ISSN: 2347-4688, Vol. 11, No.(3) 2023, pg. 915-927

Current Agriculture Research Journal

www.agriculturejournal.org

Effect of Seaweed Liquid Fertilizer on *Sorghum bicolor* and *Pennisetum glaucum*

SAMRADNI SANJAY LAD*, RUTWIK PRADEEP KHOPEKAR, AKSHADA ANAND PARAB, NILESH RAMESH KADAM and SUNIL DEORAOJI SHANKHADARWAR

Department of Botany, Ramnarain Ruia Autonomous College, Matunga, Mumbai, Maharashtra, India

Abstract

Millets are small-seeded grasses belonging to the family Poaceae that help in human and animal nourishment. They are mostly grown by using chemical fertilizers which are depleting soil fertility. Organic fertilizers are eco-friendly and help to enhance the growth and development of plants thereby maintaining soil health. Seaweed liquid fertilizer (SLF) are organic fertilizers that can be used to control the side effects caused by harmful chemical fertilizers. The present study was carried out to check the effects of seaweed liquid fertilizer on the growth and development of millets. Different concentrations of seaweed liquid fertilizer (0.25%, 0.50%, and 0.75%) were prepared from *Sargassum cinerum, Ulva intestinalis, and Padina tetrastromatica,* which were tested on *Sorghum bicolor* and *Pennisetum glaucum. Growth parameters* like root length, shoot height, flowering-fruiting, and biochemical analysis like proteins were analyzed by using seaweed liquid fertilizer and chemical fertilizer. Plants treated with 0.50% concentration of seaweed liquid fertilizer showed higher protein content. Total chlorophyll was found to be higher in treated plants than in control plants. Flowering and fruiting were observed earlier in seaweed liquid fertilizer treated plants. This concludes that seaweed extracts can be used as a promising alternative to chemical fertilizers, which plays a significant role in the holistic growth enhancement of plants.

Article History

Received: 24 August 2023

Accepted: 09 December 2023

Keywords

Millets;
Padina tetrastromatica;
Sargassum cinerum;
Seaweed Liquid Fertilizer (SLF); *Ulva intestinalis*.

Introduction

Around half of the population of India is employed in agriculture and has the second-largest cultivable land area in the world. After the onset of the 20th century, India's population grew significantly and hence to feed the ever-increasing population, excessive use of chemical fertilizers and pesticides has done to expedite crop development. Crops grow rapidly as a result, but excessive use affects human health and degrades soil fertility.[1] Consequently, there is

CONTACT Samradni Sanjay Lad samradnilad@gmail.com Department of Botany, Ramnarain Ruia Autonomous College, Matunga, Mumbai, Maharashtra, India.

Doi: https://dx.doi.org/10.12944/CARJ.11.3.20

an alarming need to choose and utilize organic fertilizers, which are usually administered in the form of manures and bio-stimulants. Microorganisms, organic compost, animal dung, chicken droppings, and domestic sewage are just few examples of the sources that organic fertilizers comprise of. Moreover, macro and microscopic algae have been used to make organic fertilizers.[2]

An alga plays an important role in agriculture since it is utilized as a biofertilizer and as a soil stabilizer. It increases the uptake of phosphorus and nitrogen. They contain high levels of iodine, calcium, phosphorus, magnesium, iron, sodium, and potassium. Several major trace elements, including chromium, manganese, selenium, zinc and copper are additionally present.[3] They contain a variety of bioactive components including various minerals, lipids, proteins, carbohydrates, amino acids, and phytohormones.[4] Similar characteristics are witnessed in seaweeds, which are readily available in the coastal region. Seaweeds are used as bio-fertilizers and bio-stimulants. It investigated the effect of seaweed liquid fertilizer (SLF), specifically *Sargassum wightii* and *Ulva lactuca*, without the use of chemical fertilizers on seed germination, growth, and biochemical characteristics of the legume plant Glycine max (Soybean). This led to the use of seaweed liquid fertilizer at low concentrations to improve the germination of seeds and the growth of seedlings in farmed crops. Furthermore, increased pigment levels were seen in crops treated with low-concentration seaweed liquid fertilizer.[5] Additionally, it has been noted that applying seaweed liquid fertilizers to rice crops can reduce NPK doses while promoting plant development on an agronomic level.[6] Application of seaweed liquid fertilizer on *Cucumis sativus* (Cucumber) showed enhancement of chemical and physical characteristics associated with immunity, productivity, stress resistance and increased yield.[7] Different combinations of seaweed liquid fertilizers are also tested with equal concentrations. This result suggests that with lower concentrations of seaweed liquid fertilizers, vegetative plant growth, and germination bioassays both considerably increased. Furthermore, the combination of seaweed liquid fertilizer (SLF) enhanced photosynthetic pigments, total soluble sugar, and total soluble protein and its agronomic growth compared with single seaweed liquid fertilizer treatment.[8] Ascophyllum nodosum, *Fucus* spp., *Sargassum* spp., *Laminaria* spp., and *Turbinaria* spp. (Phaeophyceae) are utilized as agricultural biofertilizers and are among the most researched brown algae species. According to studies, seaweed protects plants from bacterial, viral, and fungal diseases.[9] Seaweed like *Sargassum cinereum*, *Padina tetrastromatica*, *Ulva intestinalis*, *Ulva rigida,* etc. are primarily found in our nation; therefore, they are primarily used as biofertilizers and biostimulants for growth promotion as they are comparatively less expensive than the seaweeds that are exported from European Countries such as *Ascophyllum nodusum*, a brown alga. Due to its high price, it suffers from lower demand and popularity.[10] Because of this, different concentrations of seaweed liquid fertilizer (0.25%, 0.50%, and 0.75%) were made from *Ulva intestinalis*, *Padina tetrastromatica*, their combination, and *Sargassum cinerum* were used as foliar and fertilizers to study how it improved agronomic growth on *Sorghum bicolor* and *Pennisetum glaucum*. The chosen crops are given NPK and Control treatments to compare their agronomic and biochemical characteristics.

The use of seaweeds also makes a significant contribution to economic growth because they are prepared using inexpensive, naturally occurring resources. The local villagers and fishermen can take advantage of the numerous employment opportunities it offers. They prepare seaweed liquid fertilizer as their prosperous start-up by gathering seaweeds.

Materials and Methods

Collection of Seaweed

Samples of seaweed were taken from Maharashtra Coastline. *Ulva intestinalis* and *Padina tetrastomatica* belonging to class Chlorophyceae and Phaeophyceae were collected from rocky areas in Bandra and Devgad, respectively. The seaweeds were properly cleaned to eliminate any salt or sand contents, and large contaminants such as sea snails and shrimp were separated. They were cleaned with regular tap water and dried under shade at room temperature. To preserve the biochemical properties, they were sealed up in collection bags and kept in an incubator at 37 °C. For the further study, samples were used in dried form.

Preparation of Seaweed Liquid Fertilizer

1gm of dried seaweed powder was dice in which 100 ml Distilled water was added. It was autoclaved for 1 hour at 15 psi. The autoclaved extract was cooled at room temperature and was filtered through a muslin cloth/ cheese cloth. The cooled extracts were centrifuged at 3000 rpm for 10 minutes at 30 °C. Supernatant was transferred into a clean conical flask, cotton capped, and placed in the refrigerator for further use. The prepared 1% Seaweed liquid fertilizer was made into different concentrations using sterile distilled water, as 0.25%, 0.50% and 0.75% respectively. As a result, various concentrations of each extract were obtained and used to treat seeds. Using this technique, two seaweeds extracted along with a combination of both were each converted into seaweed liquid fertilizers and was then diluted to test the impact of changing concentrations.

Procedure of Seed Preparation

The seeds were rinsed twice with distilled water, followed by a 70% alcohol and D/W wash. They were cleaned again with Mercuric chloride and rinsed 2-3 times with sterile distilled water to prevent infection. Seeds were first dried on filter paper before being added to various seaweed liquid fertilizer concentrations. For 48 hours, 10 seeds were soaked in each seaweed liquid fertilizer concentration. 10 seeds were steeped in normal D/W as a control. The seed was inspected after 48 hours and then placed in distinct, labelled pots with various seaweed liquid fertilizer concentrations and control.

Maintenance of Seeds

After the seeds were planted in pots, they were kept in a greenhouse to maintain temperature and humidity. Seaweed liquid fertilizer was applied to the plants every week. 25 ml of each concentration was applied directly into the soil as well as foliar spray. Control plants were also tested in the same way i.e., 25 ml of 1% NPK was added to the control treated plant every week. Rest of the days the plants were watered with tap water. Plants were thus maintained and observed daily. Plants were carefully grown until the fruiting was observed and matured fruits were further monitored in the study.

Agronomic Characters

After seeds being sown for three days, leaves were visible. After 7 days, observation of each shoot length was recorded. Triplicates of each set of seaweed liquid fertilizer concentrations, along with controls and water were formed, to study the effect of seaweed liquid fertilizer on the germination rate of the seeds. Germination rates were recorded for 24, 48, and 72 hours. Observations of panicle growth were made 90 days after planting.

Weight and length of the panicle as well as number of seeds it bore were also studied.

Biochemical Parameter

Chlorophyll Estimation

Plants grown for 40 days were selected and chlorophyll content was estimated. Chlorophyll estimation was carried out by Aaron's method. Further, measurements of absorbance were made at 645, 652, and 663 nm using UV-Vis spectrophotometer / colorimeter.

Formula- 20.2(A675) + 8.02(A663) x V/100 x W

Procedure for Protein Estimation

Lowry's method of estimation of protein was carried out. Seeds collected from selected fully matured plants were extracted into aqueous extracts. 1 g of seeds and 3 ml of D/W were ground in a mortar and pestle. For preparation of standard, 0.1% Bovine Serum Albumin was used. Further procedure was conducted as per Lowry's method (11) and analysed at 660 nm.

Bio-active Compounds Test

Qualitative Phytoconstituents Analysis

A qualitative phytochemical analysis of crude powder was done to isolate various phytoconstituents. For these tests, the solvent with the highest extractive value i.e. aqueous extract was utilized. Among the phytoconstituents examined were alkaloids, flavonoids, phenols, saponins, tannins, and polysaccharides.

Alkaloids

Wagner's test

1 ml of seaweed liquid fertilizer extract + 5-6 drops of Wagner's reagent. (Formation of brown/reddish precipitate showed the presence of alkaloids.)

Mayer's Test

1 ml of seaweed liquid fertilizer extract + 5-6 drops of Mayer's reagent. (Formation of creamish yellow precipitate indicated the presence of alkaloids).

Flavonoids (Alkaline Reagent Test)
Seaweed liquid fertilizer Extract + a few drops of NaOH solution. (Intense yellow colour is formed, which becomes colourless in addition to diluting HCl, confirming the presence of flavonoids).

Tannins (Using Lead Acetate)
1 ml of the seaweed liquid fertilizer extract + 1 ml of lead acetate. (Formation of white precipitate indicated the presence of Tannins).

Saponins (Foam Test)
2 ml of seaweed liquid fertilizer extract + 2 ml of D/W were shaken well. (Formation of persistent foam indicated the presence of saponins).

Phenols (Using lead acetate)
1 ml of seaweed liquid fertilizer extract + 1 ml of lead acetate. (Formation of white precipitate indicated the presence of Phenols).

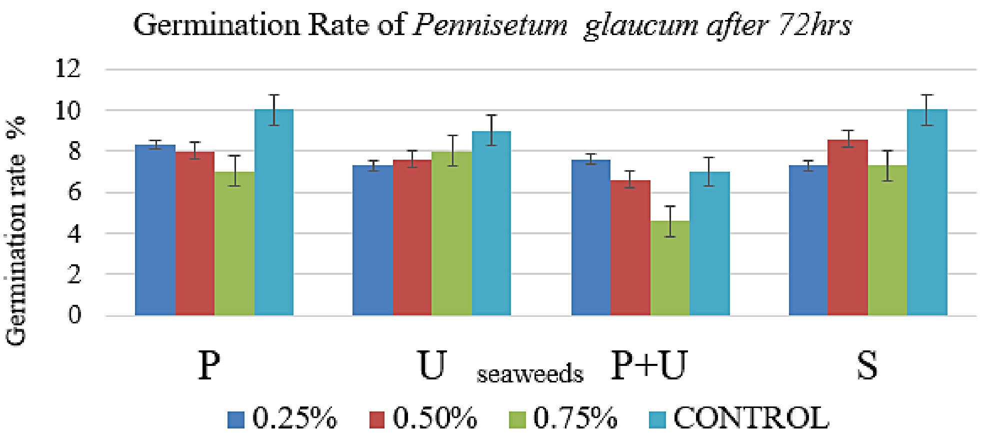
Polysaccharides (Molisch's Test)
2 ml of seaweed liquid fertilizer extract + 2-3 drops of Molisch reagent (Violet precipitate indicated the presence of polysaccharides).

Elemental Analysis using the ICP-AES Method
Prepared seaweed extracts were tested for presence of heavy metals as well as micro and macro elements. It was analysed using Induced coupled plasma atomic emission spectroscopy (ICP-AES) method from SAIF lab – IIT Bombay, Mumbai.

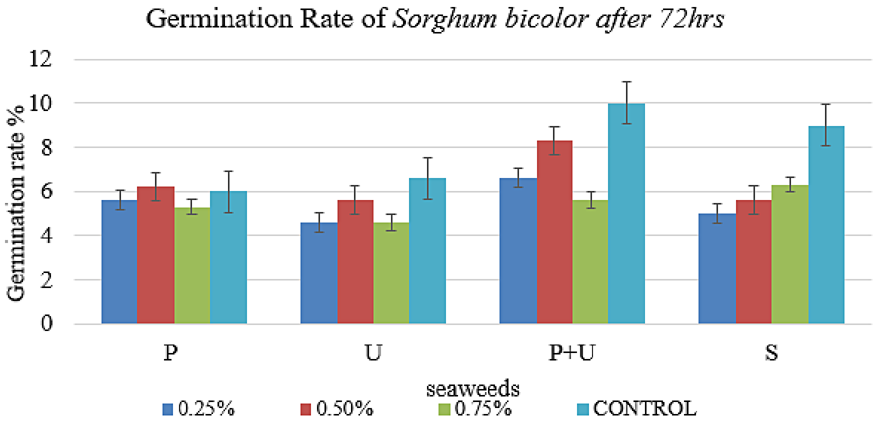
Shelf-life of seaweed liquid Fertilizer
It has been noted that seaweed liquid fertilizer becomes contaminated with bacteria and fungi when exposed to the environment. Therefore, keeping it in the refrigerator is necessary. Using natural preservatives like clove oil, the storage of seaweed liquid fertilizers at room temperature was also put to the test. To prevent contamination and extend the shelf life of seaweed liquid fertilizer, clove oil was employed as a preservative.

Results

Germination Rate
Rates of germination were observed for 24 hrs, 48 hrs and 72 hrs. Tables 1.1 and 1.2 show results for germination rate after 72 hrs of treatment with seaweed liquid fertilizer as well as water as control. In table 1.1, SLF of *Ulva intestinalis* treated showed gradual increase in rate of germination. While in Table 1.2, Combination of Seaweed extracts showed maximum germination rate. Based on this data, further *Pennisetum glaucum* were treated with *Ulva intestinalis* SLF and Sorghum bicolor was treated with a combination of Seaweed liquid fertilizer, respectively.



Graph 1: Germination Rate of Pennisetum glaucum treated with different Seaweed liquid fertilizer.



Graph 2: Germination Rate of Sorghum bicolor treated with different Seaweed liquid fertilizer.

Shoot lengths

Shoot lengths of the plants were recorded after every 7 days. As observed from table no 1, initial growth was observed in plants treated with 0.50% concentration and control. According to further observations, maximum growth was observed in 0.50% concentration of *Ulva intestinalis* treated *Pennisetum glaucum* crop also in combination of *Ulva intestinalis* and *Padina tetrastromatica* treated *Sorghum bicolor* crop.

Table 1: Shoot length (in cm) of Pennisetum glaucum treated with U. intestinalis and Sorghum bicolor treated with P. tetrastromatica + U. intestinalis

Seaweed liquid fertilizer		Shoot length growth (cm) in concentration				
		0.25%	0.50%	0.75%	NPK	WATER
7 days	*Pennisetum glaucum*	1 ± 0.3	10 ± 0.5	10 ± 0.2	10 ± 0.2	12 ± 0.3
	Sorghum bicolor	8 ± 0.2	6 ± 0.6	7 ± 0.4	5 ± 0.4	7 ± 0.4
28 days	*Pennisetum glaucum*	14 ± 0.4	63 ± 0.6	49 ± 0.4	40 ± 0.3	51± 0.4
	Sorghum bicolor	35 ± 0.4	43 ± 0.6	42 ± 0.3	28 ± 0.4	35 ± 0.3
49 days	*Pennisetum glaucum*	35 ± 0.3	108 ± 0.5	89 ± 0.4	42 ± 0.3	90 ± 0.4
	Sorghum bicolor	96 ± 0.5	109 ± 0.7	101 ± 0.5	90 ± 0.4	97 ± 0.4
70 days	*Pennisetum glaucum*	56 ± 0.3	137 ± 0.6	94 ± 0.4	48 ± 0.4	107 ±0.3
	Sorghum bicolor	130 ± 0.5	138 ± 0.5	125 ± 0.3	125 ± 0.4	129 ± 0.4

Pennisetum glaucum and *Sorghum bicolor* were treated with 0.50% *U. intestinalis* and a combination of P. *tetrastromatica* and *U. intestinalis*, respectively, and both showed satisfactory results.

Additional tests were carried out on treated plants chosen basically depending on their pace of growth.

Pigment Estimation Test

Pigment estimation from leaves of *Pennisetum glaucum* and *Sorghum bicolor* crops treated with 0.50% concentration of *Ulva intestinalis* and combination of *Ulva intestinalis* and *Padina tetrastromatica* respectively was performed by Aron's Method. In this, particularly Chl a, Chl b and total chlorophyll contents were studied. Results showed maximum chlorophyll content in crops treated with 0.50% seaweed liquid fertilizer compared to other concentration extract, NPK and Control (Table 2 a & 2 b).

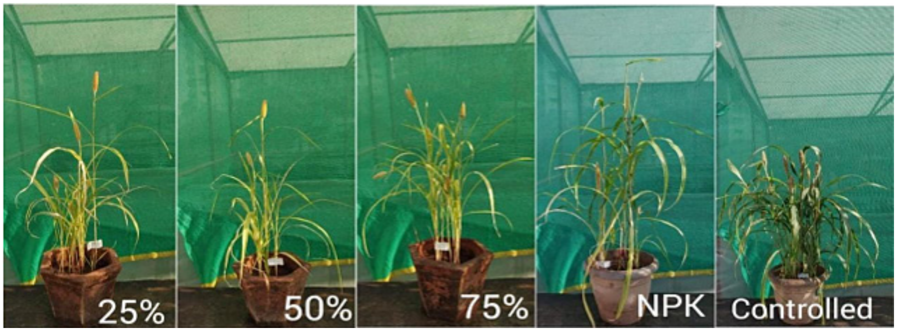


Fig 1: Agronomic growth and Fruiting in *Pennisetum glaucum* treated with (0.25%, 0.50%, and 0.75%) concentration of *U. intestinalis,* along with NPK and control.

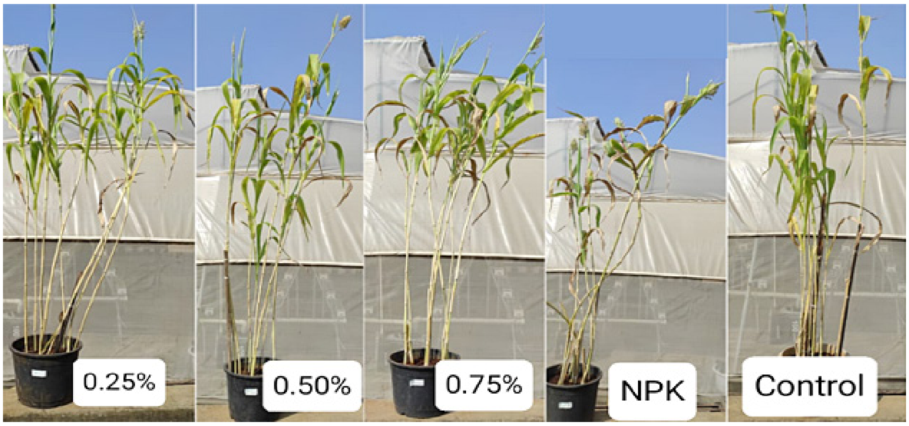


Fig 2 : Agronomic growth and Fruiting in *Sorghum bicolor* is treated with (0.25%, 0.50%, and 0.75%) concentrations of *U. intestinalis* and *P. tetrastromatica* combined, along with NPK and control.

Table 2(a & b): Chlorophyll estimation of Pennisetum glaucum and Sorghum bicolor crops treated with seaweed liquid fertilizer of 0.50% concentration.

Table 2 a

Plant Sample	Concentration	Chlorophyll a	Chlorophyll b	Total Chlorophyll
Ulva intestinalis	0.25%	2.69 ± 0.04	2.95 ± 0.03	5.64 ± 0.03
SLF on	**0.50%**	**4.71 ± 0.08**	**4.39 ± 0.07**	**9.10 ± 0.09**
Pennisetum	0.75%	1.36 ± 0.05	1.12 ± 0.04	2.17 ± 0.05
glaucum	NPK	4.12 ± 0.06	4.17 ± 0.05	8.29 ± 0.04
	Control	4.12 ± 0.07	4.17 ± 0.06	8.29 ± 0.06

Table 2 b

Plant Sample	Concentrations	Chlorophyll a	Chlorophyll b	Total Chlorophyll
Ulva intestinalis +	0.25%	1.49 ± 0.04	1.83 ± 0.05	3.33 ± 0.05
Padina tetrastromatica	**0.50%**	**4.40 ± 0.09**	**5.40 ± 0.08**	**9.81 ± 0.08**
on *Sorghum*	0.75%	2.35 ± 0.06	2.90 ± 0.06	5.25 ± 0.04
bicolor	NPK	2.36 ± 0.07	2.89 ± 0.06	5.26 ± 0.06
	Control	1.39 ± 0.03	1.74 ± 0.04	3.13 ± 0.03

Protein Estimation

Protein estimation of seeds harvested by treating *Pennisetum glaucum* and *Sorghum bicolor* plants were studied by Lowry's method. It is observed that the highest protein content was estimated in the seeds harvested from the *Pennisetum glaucum* crop treated with 0.50% concentration of *Ulva intestinalis*. On the other hand, similar results were obtained in seeds of Sorghum bicolor crop that were treated with 0.50% concentration of combined *Ulva intestinalis* and *Padina tetrastromatica*. Highest protein content was found in seeds harvested from plants treated with 0.50% of seaweed liquid fertilizer. (Table no 3)

Table 3: Protein content present in *Pennisetum* fruiting treated with *U. intestinalis* and *Sorghum* fruiting treated with *P. tetrastromatica* + *U. intestinalis.*

Treated plants (Concentration)	Protein Content of Pennisetum glaucum (mg/g)	Protein Content of Sorghum bicolor (mg/g)
0.25%	0.226 ± 0.25	0.226 ± 0.23
0.50%	0.253 ± 0.35	0.247 ± 0.33
0.75%	0.219 ± 0.26	0.227 ± 0.28
NPK	0.229 ± 0.26	0.224 ± 0.27
Control	0.222 ± 0.33	0.226 ± 0.34

Flowering and Fruiting

Fruiting started after 90 days of potting. Maximum yield of flowering and fruiting was observed in *Pennisetum glaucum* and *Sorghum bicolor* treated with 0.50% concentration of *Ulva intestinalis* and combined *Ulva intestinalis* and *Padina tetrastromatica* respectively compared to NPK and Control (Table no. 4). Panicle study was conducted which includes weight, length, and total number of seeds it bears. Panicles harvested from 0.50% concentration of seaweed liquid fertilizer in both the crops showed highest results and optimum development (Table no. 5(a) and 5(b).

Table 4: Flowering and fruiting in Pennisetum glaucum treated with U. intestinalis and Sorghum bicolor treated with U. intestinalis+ P. tetrastromatica

Sample (Conc.)	Total yield of fruiting seen in Pennisetum glaucum	Total yield of fruiting seen in Sorghum bicolor
0.25%	1	4
0.50%	2	7
0.75%	1	5
NPK	1	5
Control	2	3

Panicle Study

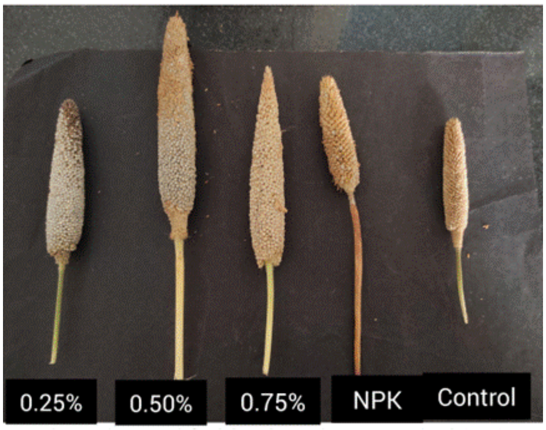


Fig 3: *Pennisetum glaucum* treated with *U. intestinalis* SLF, NPK, & Control

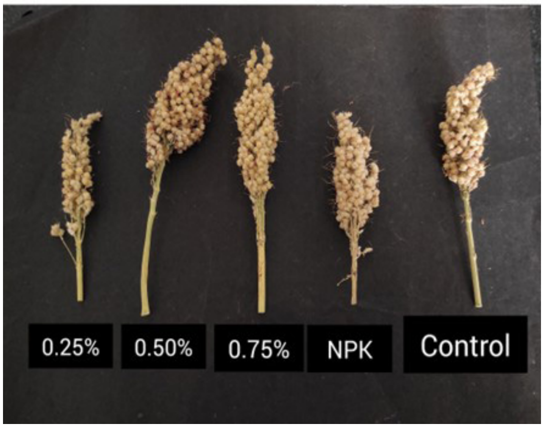


Fig 4: *Sorghum bicolor* treated with the combination of *P. tetrastromatica* and *U. intestinalis SLF*, NPK, & Control

Table 5 (a): Panicles of *Pennisetum glaucum* and *Sorghum bicolor* treated with seaweed liquid fertilizer, NPK, and Control, (b): Weight, No. of seeds, Length of panicle of *Pennisetum glaucum* and *Sorghum bicolor*

Seaweed liquid fertilizer (Conc.)	***Pennisetum glaucum* treated with *U. intestinalis SLF***	***Sorghum bicolor* treated with *P. tetrastromatica + U. intestinalis SLF***
0.25%	Weight:- 6.6g No. of seeds:- 230 Length of panicle:- 11cm	Weight:- 6.60g No. of seeds:- 90 Length of panicle:- 2cm
0.50%	Weight:- 14.7g No. of seeds:- 445 Length of panicle:- 15cm	Weight:- 9.97g No. of seeds:- 275 Length of panicle:- 12cm
0.75%	Weight:- 11.9g No of seeds:- 339 Length of panicle:- 13.5cm	Weight:- 6.59g No. of seeds:- 195 Length of panicle:- 10cm
NPK	Weight:- 2.3g No of seeds:- 12 Length of panicle:- 8.5cm	Weight:- 9.06g No. of seeds:- 239 Length of panicle:- 11.2 cm
Control	Weight:- 0.6g No of seeds:- 6 Length of panicle:- 6.5cm	Weight:- 4.8g No. of seeds:- 184 Length of panicle:- 7.5cm

Qualitative Phytoconstituents Analysis of Seaweed Liquid Fertilizers

According to the analysis, phytoconstituents like alkaloids, tannins, saponins, polysaccharides, phenols were present. While flavonoids were not detected in the seaweed liquid extract of *Ulva intestinalis* and combined *Ulva intestinalis* with *Padina tetrastromatica* (Table no. 6)

Table 6: Qualitative phytoconstituents analysis of *U. intestinalis, P. tetrastromatica, U. intestinalis + P. tetrastromatica.*

Tests	*U. intestinalis*	*P. tetrastromatica*	*U. intestinalis + P. tetrastromatica*
Alkaloids (Wagner's test)	+	+	+
Alkaloids (Mayer's test)	+	+	+
Flavonoids (Alkaline reagent test)	-	-	-
Tannins (using lead acetate)	+	+	+
Saponins (foam test)	+	+	+
Polysaccharides (Molisch's test)	+	+	+
Phenols (using lead acetate)	+	+	+

Note: (+) denotes presence, whereas (-) indicates absence of phytochemical

Detection of Elements by ICP-AES
Elements like Boron, Calcium, Magnesium, Sodium, Manganese, Sulphur, and Strontium are present, while Copper, Nickel, Zinc and Molybdenum are undetected in extract of *Ulva intestinalis*. Similarly, micro-nutrients like Manganese, Copper, and Zinc were present, Boron, Calcium Magnesium, Sodium, Strontium and Sulphur are undetected in extract of *Padina tetrastromatica*. Also, in the extract of combined *Ulva intestinalis* and *Padina tetrastromatica*, Calcium Magnesium, Sodium, Manganese, Sulphur and Strontium were present while Boron, Copper, Nickel and Zinc are undetected.

Table 7: Detection of Micro-Nutrients by ICP-AES of *U. intestinalis, P. tetrastromatica, U. intestinalis + P. tetrastromatica*

Metals (in ppm)	*U. intestinalis*	*P. tetrastromatica*	*U. intestinalis + P. tetrastromatica*
B	1	ND	ND
Ca	78	ND	27
Mg	102	ND	32
Na	18	ND	3
Mn	1	0.229	1
S	272	ND	68
Sr	1	ND	2
Cu	ND	0.022	ND
Ni	ND	0.019	ND
Zn	ND	0.066	ND
Mo	ND	ND	ND

Discussion
The use of seaweed as fertilizers have been studied throughout the last few decades. Seaweed liquid fertilizer (SLF) is utilized as a bio-stimulant. Europe has the world's largest supply of seaweed, and *Ascophyllum nodosum* is one of the seaweed species found there.[12] These seaweeds are utilized as bio-stimulants for enhancing plant development characteristics such as panicle growth, chlorophyll content, and protein content. They are applied as foliar sprays and added to the soil at regular intervals to act as fertilizer.

Two of the three seaweeds employed in the current experimental study showed maximum growth enhancement. On *Pennisetum glaucum* and

Sorghum bicolor, seaweed liquid fertilizer of *Ulva intestinalis* and a combination of *Ulva intestinalis* and *Padina tetrastromatica* were administered respectively. As described by Bhosale *et.al.*[13] Seaweeds were autoclaved with distilled water to prepare seaweed liquid fertilizer, which is a relatively inexpensive and efficient process. Adding distilled water produced additional, different concentrations of 0.25%, 0.50%, and 0.75% of the corresponding seaweed liquid fertilizer concentrations and were applied to the plants as treatment, with NPK while water served as the control.

By treating the seeds with *Ulva intestinalis*, *Padina tetrastromatica*, a combination of it, and *Sargassum cinerum* the rate of germination on both plants were examined. The seeds were soaked and later examined after 48 hrs. Among them, the early and highest germination rate was seen in 0.50% of *Ulva intestinalis* and a combination of *U. intestinalis* + P. *tetrastromatica* as compared to the control which showed the beneficial results. Brinjal, Tomato, and Chilly treated with seaweed liquid fertilizers of *Gracilaria textorii* and *Hypnea musciformis* showed that maximum seed germination was observed in 1:4 and 1:6 concentration of *Gracilaria textorii* and 1:6 concentration of *Hypnea musciformis*.[14] *Capsicum longum* seeds treated with seaweed liquid fertilizer Caulerpa taxifolia exhibited greatest germination percentages at 2%, 3%, and 4% concentrations, whereas seeds treated with seaweed liquid fertilizer *Caulerpa racemosa* exhibited highest growth at 5% concentration.[15]

As a result, they were later planted and grown in soil. The plants after 2 weeks of growth were treated with a foliar spray made up of *Ulva intestinalis*, *Padina tetrastromatica*, and a combination of it with their different concentrations respectively. It was observed that after 8 weeks the seaweed liquid fertilizer-treated plants with 0.50% showed longer shoot lengths as compared to control plants. Likewise, the application of 20% of seaweed liquid fertilizer *Sargassum wightii* on *Triticum aestivum* shows better results in agronomic growth where it shows a 6.7% increase in shoot length over control.[16] Tomato plants treated with 0.4% and 1.0% seaweed liquid fertilizer *Ecklonia maxima* were significantly bigger than control plants.[17] Further, the pigment estimation of leaves of both the seaweed liquid fertilizer treated plants and control was carried out among which both seaweed liquid fertilizer treated plants showed good results in both chlorophyll a and b, carotenoid, treated with *Ulva intestinalis*, *Padina tetrastromatica*, a combination of it. Solanum lycopersicum Mill. leaf chlorophyll content and photosynthetic rates positively increased with the application of seaweed extract of *Sargassum horneri*.[18] *Solanum lycopersicum* treated with the fresh and dried combination of *Ulva reticulata* showed high ascorbic acid, beta-carotene, and lycopene contents.[19]

After 13 weeks, flowering and fruiting were noticed, *Pennisetum glaucum* and *Sorghum bicolor* were treated with U.intestinalis and a combination of *U. intestinalis* and P. tetrastromatica respectively, both displayed early and maximum fruiting. Even in the panicle study, the greatest panicle length and the total number of seeds in the 0.50% seaweed liquid fertilizer have been observed. The protein content in seeds of *Pennisetum glaucum* fruiting treated with 0.50% of *U. intestinalis* was 0.253 mg/g, which was higher than NPK, which is 0.229 mg/g, and the control is 0.222 mg/g. The protein content in seeds of Sorghum bicolor fruiting treated with 0.50% of P. tetrastromatica + *U. intestinalis* was 0.247 mg/g, which was higher than NPK, which is 0.224 mg/g, and for control is 0.226 mg/g. Similar research was done in the Effect of Seaweed Liquid Fertilizer of Colpomenia sinuosa (Mert. ex-Roth) Derbes & Solier, where *Pennisetum glaucum* was treated with Colpomenia sinuosa (brown algae) as seaweed liquid fertilizer. Greater agronomic growth with a 10% concentration was the result of the studies.[20]

Using ICP-AES, the presence of micronutrients and heavy metals have been detected. Calcium, Magnesium, Potassium, and Phosphorus are the micronutrients essential for plants among which Calcium and Magnesium are present in seaweed liquid fertilizer of *U. intestinalis* and also in its combination with P. tetrastromatica. In both stressful and non-stressful environments, Ca2+ ions act as secondary messengers for plant growth and development.[21] Furthermore, it promotes other nutrient absorption by roots and translocation throughout the plant. Magnesium is the second-most common cation in plants and is essential for the formation of nucleic acids, proteins, and enzymes as well as for photosynthesis .[22]

Thus, from this study, it can be concluded that seaweed liquid fertilizers play a significant role in the holistic growth and enhancement of plants as compared to chemical fertilizers.

Conclusion

According to the results of the current study, *U. intestinalis*, P. tetrastromatica, its combination, and S. cinerum exhibited beneficial effects on *Pennisetum glaucum* and Sorghum bicolor, observations were carried out from the treatment of the seeds to its fruiting stage. Germination rate was reported after 48hrs in seeds treated with 0.50% concentration seaweed liquid fertilizer when compared to control seeds. 85% germination in *Pennisetum glaucum* was observed in only 0.50% concentration *U. intestinalis* treated seeds which is 18 - 20% greater than the control crop. On the other hand, 96% germination rate in Sorghum bicolor was observed in 0.50% concentration combination of *U. intestinalis* and P.tetrastromatica treated seeds only which is 15-16% greater than the control crop. The investigation of subsequent growth in crops with increased germination was done following the findings of the germination study. Crops treated with 0.50% seaweed liquid fertilizers demonstrated general agronomic growth, including growth in shoot and root length, leaf size, stem diameter, and fruiting. According to the panicle study, crops treated with 0.50% seaweed liquid fertilizer had panicles longer, heavier and with more seeds overall. The protein and Chlorophyll content of these crops were also in favour of 0.50% treated crops. According to the qualitative phytochemical analysis performed, Alkaloids, Tannins, Saponins, Phenols, and Polysaccharides are found in seaweed liquid fertilizers to enhance the morpho-agronomic and bioactive characteristics of crops.[23] The existence of bioactive components is confirmed by ICP-AES results, confirming the enhancement carried on by seaweed liquid fertilizer. Hence, seaweed liquid fertilizer is proved to be the most efficient and affordable bio-stimulant for agronomic growth and enhancement of crops.

Acknowledgement

Authors would like to acknowledge Department of Botany, Ramnarain Ruia Autonomous College for providing necessary research facilities and technical support. Authors also thank SAIF lab IIT-Bombay for ICP-AES analysis.

Funding

We are thankful to Ramnarain Ruia Autonomous College, Matunga, Mumbai.

Conflict of Interest

Authors have no conflict of interest.

References

1. Tudi, M., Daniel Ruan, H., Wang, L., Lyu, J., Sadler, R., Connell, D., Chu, C., & Phung, D. T. Agriculture Development, Pesticide Application, and Its Impact on the Environment. *International journal of environmental research and public health* 2021; 18(3): 1112. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7908628/ (Accessed: 15 June 2023). https://doi.org/10.3390/ijerph18031112.
2. Zhou, Zhongkai, Siyu Zhang, Na Jiang, Weiming Xiu, Jianning Zhao, and Dianlin Yang. Effects of organic fertilizer incorporation practices on crops yield, soil quality, and soil fauna feeding activity in the wheat-maize rotation system. Frontiers in *Environmental Science 10 2022; 2292. Available at*: https://www.frontiersin.org/articles/10.3389/fenvs.2022.1058071/full. (Accessed: 16 June 2023). https://doi.org/10.3389/fenvs.2022.1058071.
3. Mouritsen, O. G. The science of seaweeds. American Scientist 2018; 101(6):458. Available at: https://www.americanscientist.org/article/the-science-of-seaweeds. (Accessed: 16 June 2023). DOI:10.1511/2013.105.458
4. Ali, O., Ramsubhag, A. and Jayaraman, J. Biostimulant properties of seaweed extracts in plants: Implications towards sustainable crop production. Plants 2021; 10(3):, 531. (Accessed: 16 June 2023). https://doi.org/10.3390/plants10030531
5. S. Ramarajan1, L. Henry Joseph, A. Saravana Ganthi, Effect of Seaweed Liquid Fertilizer on

the Germination and Pigment Concentration of Soybean. *A Journal of Crop Science and Technology* 2012; 1(2): 1-5. Available at: https://www.researchgate.net/profile/Sekar-Ramarajan/publication/232702296 (Accessed: 31 July 2023).

6. Sunarpi, S., Jupri, A., Kurnianingsih, R., Julisaniah, N. I., & Nikmatullah, A. Effect of seaweed extracts on growth and yield of rice plants - neliti. Nusantara Bioscience 2010; 2(2): 73-77. Available at: https://media.neliti.com/media/publications/220589-effect-of-seaweed-extracts-on-growth-and.pdf. (Accessed: 16 June 2023).
7. Hassan, S.M. Impact of seaweed liquid extract biostimulant on growth, yield, and chemical composition of cucumber (Cucumis sativus). Agriculture 2021; 11(4): 320. Available at: https://www.mdpi.com/2077-0472/11/4/320. (Accessed: 16 June 2023). https://doi.org/10.3390/agriculture11040320
8. Rathinapriya, P. Effects of liquid seaweed extracts in improving the agronomic performance of Foxtail Millet. Ben-Gurion University Research Portal 2020; 43(19). Available at: https://cris.bgu.ac.il/en/publications/effects-of-liquid-seaweed-extracts-in-improving-the-agronomic-per. (Accessed: 16 June 2023). https://doi.org/10.1080/01904167.2020.1799002.
9. Polat, S. Recent advances in industrial applications of seaweeds. Critical Reviews in Food Science and Nutrition 2023;63(21):4979-5008. Available at: https://www.bib.irb.hr/1170407. (Accessed: 16 June 2023). DOI: 10.1080/10408398.2021.2010646
10. Parab, A. and Shankhadarwar, S. Growth enhancement of agricultural crops using seaweed liquid fertilizer, Plant Science Today. 2022; 9 (2) Available at: https://horizonepublishing.com/journals/index.php/PST/article/view/1439 (Accessed: 16 June 2023) DOI: https://doi.org/10.14719/pst.1439
11. Rj; L.O.N.A. Protein measurement with the Folin phenol reagent, *The Journal of biological chemistry*1915; 193 (1): 265-275; Available at: https://pubmed.ncbi.nlm.nih.gov/14907713/ (Accessed on: 31 July 2023) DOI:10.1016/S0021-9258(19)52451-6
12. Craigie, J. Seaweed extract stimuli in plant science and agriculture. *Journal of Applied Phycology,* 2011 5(1); 371-393. Available at: freettps://scirp.org/reference/referencespapers.aspxreferenceid=1394434 (Accessed: 16 June 2023) DOI: http://dx.doi.org/10.1007/s10811-010-9560-4
13. Bhosle, N.B., Untawale, A.G. and Dhargalkar, V.K. Effect of seaweed extract on the growth of Phaseolus vulgaris L., NIScPR Online Periodical Repository: Home. 1975; 4 (2): 208-210; Available at: https://nopr.niscp.res.in/handle/123456789/39678 (Accessed: 16 June 2023)
14. Chatterjee, R. Effect of seaweed liquid fertilizer from Gracilaria textorii and Hypnea musciformis on seed germination and productivity of some vegetable crops, Universal Journal of Plant Science; 2019; 2(7): 115-120 (PDF) Effect of Seaweed Liquid Fertilizer from Gracilaria Textorii and Hypnea Musciformis on Seed Germination and Productivity of Some Vegetable Crops | Reshmi Chatterjee - Academia.edu Available at: DOI: 10.13189/ujps.2014.020701
15. Abhilash.E.S, Athira.S and P, A.Balan. A study on the effects of seaweed liquid fertilizer on the germination and growth of Capsicum longum (apsara), JETIR 2021; 10 (12): 117-122 Available at: https://www.jetir.org/view?paper=JETIR2112116 (Accessed: 16 June 2023)
16. Kumar, G. and Sahoo, D. Effect of seaweed liquid extract on growth and yield of *Triticum aestivum* var. pusa gold 2011; 23: 251-255. Available at: https://link.springer.com/article/10.1007/s10811-011-9660-9 (Accessed: 16 June 2023). DOI: https://doi.org/10.1007/s10811-011-9660-9
17. Crouch, I.J. and Staden, J.V. (1992) Effect of seaweed concentrate on the establishment and yield of greenhouse tomato plants. Journal of Applied Phycology 1992; 4: 291-296, Available at: https://link.springer.com/article/10.1007/BF02185785 (Accessed: 16 June 2023). https://doi.org/10.1007/BF02185785
18. Yao, Y., Wang, X., Chen, B., Zhang, M., & Ma, J. Seaweed extract improved yields, leaf photosynthesis, ripening time, and net returns of Tomato (Solanum lycopersicum

mill.), ACS omega 2020; 5 (8): 4242-4249; Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7057707 (Accessed: 16 June 2023). DOI: https://doi.org/10.1021/acsomega.9b04155

19. Abu, N. J., Bujang, J. S., Zakaria, M. H., & Zulkifly, S. Use of Ulva reticulata as a growth supplement for Tomato (Solanum lycopersicum), PloS one. 2022;17 (6) Available at: https://pubmed.ncbi.nlm.nih.gov/35759504/ (Accessed: 16 June 2023). (2022) DOI: 10.1371/journal.pone.0270604
20. Paul J., J.P. Effect of Seaweed Liquid Fertilizer of Colpomenia sinuosa (Mert. ex Roth) Derbes & Solier (Brown Seaweed) on Vigna radiata (L.) R. Wilczek. In Koothankuzhi, Tirunelveli district, Tamil Nadu, India. Int. J. Pure App. Biosci, 2014; 2: 177-184. Available at: https://www.researchgate.net/publication/327156140_Effect_of_Seaweed_Liquid_Fertilizer_of_Colpomenia_sinuosa_on_Pennisetum (Accessed: 31 July 2023)
21. Hepler, P.K. Calcium: A central regulator of plant growth and development, OUP Academic 2005;17 (8):2142-2155 Available at: https://academic.oup.com/plcell/article/17/8/2142/6114599 (Accessed: 16 June 2023 https://doi.org/10.1105/tpc.105.032508
22. Chen ZC, Peng WT, Li J, Liao H. Functional dissection and transport mechanism of magnesium in plants, Seminars in cell & developmental biology 2017; 74: 142-152; Available at: https://pubmed.ncbi.nlm.nih.gov/28822768 (Accessed: 16 June 2023). DOI: 10.1016/j.semcdb.2017.08.005
23. Ashour M, Hassan SM, Elshobary ME, Ammar GAG, Gaber A, Alsanie WF, Mansour AT, El-Shenody R. Impact of Commercial Seaweed Liquid Extract (TAM®) Biostimulant and Its Bioactive Molecules on Growth and Antioxidant Activities of Hot Pepper (Capsicum annuum). Plants. 2021; 10(6):1045. Available at: https://www.mdpi.com/2223-7747/10/6/1045 DOI: https://doi.org/10.3390/plants10061045