 2012]. The statistical similarity between gelatin @1%, biomix @100 ml/kg and chitosan @ 5g/kg suggests that these treatments may have comparable effects on germination of pearl millet and the choice among them could depend on factors such as cost-effectiveness, availability, and specific needs of the cultivation system.

CONCLUSION

Priming with seaweed extract @100ml/kg seeds for 6 hours with one and a half volume of solution at 36? is effective in seed quality enhancement. It can enhance the germination of A line by 11.54%, B line by 7.94%, R line by 10.56% and HHB 299 by 10.00% over unprimed seeds in pearl millet. Hence, seaweed extract @ 100ml/kg and gelatin @ 1% is very effective for seed priming in saline-affected areas to ensure better germination and seedling establishment of pearl millet.

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