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Research Article

Influence of seed treatment and foliar spraying of seaweed extracts on wheat (*Triticum aestivum* L.) in *Terai* region of West Bengal

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Abstract

The seaweed extracts (SWE) is one of the recently developed and more significant plant derived extract in terms of growth and yield stimulation as it contains many growth promoting hormones, macro and micro nutrients that provide balanced nutrition to plants. A field experiment was carried out during *rabi* season of 2021-2022 and 2022-2023 at Instructional Farm, Uttar Banga Krishi Viswavidyalaya, West Bengal to evaluate the impact of foliar application of SWE on growth, yield, nutrient uptake and production economics of wheat (*Triticum aestivum* L.). The experiment was laid out in a factorial randomized block design having 12 treatment combination consisting of two factors. The factor 1 comprised of with and without seed treatment; while factor 2 included foliar application of SWE at different rates and at different growth stages. The wheat variety used in the experiment was DBW 187. The results revealed that seed treatment with SWE resulted in significantly higher growth and yield parameters, grain yields and nutrient uptake over untreated seeds. Foliar application of SWE had a significant impact and spraying of SWE @ 2 ml litre^{-1} at tillering and heading stage resulted in significantly higher spike no. m^{-2} (325), grain yield (5901 kg ha^{-1}), straw yield (9146 kg ha^{-1}) and nutrient uptake (110.5, 15.2 and 119.8 kg ha^{-1} N, P and K, respectively). The same treatment also achieved the highest net returns (67188) and B:C (2.50). It can be concluded that seed treatment with SWE @ 3 ml kg^{-1} of seed and foliar application @ 2 ml litre^{-1} twice at tillering and heading stage could increase the growth, yield, NPK uptake and profitability of wheat under terai region of West Bengal.

Key Words: Seaweed extracts, Seed treatment, Foliar application, Nutrient uptake, Profitability.

1. Introduction

Globally, wheat (*Triticum aestivum* L.) constitutes the predominant food grain crop and in India it is being prioritized after rice and constitutes around 30% of the country's food basket (Kewat *et al.*, 2022). In India during 2021-2022, wheat was cultivated in about 31.13 M ha with 109.59 MT of production with an average productivity of 3421 kg ha^{-1} (USDA, 2023). However, in recent years a decrease in land productivity was noticed under wheat in the country (Mishra *et al.*, 2021). Though nutrient applications have increased the yield, some of the key issues related to the use of chemical fertilizers includes degradation of soil health, biodiversity with adverse environmental effects (Mitra *et al.*, 2023a). Therefore, it is crucial to use fertilizers, N in particular precisely

(Mitra *et al.*, 2023b) and wherever possible the chemical loads are to be reduced through recent biotechnological advancements (Biswas *et al.*, 2019). In agriculture the use of bio-stimulants like seaweed extracts (SWE) might turn out to be a productive and sustainable substitute which can reduce the usage of chemical fertilizers partially.

The bio-stimulants when applied as seed treatment or foliar application in combination with fertilizers, that acts as nutrient source to crops and improves growth and productivity (Abbas *et al.*, 2020). Around the world, 15 million tonnes of seaweed products are manufactures annually (FAO, 2006). Seaweeds are multicellular, macroscopic and marine algae which have naturally developed in coastal environments and the extracts are mostly used as cattle feed, human food, alternative to chemical fertilizers and as a source to different fine chemicals (Khan *et al.*, 2009). In recent years, application of liquid SWE on different crops not only resulted in reducing the application rates of nitrogen, phosphorous and potassic fertilizers but also improved the growth and productivity of many plant species (Durand *et al.*, 2003). Seaweed contains plant growth hormones, trace elements, plant growth regulators (auxin, cytokinin and gibberellin) that help in boosting the crop productivity by promoting the plant metabolic process (Pal *et al.*, 2015). In some trials conducted under All India Coordinated Project, seaweed extract was found to be highly beneficial in increasing growth, yield attributes, yield and profitability of wheat. However, the concentration, timing as well as the stages of application are yet to be standardized. Keeping this in backdrop a field experiment was conducted to standardize the concentration and application rate of SWE at different growth stages for improved performance of wheat in terms of growth, yield, nutrient uptake and profitability.

2. Materials and Methods

The field trial was conducted during two consecutive *rabi* seasons of 2021-2022 and 2022-2023 at All India Coordinated Wheat and Barley Improvement Project (AICW & BIP) Block of Uttar Banga Krishi Viswavidyalaya, Coochbehar, West Bengal. The research site was located at 43 meters above mean sea level (msl) with 26°19'86"N latitude and 89°23'53"E longitude. The climate of experimental site represents a per humid climate with average annual precipitation of around 3000 mm with a cool and drier winter month favourable for the growth of wheat crop. The texture of the experimental soil was sandy loam with pH 5.90, Organic C (0.84 %), mineralizable N (201.80 kg ha^{-1}), available P_2O_5 (42.30 kg ha^{-1}) and available K_2O (142.90 kg ha^{-1}). For past 5 years the site was continuously under rice (puddled) - wheat (conventional tillage) cropping system.

The experiment was laid out in factorial randomized block design comprising 2 levels of seed treatment (Factor 1) and 6 levels of foliar application (Factor 2) with altogether 12 treatment combinations, each replicated thrice. The size of each experimental plot was 5 m × 3.5 m. The details of treatments are presented in Table 1.

Table 1: Treatment details

Treatments	
A.	**Factor 1 (Seed treatment)**
S_1	Without seed treatment with SWE
S_2	Seed treatment with SWE @ 3 ml kg^{-1} **seed**
B.	**Factor 2 (Foliar application)**
F_1	Foliar application of SWE @ 2 ml $litre^{-1}$ water at tillering stage
F_2	Foliar application of SWE @ 4 ml $litre^{-1}$ water at tillering stage
F_3	Foliar application of SWE @ 2 ml $litre^{-1}$ water at heading stage
F_4	Foliar application of SWE @ 4 ml $litre^{-1}$ water at heading stage
F_5	Foliar application of SWE @ 2 m $litre^{-1}$ water at tillering & heading stage
F_6	Foliar application of SWE @ 4 ml $litre^{-1}$ water at tillering & heading stage

Land preparation was done by ploughing the field twice with tractor-drawn cultivator. To attain ideal tilth, a rotavator was used crosswise afterwards. Seeds were sown in lines maintaining a row spacing of 20 cm, taking seed rate of 100 kg ha^{-1}. The wheat variety used in this study was DBW 187, developed by Indian Council of Agricultural Research (ICAR)-Indian Institute of Wheat & Barley Research (IIWBR), Karnal, Haryana suitable for irrigated timely sown conditions of NEPZ, maturing in about 115-120 days with a potential yield of 6.47 t ha^{-1}. The crop received 150: 60: 40 N: P_2O_5: K_2O in kg ha^{-1}. Nitrogen was applied as urea in three equal splits (basal, crown root initiation and tillering stage); entire amount of phosphorous and potassium were applied as basal. SWE was sprayed based on the treatment at different stages using Sagarika - Seaweed Extract Concentrate (28 % w/w), marketed by IFFCO. To control the weeds, carfentrazone @ 50 g a.i ha^{-1} and clodinofop propagyl @ 0.75 kg a.i ha^{-1} was applied at 3 days after sowing (DAS). Boron was sprayed twice using Solubor (20% B) @ 0.20% at 35 DAS and 55 DAS. Chelated zinc (Chelamin) @ 0.10% was also foliar sprayed at 55 DAS. Three irrigations were given following check basin method with a depth of 5 cm.

The data on growth parameters like tiller number m^{-2} and dry matter accumulation (g m^{-2}) was recorded periodically at 30 days interval; while plant height was taken at harvest. Yield parameters like spike number m^{-2}, number of grains $spike^{-1}$, spike length (cm), 1000-grain weight (g) were recorded at harvest. For estimation of grain and straw yield the entire produce from net plot area of 8 m^2 (4 m x 2 m) demarcated previously excluding border rows was harvested manually. After threshing grain were sun dried to bring the moisture of grain to 12% and then samples were weighed separately and obtained value was expressed in kg ha^{-1}. The harvest index was calculated by taking the ratio of economic yield to biological yield.

2.1 Plant analysis

The total N content in plant samples was estimated by a semi-automated kjeldhal unit (Jackson, 1973). The phosphorous estimation was carried out by Vanado-molybdate method and absorbance was observed at 420 nm using spectrophotometer (Jackson, 1973). The potassium content in plant samples was determined using tri-acid digestion method, then estimated with the help of a calibrated flame photometer (Piper, 1966).

Plant N, P and K uptake

After estimation of the nutrient concentration, total N, P and K uptake were calculated using the following formulae:

$$\text{Nitrogen uptake (kg ha}^{-1}\text{)} = \frac{\text{Grain N (or) Straw N content (\%)} \times \text{Grain yield (or) straw yield (kg ha}^{-1}\text{)}}{100}$$

$$\text{Phosphorous uptake (kg ha}^{-1}\text{)} = \frac{\text{Grain P (or) Straw P content (\%)} \times \text{Grain yield (or) straw yield (kg ha}^{-1}\text{)}}{100}$$

$$\text{Potassium uptake (kg ha}^{-1}\text{)} = \frac{\text{Grain K (or) Straw K content (\%)} \times \text{Grain yield (or) straw yield (kg ha}^{-1}\text{)}}{100}$$

The total N, P and K was then calculated by adding grain and straw uptake of the corresponding treatment.

2.2 Production Economics

To find out the most profitable treatment, economic analysis including cost of cultivation (₹ ha^{-1}), gross returns (₹ ha^{-1}), net returns (₹ ha^{-1}) and benefit-cost ratio (B:C) were calculated for wheat under different application methods of SWE. Cost of cultivation was calculated by considering the prevailing costs of various inputs *viz.,* SWE, fertilizers, seeds, labour, herbicides, insecticides and other inputs associated with crop production. For calculating the output prices, farm gate price of wheat grain was taken into consideration.

2.3 Statistical Analysis

Analysis of variance (ANOVA) method for factorial randomized block design was used to analyze the pooled data of both the years. The significance of seed treatment, foliar application and interaction effects were tested using mean square error (MSE) as suggested by Fisher-Snedecor at a 5 % level of probability using OPSTAT software.

3. Results and Discussion

3.1 Growth Parameters

Plant height at harvest did not show any significant effect due to seed treatment and foliar application of SWE. Perusal of data (Table 2) clearly indicated that SWE did not impact much when seeds were treated with SWE; however, foliar application had a significant impact on tiller number at all the growth stages. Significantly higher tiller number at 60 and 75 DAS (359 and 345 m^{-2}, respectively) was achieved under treatment in which SWE was sprayed twice @ 4 ml $litre^{-1}$ at tillering and heading stage (F_6). At later stages (90 DAS), the treatment comprising foliar spray of SWE twice @ 2 ml litre^{-1} at tillering and heading stage (T_5) recorded the highest number of tillers m^{-2} (332), closely followed by spraying SWE twice @ 4 ml litre^{-1} at tillering and heading stage (F_6), being statistically *at par* with each other. The higher tiller number under the treatments where SWE was foliar sprayed twice might be attributed to better root growth and seedling vigour and enhanced meristematic growth as SWE contains macro and micronutrients, phytoharmones (Auxins, gibberellins and phenyl acetic acid) that enhance growth (Sivasankari *et al.*, 2006; and Hassan *et al.*, 2021). The results were in close conformity with the findings reported by Singh *et al.* (2015) and Choudhary *et al.* (2023) who noticed that foliar spray of SWE twice at tillering and heading enhanced the tillering ability in wheat as compared to single spraying at tillering stage. The dry matter accumulation differed significantly with SWE seed treatment (Table 2) at all the periodic stages of growth. Significantly higher dry matter accumulation was noted at all the stages of recording observations (204, 657 and 1207 g m^{-2} at 30, 60 and 90 DAS, respectively) under the treatment S_2 in which the seeds were treated with SWE @ 3ml kg^{-1} of seeds. The foliar spraying of SWE had a significant impact on dry matter accumulation at 60 and 90 DAS. The maximum dry matter accumulation at 60 and 90 DAS (662 and 1215 g m^{-2}, respectively) was achieved with foliar spray of SWE twice @ 2 ml litre^{-1} water at tillering and heading stage (F_5), being statistically at par with foliar spray of SWE twice @ 4 ml litre^{-1} at tillering and heading stage ($F_{6)}$ (629 and 1158 g m^{-2} at 60 and 90 DAS, respectively). The higher dry matter accumulation under the respective treatments might be due to induced physiological responses by SWE that enhance the mobility of nutrients, plant partitioning capacity to trap maximum solar energy for increased photosynthesis and thereby better crop growth and higher dry matter accumulation (Shah *et al.*, 2012; Biswajit *et al.*, 2013; and Devi and Mani, 2015). However, the interaction effect of seed treatment and foliar application of SWE did not show any significant effect on tiller number as well as dry matter accumulation in wheat.

Table 2. Growth parameters of wheat as influenced by sea weed extracts

Treatments	Plant height (cm) at harvest	Tiller number m^{-2}			Dry matter accumulation (g m^{-2})		
		60 DAS	75 DAS	90 DAS	30 DAS	60 DAS	90 DAS
Seed treatment							
S_1: No treatment	95.86	337	325	317	182	593	1118
S_2: SWE @ 3 ml kg^{-1} of seeds	97.80	351	341	330	204	657	1201
CD (P=0.05)	NS	NS	NS	NS	15.2	22.8	55.8
Foliar application							
F_1: Spraying SWE once @ 2 ml litre^{-1} at tillering	97.80	322	314	307	178	588	1105
F_2: Spraying SWE once @ 4 ml litre^{-1} at tillering	95.80	320	309	299	184	635	1164
F_3: Spraying SWE once @ 2 ml litre^{-1} at heading	96.05	319	310	301	176	615	1198
F_4: Spraying SWE once @ 4 ml litre^{-1} at heading	96.80	315	304	294	175	588	1167
F_5: Spraying SWE twice @ 2 ml litre^{-1} at tillering and heading	97.55	351	341	332	182	662	1215
F_6: Spraying SWE twice @ 4 ml litre^{-1} at tillering and heading	98.15	359	345	330	180	629	1158
CD (P=0.05)	NS	36.5	33.8	29.7	NS	39.7	72.8
Interaction							
Seed treatment x Foliar application	NS	NS	NS	NS	NS	NS	NS

3.2 Yield Attributes

The data presented in Table 3 reflected that the seed treatment and foliar application of SWE had a significant impact on spike number though the other yield attributes did vary significantly. With respect to seed treatment, significantly higher number of spikes (331 m^{-2}) was obtained under treatment in which seeds were treated with SWE @ 3ml kg^{-1}. As far as the foliar application of

SWE was concerned, the treatment F_5 (foliar spray of SWE twice @ 2 ml litre^{-1} at tillering and heading stage) achieved significantly higher spike number (325 m^{-2}), being statistically at par with treatment F_6 (foliar spray of SWE twice @ 4 ml litre^{-1} at tillering and heading stage) where the recorded spike number per square meter was 311. From the data it was also observed that foliar spray of SWE once @ 2ml or 4 ml litre^{-1} of water either at tillering or heading did not show much positive effect on spike number of wheat crop. Similar findings of increased spike number due to foliar application of SWE was also previously reported by Raj *et al.* (2016); Saudi (2017) and Sarita *et al.* (2021). The spike length, grains spike^{-1} and 1000-grain weight did not vary significantly with seed treatment and foliar application of SWE (Table 3).

3.3 Grain and Straw Yield (kg ha^{-1})

The grain and straw yields of wheat were significantly influenced due to seed treatment as well as foliar application of SWE (Table 3). The treatment comprising seed treatment with SWE recorded significantly higher grain yield (5873 kg ha^{-1}) and straw yield (8633 kg ha^{-1}) over no seed treatment. Increase in grain and straw yield of wheat under seed treatment was 10.60% (grain yield) and 7.67% (straw yield) over the untreated seeds. This was due to the reason that SWE improved the soil environment, thereby enhancing root proliferation and increased moisture and nutrient absorption which in turn resulted in higher growth and yield attributes *vis-à-vis* productivity. Among the foliar spray treatments, the maximum grain yield (5901 kg ha^{-1}) and straw yield (9146 kg ha^{-1}) were noted with the treatment F_5 (foliar spray of SWE twice @ 2 ml litre^{-1} at tillering and heading stage). This treatment was statistically at par with treatment F_6 (foliar spray of SWE twice @ 4 ml litre^{-1} water at tillering and heading stage) having 5725 and 8702 kg ha^{-1} of grain yield and straw yield, respectively. It was also observed that spraying higher concentration of SWE (4 ml litre^{-1}) at tillering stage only resulted in lower grain and straw yields of wheat. It was also noted that spraying during active tillering alone or both at active tillering and heading resulted in higher yield performances over its spraying at heading stage alone irrespective of concentrations. This was because SWE applied either as a seed treatment or foliar spray had various growth promoting hormones in it which led to increase in the yield. Improved vegetative growth with increased value of yield attributing characters such as number of spikes, total number of filled grains as well as 1000-grain weight of crop also resulted in higher grain yield. It was quite obvious that SWE had a pronounced effect on improving yield performances of the wheat crop. Regarding standardization of doses, it was quite evident that spraying at active tillering was supposed to be better over its spraying at heading stages; two spraying at tillering and heading was better over single application at any of these stages. Kumari *et al.* (2013) also found that spraying SWE twice enhanced grain and straw yields of wheat. The results were also in close conformity with the findings of Singh *et al.* (2015) and Sarita *et al.* (2021) who noticed that foliar spray of SWE at critical growth stages improved wheat productivity. As the increase in both grain and straw yield was achieved with foliar application and seed treatment of SWE, harvest index did not vary significantly.

Table 3. Yield attributes and yields of wheat as influenced by sea weed extracts

Treatments	Spike no. m^{-2}	Grains spike^{-1}	Spike length (cm)	1000-grain weight (g)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest Index
Seed treatment							
S_1: No treatment	313	42.2	11.11	40.2	5310	8018	0.40
S_2: SWE @ 3 ml kg^{-1} of seeds	331	43.7	11.40	40.6	5873	8633	0.40
CD (P=0.05)	16.8	NS	NS	NS	389	467	NS
Foliar application							
F_1: Spraying SWE once @ 2 ml litre^{-1} at tillering	298	42.2	11.11	40.2	5055	7684	0.40
F_2: Spraying SWE once @ 4 ml litre^{-1} at tillering	290	42.4	11.16	40.2	4943	7316	0.40

F_3: Spraying SWE once @ 2 ml litre^{-1} at heading	285	43.9	11.34	40.5	5067	8107	0.38
F_4: Spraying SWE once @ 4 ml litre^{-1} at heading	290	44.1	11.39	40.7	5205	8068	0.39
F_5: Spraying SWE twice @ 2 ml litre^{-1} at tillering and heading	325	44.5	11.54	40.8	5901	9146	0.39
F_6: Spraying SWE twice @ 4 ml litre^{-1} at tillering and heading	311	44.9	11.62	41.0	5725	8702	0.40
CD (P=0.05)	27.3	NS	NS	NS	465	669	NS
Interaction							
Seed treatment x Foliar application	NS	NS	NS	NS	NS	NS	NS

3.4 Nutrient Uptake

The seed treatment of SWE showed a significant difference in nitrogen, phosphorous and potassium uptake. Significantly higher uptake of nitrogen (110.5 kg ha^{-1}), phosphorus (14.1 kg ha^{-1}) and potassium (117.7kg ha^{-1}) was noticed under treatment S_2 (seed treatment with SWE @ 3ml kg^{-1} of seeds). It was also observed that the uptake of nitrogen, phosphorous and potassium with SWE seed treatment was 10.72, 9.30 and 11.98% higher over no seed treatment (S_1) (Table 4). This could be due to presence of numerous organic compounds in SWE that serve as bio-stimulants to improve nutrient availability and uptake in the plant system (Salat, 2004). Additionally, plant growth promoting hormones were present in the SWE which helped in maximum root proliferation and higher root densities in turn helped in enhanced nutrient uptake in wheat (Mancuso *et al.*, 2006; and Prasad *et al.*, 2010). As

Table 4. Nutrient uptakes and production economics of wheat as influenced by sea weed extracts

Treatments	Nutrient uptake (kg ha^{-1})			Production economics			
	Nitrogen	Phosphorus	Potassium	Total cost of cultivation (₹ ha^{-1})	Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	B:C
Seed treatment							
S_1: No treatment	99.8	12.9	105.1	44483	100887	56404	2.27
S_2: SWE @ 3 ml kg^{-1} of seeds	110.5	14.1	117.7	44633	111581	66948	2.50
CD (P=0.05)	8.2	0.9	10.1	-	8768	4320	0.11
Foliar application							
F_1: Spraying SWE once @ 2 ml litre^{-1} at tillering	101.2	13.5	111.3	43925	96052	52127	2.19
F_2: Spraying SWE once @ 4 ml litre^{-1} at tillering	99.7	13.2	106.2	44375	93917	49542	2.12
F_3: Spraying SWE once @ 2 ml litre^{-1} at heading	100.8	12.9	104.6	43925	96276	52351	2.19
F_4: Spraying SWE once @ 4 ml litre^{-1} at heading	103.3	13.3	107.5	44375	98897	54522	2.23
F_5: Spraying SWE twice @ 2 ml litre^{-1} at tillering and heading	110.5	15.2	119.8	44925	112113	67188	2.50
F_6: Spraying SWE twice @ 4 ml litre^{-1} at tillering and heading	107.3	14.9	110.5	45825	108779	62954	2.37
CD (P=0.05)	NS	NS	NS	-	12150	6283	0.18
Interaction							
Seed treatment x Foliar application	NS	NS	NS	-	NS	NS	NS

far as the foliar application of SWE was concerned, the uptake of nitrogen, phosphorus and potassium did not vary significantly. However, numerically higher uptake of nitrogen (110.5 kg ha^{-1}), phosphorous (15.2 kg ha^{-1}) and potassium (119.8 kg ha^{-1}) was observed under treatment F_5 (foliar spray of SWE twice @ 2 ml litre^{-1} water at tillering and heading stage) as compared to other treatments.

3.5 Production Economics

Data with respect to production economics (Table 4) revealed that cost of cultivation varied due to different SWE treatments. The minimum cost of cultivation was incurred under the treatment where foliar spraying of SWE was done once at lower rates. The gross returns and net returns of wheat were significantly influenced due to seed treatment and foliar application of SWE. As far as the seed treatment was concerned, significantly higher gross returns (111581) and net returns (66948) were obtained under treatment S_2 (seed treatment with SWE @ 3ml kg^{-1} of seeds). Among foliar application treatments, the highest gross returns (112113) and net returns (67188) were noticed under treatment F_5 (foliar spray of SWE twice @ 2 ml litre^{-1} at tillering and heading stage). Similarly, the treatments having higher gross and net returns significantly recorded highest cost benefit ratio. The maximum B:C (2.50) was attained with the treatment in which seeds were treated with SWE @ 3 ml kg^{-1} of seeds (S_1) as well as with foliar application of SWE twice @ 2 ml litre^{-1} water at tillering and heading stage (F_5). The maximum gross returns, net returns and B:C under the respective treatments might be attributed to the enhanced the crop growth and productivity with addition of SWE. The results were in conformity with the findings of Singh *et al.* (2023) who noticed that application of SWE either as seed treatment or foliar application increased gross returns, net returns and B:C of wheat.

Conclusion

It can be concluded from this 2-years trial that both seed treatment and foliar spraying of SWE were quite effective in enhancing the growth and yield performances of wheat. The seed treatment @ 3 ml kg^{-1} of seeds and foliar application of SWE @ 2 ml litre^{-1} at active tillering and heading stage could improve growth, yield, nutrient uptake and profitability of wheat in this region. While spraying, it was suggested to use lower concentration (2 ml litre^{-1}) over higher concentration (4 ml litre^{-1}).

Author contributions

Conceptualization of research (CSNT and BM); Designing of the experiments (BM and MSLR); Contribution of experimental materials (CSNT and RB); Execution of field/lab experiments and data collection (CSNT and RB); Analysis of data and interpretation (CSNT, RB, BM); Preparation of the manuscript (MSLR, VKB, BM).

Conflict of interest

No

Declaration

The authors declare no conflict of interest.

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