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APPLICATION OF SEA WEED EXTRACT AND CITRIC ACID SEED PRIMING FOR ENHANCED GERMINATION AND YIELD ATTRIBUTES OF LENTIL (*LENS CULINARIS* L.)

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ABSTRACT

This study investigates the effects of seed priming with seaweed extract (SWE) and citric acid (CA) on the germination, seedling development, and yield attributes of lentil (*Lens culinaris* L.). The use of natural biostimulants such as SWE and organic acids like CA has gained attention for their potential to enhance crop performance in a sustainable manner. Lentil seeds were primed with varying concentrations of SWE (1, 2, 3 and 4) and CA (50, 100, 200 and 300 ppm), applied both individually and in combination. Parameters assessed included germination percentage, mean germination time, seedling length, vigor index, chlorophyll content, and yield-related traits such as pod number, seed weight, and biological yield. Among all treatments, the combined application of citric acid (50 ppm) and seaweed extract (4%) resulted in the most significant improvements across germination and yield parameters. This synergistic effect suggests that SWE and CA enhance seed metabolic activity and physiological functions, thereby promoting better crop establishment and productivity. These findings highlight the potential of using SWE and CA as sustainable priming agents in lentil cultivation.

Key words : Seed priming, Germination, Seedling vigor, Chlorophyll content, Yield attributes, Biostimulants, Sustainable agriculture.

Introduction

Lentil is a significant cool-season food legume that ranks second in terms of productivity and production after chickpeas (Dixit *et al.*, 2017). Lentils are produced at a rate of 870 kg/ha in India and 1074 kg/ha worldwide (FAO STAT, 2020). Legumes' capacity to fix nitrogen contributes to the preservation of soil fertility and raises the production of other crops cultivated in rotation. It is one of the most significant grain legumes, mostly cultivated for its great nutritional value as animal feed and human consumption. Lentil has significant amounts of protein (20–30%), low-digestible carbs (20%), fat (1%), iron (Fe), zinc (Zn) and several vitamins; lentil is a nutrient-dense pulse crop. 24–28% protein, 30–40% minerals and 22% vitamins are included in lentil seeds. It is mostly grown in a semi-arid climate and frequently experiences abiotic challenges during the early stages of seedling growth, such as salinity and dehydration. Due to its high vulnerability, increased abiotic stress poses a serious danger to the production of pulses worldwide (Kaya *et al.*, 2006).

According to Sinha *et al.* (2023), the most delicate stage of a plant's life cycle is germination. For the formation of crop plant stands, the most crucial phase is seed germination and the growth of the resulting seedlings. Many abiotic stressors cause delays in seed germination. Therefore, it is crucial to find solutions for early plant establishing issues. Seed priming is one technique for improving germination and seedling quality. Enhancement of seed quality, including seed covering (Sharam *et al.*, 2019) and seed priming, a method of seed enhancement, induces early seedling emergence by means of pre-germinative metabolism in the presence of salt stress. It speeds up and evens out germination by decreasing the average germination time, improving pre-germinative biochemical reactions, cell healing, and other activities. The effects of seed priming with different chemical agents, such as ascorbic acid, salicylic acid and KNO_3 (Rabnawaz *et al.*, 2020), on enhancing germination, seedling emergence, plant stand establishment, crop growth, nodulation, and productivity in cowpea (Tetteh *et al.*, 2024) and quinoa (Bhuker *et al.*, 2020), as well as in various crop species (Waqas *et al.*, 2019), according to multiple reports. Even if the chemicals used for seed priming have proven beneficial, there remain environmental concerns about their use. Therefore, the search for eco-friendly substances such as seaweed extract (SWE) and citric acid (CA) is essential for sustainable agriculture. Thus, this study set out to examine the impact of chemical priming with seaweed extract and citric acid on improving the qualitative attributes of lentil seeds and yield.

Materials and Methods

Experimental methods

The experiment was conducted at field and laboratory in the division of Amity Institute of Organic Agriculture, Amity University, Noida. IPL - 316 variety of lentil was taken from ICAR - IARI, New Delhi and this variety of lentil was used in the experiment. After standardization two different chemical citric acid and seaweed extract for various concentrations and durations for seed priming, the final seed priming was carried out with three different treatments *viz*., T_1 = Citric acid 50ppm, T_2 = Control, T_3 = Seaweed extract, were used for evaluation for the yield and yield attributes traits. In laboratory, all the seed quality parameter was observed under normal condition and in field conditions. In field, the experimental treatments were laid out using a randomized block design (RBD) with three replications and the row to row spacing was 30 cm × 10 cm and 3 m^2 was total plot size.

Germination tests (ISTA, 2021)

To initiate the germination experiment, lentil seeds were first surface sterilized using a 1% acetone solution to minimize the risk of contamination. Following sterilization, the seeds were soaked in their respective treatment solutions under controlled temperature and duration as per the experimental protocol. Once treated, 25 seeds were carefully arranged at equal distances on two layers of moistened filter paper within sterile Petri plates. These plates were then incubated at a constant temperature of 20°C. The initial germination count was recorded on the 5th day. A second count was taken on the 10th day, during which the seedlings were classified into four categories: normal seedlings, abnormal seedlings, hard seeds and dead seeds. The percentage of normal seedlings was used to determine the standard germination rate.

Chlorophyll content

Fresh samples were collected from young lentil seedlings for pigment analysis. The collected seed were weighed accurately and then macerate using 3.0 mL of 80% acetone to extract chlorophyll and related pigments. The macerate seed was transferred into Eppendorf tubes and subjected to centrifugation at 10,000 rpm for 7 minutes to separate the supernatant. The absorbance of the clear supernatant was then measured using an ELISA plate reader at specific wavelengths of 470, 645, 652 and 663 nm, following the protocol described by Arnon (1949).

$$\text{Chl a} = 12.9\ (\text{Ab663}) - 2.69\ (\text{Ab645}) \times V/1000 \times W$$

$$\text{Chl b} = 22.9\ (\text{Ab645}) - 4.68\ (\text{Ab663}) \times V/1000 \times W$$

$$\text{Total Chl} = \text{Chl a} + \text{Chl b}$$

Field parameters

The various parameters of seed quality features were measured at various stages of maturation. Plant height (cm) with varying vegetative growth intervals, the number of primary branches growing straight from the main stem, secondary branches originating from primary ones, and tertiary branches developing from secondary branches were manually counted. The SPSS 16.01 program was used to analyse the data using 3 replications and the random block design (RBD).

Results and Discussion

Germination percentage

Seaweed Extract 4% (SWE 4%) significantly enhanced lentil germination compared to Citric Acid 50 ppm and the Control. From Day 7 to Day 14, SWE 4% showed steady improvement, reaching around 13% by Day 14 and achieving the highest average germination rate of 87%. In contrast, Citric Acid 50 ppm peaked at 12% on Day 14 with a lower average of 79%, while the Control lagged behind with just 10% on Day 14 and a 52% average. Clearly, SWE 4% emerged as the most effective treatment in promoting faster and more uniform germination in lentils (Fig. 1).

Seed priming with 4% Seaweed Extract (SWE) significantly enhanced lentil germination compared to Citric Acid 50 ppm and the control. The higher germination rate from Day 7 to Day 14 indicates increased seed Vigor, likely due to the presence of natural phytohormones such as cytokinin, auxins, and betaines that stimulate early cell division and enzymatic activity (Khan *et al.*, 2021). SWE-treated seeds also showed faster and more uniform

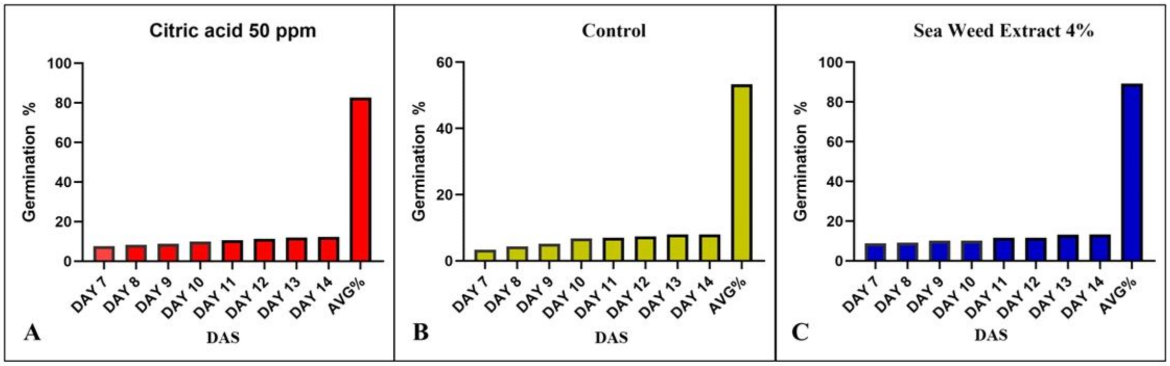

Fig. 1 : Effect of the germination percentage on the different treatments.

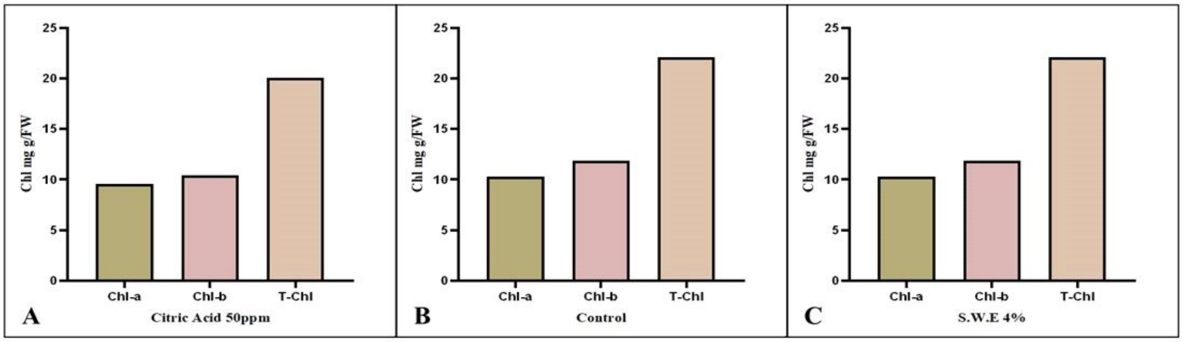

Fig. 2 : Effect of the different treatments on the chlorophyll content.

emergence, essential for consistent crop establishment (Rathore *et al*., 2020). Although, Citric Acid showed moderate improvement, SWE proved more effective. This highlights the potential of marine-derived bio stimulants in promoting sustainable, chemical-free farming (Verma *et al*., 2022; Ali *et al*., 2023), particularly for improving lentil productivity in stress-prone environments.

Chlorophyll content

The chlorophyll content in lentils treated with S.W.E 4%, Citric Acid (CA) 50 ppm, and Control reveals notable differences. Significantly, S.W.E 4%, chlorophyll-a (Chl-a), chlorophyll-b (Chl-b), and total chlorophyll (T-Chl) were approximately 10.1, 12.2 and 22.3 mg/g FW, respectively. For CA 50 ppm, values were slightly lower: Chl-a 9.4, Chl-b 10.3, and T-Chl 19.7 mg/g FW. The control showed the least chlorophyll content, with Chl-a at 10.2, Chl-b at 11.9 and T-Chl at 21.5 mg/g FW. Overall, S.W.E 4% treatment showed a superior effect, especially in boosting total chlorophyll, highlighting its potential as the most effective enhancer of photosynthetic pigment concentration in lentils (Fig. 2).

The SWE 4% treatment significantly enhanced chlorophyll-a, chlorophyll-b and total chlorophyll in lentils, indicating improved photosynthetic capacity. This effect is attributed to the presence of micronutrients and growth regulators in seaweed extract that stimulate chloroplast development and pigment synthesis (Elansary *et al.*, 2020; Rathore *et al.*, 2021). Citric acid (CA 50 ppm) also improved chlorophyll levels, likely by enhancing iron and magnesium uptake (Ali *et al.*, 2019). Overall, SWE 4% proved most effective in boosting chlorophyll content under nutrient-enriched conditions.

Measuring parameter (Plant height of 30 das, 60 das, 90 das, 120 das, average plant height, Primary branch, Secondary branch, Tertiary branch, Number of pods per plant, Number of seed per plant, root length)

SWE 4% treatment significantly enhanced lentil growth compared to CA 50 ppm and the Control. At 30 DAS, plant height under SWE 4% reached 26 cm, surpassing CA 50 ppm (23 cm) and Control (19 cm). This trend continued consistently at 60, 90 and 120 DAS with heights of 36 cm, 44 cm, and 52 cm, respectively, for SWE 4%, while CA 50 ppm recorded 32 cm, 40 cm, and 46 cm and Control lagged at 27 cm, 33 cm and 39 cm. The average plant height (APH) was highest in SWE 4% (39.5 cm), followed by CA 50 ppm (35.25 cm) and Control (29.5 cm). Branching patterns also favoured SWE 4%, with primary branches (5.7), secondary branches (6.2) and tertiary branches (4.8) all exceeding the other treatments. Pod and seed counts were similarly elevated in SWE 4% (87 pods and 102 seeds) per plant compared to CA 50 ppm (76 pods, 90 seeds) and Control (61 pods, 73 seeds). Root length under SWE 4% was longest at 13.5 cm, outperforming CA 50 ppm (11.7 cm) and Control (9.3 cm) (Figs. 3 and 4).

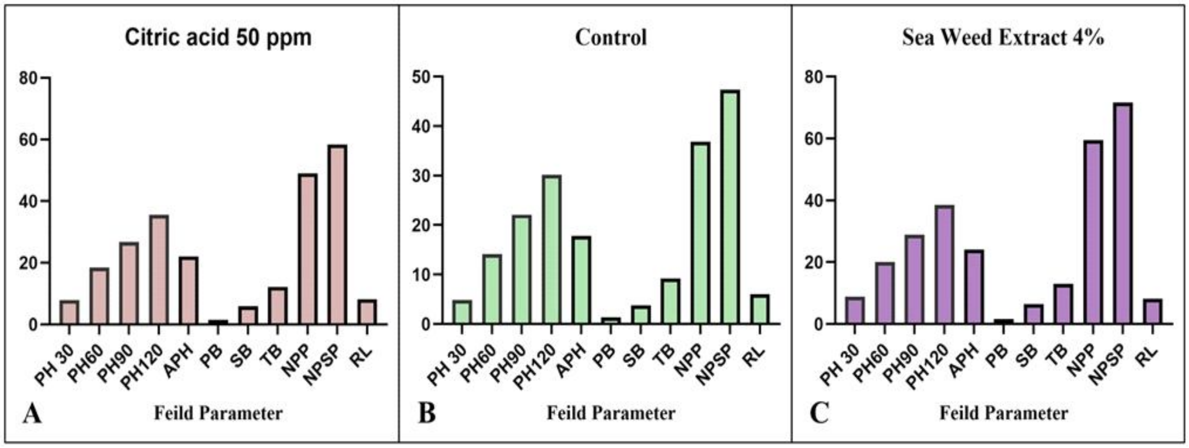

Fig. 3 : Effect of different treatments on the yield quality attributes.

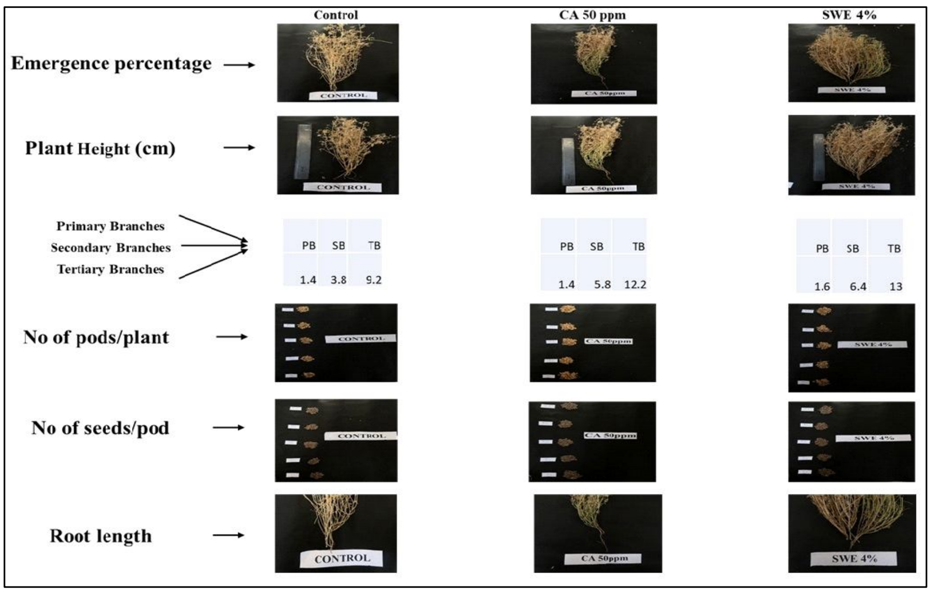

Fig. 4 : Different yield quality parameters after harvesting.

The superior growth of lentils treated with SWE 4% aligns with studies showing seaweed extracts as effective bio stimulants due to bioactive compounds like cytokinin, auxins, and trace elements that promote cell division and elongation (Khan *et al.*, 2020). These compounds likely enhanced plant height, branching, and root length, leading to increased pod and seed production. Citric acid (CA 50 ppm) also improved growth by enhancing nutrient availability through mineral chelation, but its effects were less pronounced than SWE 4% (Singh *et al.*, 2021). The improved root development under SWE 4% supports better nutrient and water uptake, boosting biomass and yield (Shukla *et al.*, 2019). Overall, SWE 4% demonstrated greater potential as a bio stimulant in lentil cultivation, suggesting its use for sustainable yield improvement, with future studies needed to optimize application strategies.

Conclusion

Hence, in comparison to other priming treatments This study demonstrates that Seaweed Extract (SWE) 4% is a highly effective bio stimulant for enhancing the growth, physiological traits, and productivity of lentils. The treatment not only led to the highest germination percentage (87%) but also significantly boosted chlorophyll-a (10.1 mg/g FW), chlorophyll-b (12.2 mg/g FW) and total chlorophyll (22.3 mg/g FW) levels—indicating a more efficient photosynthetic capacity. Plant height was consistently higher at all growth stages, averaging 39.5 cm, while branching (primary: 5.7, secondary: 6.2, tertiary: 4.8) and reproductive parameters such as pods (87) and seeds per plant (102) were superior to both Citric Acid (CA 50 ppm) and the Control. Additionally, SWE 4% resulted in the longest root length (13.5 cm), supporting improved nutrient uptake. Overall, SWE 4% emerges as a promising natural growth enhancer, capable of boosting lentil performance under micronutrient-enriched conditions and can be recommended as a sustainable approach for improving crop resilience and yield.

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