**INTRODUCTION**

Rice is the staple food for the whole world. In India, rice is an important food crop that occupies about 44 million ha, with average production and productivity of about 144.52 million tons (2020-21). Van Bussel et al. (2015) shared that rice shares 52% of area and 46% of production in total cereals under cultivation & production in India. In Tamil Nadu, the rice occupies an area of about 20 million ha, with an average production of nearly 70-80 lakh tonnes. Grassinini et al. (2015) reported that the Cauvery Delta region is the main rice cultivated zone of Tamil Nadu, contributing > 50% cultivable area. In this deltaic zone, rice is cultivated continuously as monocropping leads to deteriorating soil health. To sustain soil health economically, judicious application of chemical fertilizers and organic sources is essential. Due to the limited organic sources, the farmers need alternate one to improve the soil quality. In this context, seaweed is an alternative organic source that could be cheaply available and rich in growth-promoting substances. Raghunandan et al. (2019) reported that seaweeds are important marine algae with admirable qualities of being renewable, biodegradable, flexible, non-toxic and...
The present experimental study was conducted at the Tamil Nadu Rice Research Institute, Aduthurai, Thanjavur district, representing the Cauvery Delta Zone of Tamil Nadu during summer season 2021 with high yielding rice variety ADT 53. The soil texture of the experiment site is clay loam belong to Vertisol (soil order). The experiment was laid out in Randomized Block Design (RBD) with twelve treatments and three replications. The treatments comprised of soil application, foliar spray of seaweed products and combinations as mentioned in Table 1. All the treatments received an equal amount of recommended dose of fertilizer. As per the STCR (Soil Test Crop Response) recommendation, the entire dose of phosphorus (76kg/ha) was applied as basal and the remaining N & K were applied as the split application of about 165kg/ha and 70kg/ha respectively. The observations viz., the plant height, dry matter production (DMP), Leaf Area Index (LAI), SPAD reading, root volume and root length in each plot at the interval of 30, 60, 90 DAS and harvest were taken from randomly five plants. The yield parameters viz., no grains/panicles, no productive tillers/m², thousand grain weight, panicle length were recorded at the harvesting stage from randomly 25 hills in each plot. The post-harvest data on grain yield, straw yield and harvest index were recorded and statistically analyzed using AGRES. The post-harvest soil samples were collected and analyzed for the soil fertility parameters-the initial soil parameters are depicted in Table 2. The most reliable organic materials, which could improve the crop yield and quality of the soil. Hence to study the influence of seaweed extract in the monocropping of rice, the present research was initiated with the rice (*Oryza sativa*) var. ADT 53 in Cauvery Delta Zone of Tamil Nadu.

**MATERIALS AND METHODS**

The present experimental study was conducted at the Tamil Nadu Rice Research Institute, Aduthurai, Thanjavur district, representing the Cauvery Delta Zone of Tamil Nadu during summer season 2021 with high yielding rice variety ADT 53. The soil texture of the experiment site is clay loam belong to Vertisol (soil order). The experiment was laid out in Randomized Block Design (RBD) with twelve treatments and three replications. The treatments comprised of soil application, foliar spray of seaweed products and combinations as mentioned in Table 1. All the treatments received an equal amount of recommended dose of fertilizer. As per the STCR (Soil Test Crop Response) recommendation, the entire dose of phosphorus (76kg/ha) was applied as basal and the remaining N & K were applied as the split application of about 165kg/ha and 70kg/ha respectively. The observations viz., the plant height, dry matter production (DMP), Leaf Area Index (LAI), SPAD reading, root volume and root length in each plot at the interval of 30, 60, 90 DAS and harvest were taken from randomly five plants. The yield parameters viz., no grains/panicles, no productive tillers/m², thousand grain weight, panicle length were recorded at the harvesting stage from randomly 25 hills in each plot. The post-harvest data on grain yield, straw yield and harvest index were recorded and statistically analyzed using AGRES. The post-harvest soil samples were collected and analyzed for the soil fertility parameters-the initial soil parameters are depicted in Table 2. The most reliable organic materials, which could improve the crop yield and quality of the soil. Hence to study the influence of seaweed extract in the monocropping of rice, the present research was initiated with the rice (*Oryza sativa*) var. ADT 53 in Cauvery Delta Zone of Tamil Nadu.

**Table 1. Treatment schedule for field experiments at Cauvery Delta zone**

| Treatment | Description |
|-----------|-------------|
| T₁ | SWE gel soil application 12.5 kg/ha |
| T₂ | SWE gel soil application 25 kg/ha |
| T₃ | SWE gel soil application 37.5 kg/ha |
| T₄ | Foliar spraying of SWE gel 0.5 per cent (v/v) at tillering + Panicle initiation stage |
| T₅ | Foliar spraying of SWE liquid 0.5 per cent (v/v) at tillering + Panicle initiation stage |
| T₆ | SWE gel soil application 12.5 kg/ha + T₄ |
| T₇ | SWE gel soil application 25 kg/ha + T₄ |
| T₈ | SWE gel soil application 37.5 kg/ha + T₄ |
| T₉ | SWE gel soil application 12.5 kg/ha + T₅ |
| T₁₀ | SWE gel soil application 25 kg/ha + T₅ |
| T₁₁ | SWE gel soil application 37.5 kg/ha + T₅ |
| T₁₂ | Control (fertilizer alone) |

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soil characteristics were estimated by using standard analytical methods viz., Organic carbon by Chromic acid wet digestion (Walkey and Black 1934), available Nitrogen by alkaline permanganate method (Subbiah and Asija 1956), available phosphorus by 0.5 NaHCO₃ (pH-8.5) (Olsen 1954), available potassium by Neutral Ammonium Acetate Method (Stanford and English 1949), Exchangeable calcium and magnesium by Neutral Ammonium Acetate (pH – 7.0), available sulphur by 0.15% CaCl₂ (Chesnin and Yien 1950) and available Micronutrients viz., Fe , Zn, Cu and Mn (Lindsay and Norvell 1979).

### RESULTS AND DISCUSSION

In rice (*Oryza sativa*) var. ADT 53, the plant growth and yield attributes as well as soil properties were highly influenced by both soil and foliar application of seaweed extract.

#### Effect of seaweed extract on growth parameters of rice

The seaweed application highly influenced the plant growth parameters. Higher plant height is depicted at T₉ (soil application of SWE @ 12.5 kg/ha + foliar application of SWE liquid @ 0.5%) of 46.4 cm which was on par with T₈ (41.8 cm) and T₇ (42.3 cm) and the lowest plant height was recorded in T₁₂ (32.6 cm) in 30 DAS. The same trend of results was observed in 60 DAS and 90 DAS (Table 3). The increased plant height in T₉ might be due to plant hormones, plant growth regulators like auxin, gibberellins, cytokinin, macro and microelements in the SWE, which elicit the strong physiological response at a low dose of concentration. The results are in line with Pramanick *et al.* (2013) who reported that the foliar application of 15% seaweed extract in green gram improved the crop quality and nutrient uptake (N, P, K and micronutrients). Dilavarnaik *et al.* (2017) also reported that in hybrid maize the foliar application of seaweed at 15% concentration either *Kappaphycusalvarezii* (*K sap*) or *Gracilaria edulis* (*G sap*) significantly improved the cell wall plasticity, apical dominance, meristematic growth and translocation of photo synthetase.

Leaf Area Index (LAI) was recorded higher under T₉ were 2.5, 6.6 and 8.5, which was on par with T₁₀ (2.4, 6.4 and 8.4) and the least LAI was recorded in T₄ which was on par with T₈ (1.6, 5.6 and 7.7) and T₁₂ (1.5, 5.5 and 7.2) at 30 DAS, 60 DAS and 90 DAS (Table 3). The increased LAI might be due to the presence of bioactive substances present in the SWE, which could

| Treatments | Plant height (cm) | LAI |
|------------|------------------|-----|
|            | 30 DAS | 60 DAS | 90 DAS | 30 DAS | 60 DAS | 90 DAS |
| T₁         | 37.4   | 59.3   | 82.6   | 2.1    | 5.8    | 8.2 |
| T₂         | 36.1   | 57.9   | 80.7   | 1.9    | 5.7    | 7.9 |
| T₃         | 35.5   | 56.8   | 78.8   | 1.8    | 5.7    | 7.7 |
| T₄         | 32.8   | 50.9   | 72.4   | 1.6    | 5.5    | 7.4 |
| T₅         | 33.6   | 53.4   | 75.2   | 1.6    | 5.6    | 7.7 |
| T₆         | 42.7   | 63.4   | 87.4   | 2.3    | 6.2    | 8.3 |
| T₇         | 42.3   | 62.6   | 86.3   | 2.2    | 6.1    | 8.3 |
| T₈         | 41.8   | 62.0   | 85.2   | 2.1    | 5.9    | 8.2 |
| T₉         | 46.4   | 68.6   | 92.9   | 2.5    | 6.6    | 8.5 |
| T₁₀        | 45.4   | 67.4   | 91.4   | 2.4    | 6.4    | 8.4 |
| T₁₁        | 44.5   | 66.0   | 90.1   | 2.3    | 6.4    | 8.4 |
| T₁₂        | 32.6   | 47.7   | 71.3   | 1.5    | 5.5    | 7.2 |
| Sed        | 1.2    | 1.5    | 2.4    | 0.1    | 0.1    | 0.2 |
| CD(P=0.05) | 2.4    | 3.2    | 4.8    | 0.2    | 0.3    | 0.3 |

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Table 2. Initial soil parameters of the experimental site at Cauvery delta zone of Tamil Nadu

| Parameter                              | Value |
|----------------------------------------|-------|
| Organic carbon content (%)             | 0.6%  |
| pH                                     | 7.4   |
| EC (dsm⁻¹)                             | 0.47 dsm⁻¹ |
| available N (kg/ha)                    | 243 kg/ha |
| available P (kg/ha)                    | 47 kg/ha |
| available K (kg/ha)                    | 170 kg/ha |
| Exchangeable Ca (meq/100g)             | 12.3 meq/100g |
| Exchangeable Mg (meq/100g)             | 2.4 meq/100g |
| available Sulphur (mg/kg)              | 8.8 mg/kg |
| available Fe (ppm)                     | 31.65 ppm |
| available Zn (ppm)                     | 0.80 ppm |
| available Cu (ppm)                     | 1.74 ppm |
| available Mn (ppm)                     | 22.16 ppm |
have improved the stomatal uptake efficiency. Similar findings were reported by Rathore et al. (2009) in soybean that the foliar spraying of 15% seaweed extract could have enhanced the leaf area index, stomatal efficiency, and improved yield. The higher value of SPAD reading was also recorded in T9 (44.8) followed by T10 (43.2) and T11 (42.8). The lowest SPAD reading was revealed in T12 (37.3) in 30 DAS. A similar trend of results was also observed in 60 DAS and 90 DAS (Table 4). The higher SPAD value in T9 might be due to plant growth stimulating substances like betaines and inorganic salts that might have increased the chloroplast size, granular development and chlorophyll concentration in the leaf surface. Similar results were reported by Whapham et al. (1993) that, in cucumber cotyledons, the low concentration of betaines in seaweed extract has incrementally increased the SPAD reading at flowering stage and later it declined due to the development of fibrous material in plant tissues. The result on DMP showed that a high value was recorded under T9 (4374 kg/ha), which was followed by T10 (4197 kg/ha) and it was on par with T11 (4081 kg/ha) and the lower values was recorded under T4 (3422 kg/ha) and T12 (3350 kg/ha) at 30 DAS. The same trend of results was also observed in 60 DAS and 90 DAS (Table 4). Compared with the other treatments, T9 showed better improvement over the control due to the presence of growth-promoting substances and photo synthase in seaweed might lead to the upliftment of DMP. Pramanicket al. (2017) also suggested that in potato tubers, the foliar application of Kappaphycus sap with the concentration of 7.5% along with 100% RDF recorded higher dry matter production, crop yield and quality of potato. Similar results were also reported by Rayorath et al. (2008) in barley, who reported that the lower dose of SWE at 15% concentration would improve the nutrient mobilization, partitioning, development of vigorous root system and enhancing the plant height, leaf area index, chlorophyll content.

**Effect of seaweed extract on root length and volume of rice**

The root length and root volume were also enhanced by SWE application (Table 5). The treatment T9 achieved higher root length on 30 DAS, 60 DAS and 90 DAS (18.9 cm, 23.8 cm and 25.9 cm) and statistically on par with T10 (18.2 cm, 23.2 cm and 25.5 cm) and T11 (17.4 cm, 23 cm and 24.7 cm) and lowest value was recorded in T12 (14.7 cm, 18.2 cm and 21.5 cm) (Table 5). Similar findings were also reported by Kumar et al. (2021) that in paddy, the RDF along with two times SoliGroGr (Ascophyllum nodosum) @ 10 kg/ha improved the nutrient uptake by roots, water and nutrient use efficiency as well as enhanced the plant growth, root development and vigour of the plant. In the present study, the treatment T9 had registered higher root volume (17.5 ml), which was statistically on par with T10 (17.1 ml) and T11 (16.4 ml) and the lowest value was recorded under T12 (11.4 ml) on 30 DAS. A similar trend of results was also observed in 60 DAS and 90 DAS (Table 5). Rayorath et al. (2008) also reported that in Arabidopsis leaves, the foliar application of seaweed extract at very low concentration improved the root growth and volume, which would have stimulated the cell division of root cells and produced more lateral root growth and root biomass. Selvaraj et al. (2004) reported that in Okra the foliar application of liquid seaweed fertilizer @ 2.5% enhancing the microbial diversity and nutrient mobilization and mineralization. Dogra et al. (2012) reported that in onion, the soil application of seaweed granules @ 2.5 g/m² recorded maximum shoot height and number of shoot per plant and lowest dis-

| Treatments | DMP (kg/ha) | SPAD |
|------------|-------------|------|
| T1         | 3588        | 5211 |
| T2         | 3520        | 5104 |
| T3         | 3505        | 4911 |
| T4         | 3422        | 4668 |
| T5         | 3459        | 4864 |
| T6         | 3930        | 5365 |
| T7         | 3790        | 5314 |
| T8         | 3698        | 5263 |
| T9         | 4374        | 5667 |
| T10        | 4197        | 5574 |
| T11        | 4081        | 5459 |
| T12        | 3350        | 4592 |
| Sed        | 105         | 105  |

Table 4. Influence of seaweed extract on dry matter production and SPAD of rice
ease severity. Selvaraj et al. (2004) reported that in *Abelmoschus esculentus*, the application of seaweed liquid fertilizer improved the growth and yield parameters.

**Effect of seaweed extract on yield attributes of rice**

Total yield may appraise to be the mirror of all the growth and yield features. Higher yield attributes were recorded under T9 (soil application of SWE @ 12.5 kg/ha + Foliar spraying of SWE liquid @ 0.5%) viz, no of grains/panicle - 166, panicle length - 21.8 cm, no of productive tillers m⁻² - 275 which was on par with T10(no of grains/panicle - 164, panicle length - 21.5 cm, no of productive tillers m⁻² - 269) and T11,(no of grains/panicle - 162, panicle length - 21.3 cm, no of productive tillers m⁻² - 260). The lowest value was recorded under T12 (no of grains/panicle - 145, panicle length - 18.3 cm, no of productive tillers m⁻² - 220), which was on par with T4 (no of grains/panicle - 147, panicle length - 18.4 cm, no of productive tillers m⁻² - 223)and T6 (no of grains/panicle - 148, panicle length- 18.6 cm, no of productive tillers m⁻² - 225)(Table 6).The higher yield attributes in T9 might be due to the presence of bio-stimulant, which energizes the chlorophyll production, photosynthetic process, and thereby boosting vegetative growth. The results matched with Ishwarya et al. (2019), who observed that in green gram, the seed soaking in 0.1%
seaweed extract solution for 30 minutes along with the foliar application of seaweed extract 0.25% twice increased the plant height, root volume, number of branches significantly. Singh et al. (2015) reported that the rice fertilized with 100% RDF produced higher productive tillers, number of grains per panicle, panicle length resulting in higher grain and straw yield in rice. Regarding the grain yield and straw yield in the present study, treatment T₉ revealed the highest grain yield (5,612 kg/ha), which was on par with T₁₀(5,588 kg/ha) and T₁₁(5,471 kg/ha). The lowest grain yield was recorded under T₁₂(4,645 kg/ha), which was on par with T₄ (4,790 kg/ha) (Fig. 1). The treatment T₉ recorded a higher straw yield (7,829 kg/ha) which was on par with T₁₀ (7,691 kg/ha) and the lowest straw yield was recorded under T₁₂(6,492 kg/ha), which was on par with T₄ (6,501 kg/ha) and T₃(6,543 kg/ha) (Fig. 2). The percent increase of grain yield and straw yield in T₉ was 18 - 20% over the recommended dose of fertilizer alone. The increased yield might be due to readily available nutrients like N, P, K, and trace mineral elements in the seaweed. The similar results were reported by Nayak et al. (2020) that in rice, the application of 75% RDF + Amaze-x granule @ 10 kg/ha + Proventus DS legacy spray @ 625 ml/ha observed higher panicle length, the number of filled grains per panicle resulting higher grain and straw yield. The positive influence of seaweed extract as biostimulant in aerobic rice enhanced crops’ growth and yield, as reported by Anil et al. (2014). Leadah et al. (2015) also noted that the spraying of seaweed extract on the foliage of rice @ 15% K sap with 100% RDF recorded higher growth and yield parameters viz., no of productive tillers/hill, panicle length, test weight, grain yield and straw yield. It was found that yield of grain was increased significantly by 11.80% over the control (100% RDF). Pal et al. (2015) reported that in maize, the foliar application of seaweed extract @ 15% Gracilaria (G sap) along with RDF observed higher growth parameters, yield attributes viz., cob length, no of grain per row, green cob yield and fodder yield. The results are in line with Dwivedi et al. (2014), who proved that in Blackgram, the foliar application of 15% Kappaphycus sap and RDF resulted in an increase by 49.2% grain yield compared to RDF to control (water spray + RDF). Arun et al. (2019) reported that in rice under the transplanted condition, the application of bio-stimulant LBS6_S obtained higher yield attributes due to effective utilization of native as well as applied nutrients. Deshmukh et al. (2013) also showed that applying seaweed extract @ 1500 g/ha in sugarcane and RDF increased cane yield by 14% and sugar yield by 23.1%.

**Effect of seaweed extract on soil properties of rice**

The results obtained from the post-harvest soil analysis are depicted in Table 7. There is no significant difference in pH and EC values after applying SWE. Cation exchange capacity (CEC) and organic carbon determined the nutrient status of the soil fertility. High value of Cation exchange capacity was recorded under T₂ (39.7 c mol (+) kg⁻¹) followed by T₃ (37.6 c mol (+) kg⁻¹) and the lowest value was recorded under T₁₂ (27.2 c mol (+) kg⁻¹), which was on par with T₄ (27.7 c mol (+) kg⁻¹). Organic carbon was reported higher under T₂ (0.96%) followed by T₁ (0.90%) and the lowest value was recorded under T₁₂ (0.53%), which was on par with T₄ (0.55%) (Table 7). The higher Cation Exchange capacity and Organic carbon in T₂ might be due to the slow decomposition rate of soil carbon in rice cultivation and the highest carbon stock in seaweed. Dominguez et al. (2014) reported that the seaweed extracts in tomatoes restore plant growth in high pH and temperate conditions and Arthur et al. (2013) noted that the Kelpak (a liquid seaweed concentrate made from the kelp Ecklonia maxima) is most effective in neutral pHs, it can be used to promote plant grow that low pH and water stress conditions.

The treatment T₂(soil application of SWE @ 25 kg/ha) had the numerically higher amount of available nitrogen (259 kg/ha), which was on par with T₁(253 kg/ha) and...
T3 (252 kg/ha) and lower value was recorded under T12 (216 kg/ha) which was on par with T4 (218 kg/ha) and T5 (215 kg/ha) (Fig 3). The high value of available phosphorus (42 kg/ha) had registered under T2 (soil application of SWE @ 25 kg/ha) followed by T1 (40 kg/ha) which was on par with T3 (40 kg/ha) and least was observed under T12 (31 kg/ha) which was on par with T4 (32 kg/ha) (Fig 4). The amount of available potassium was numerically higher under T2 (170 kg/ha), which was on par with T1 (168 kg/ha) and T3 (169 kg/ha) and the least was recorded in T12 (144 kg/ha) which was on par with T4 (146 kg/ha) and T5 (146 kg/ha) (Fig 4). A similar result was reported by Pramanick et al. (2014) in rice with the application of seaweed extract @ 15% released more plant nutrients, especially nitrates, ammonium & phosphates into the soil, thereby increasing uptake of plant nutrients in sandy clay loam soil of BCKV, West Bengal. Singh et al. (2020) reported for blackgram in sandy loam soil the rice fertilized with 100% RDF produced higher nitrogen, phosphorus, potassium and sulphur uptake in grain and straw than 50% recommended fertilizer.

The high value of Exchangeable Calcium (27.7 meq/100g) was registered under T2 (soil application of SWE @ 25 kg/ha) followed by T1 (24.2 meq/100g) which was on par with T3 (21.9 meq/100g) and lower value was recorded under T12 (15.9 meq/100g) which was on par with T4 (16.8 meq/100g) and T5 (17.2 meq/100g). Exchangeable magnesium (5.5 meq/100g) was recorded higher under T2 (soil application of SWE @ 25 kg/ha) followed by T1 (4.9 meq/100g) which was on par with T3 (4.4 meq/100g) and least was recorded under T12 (3.2 meq/100g) which was on par with T4 (3.4 meq/100g) and T5 (3.4 meq/100g) (Table 5). The amount of available Sulphur was higher in T2 (18.2 mg/kg) followed by T1 (17.3 mg/kg) which was on par with T3 (15.9 mg/kg) and the treatment T12 (10.1 mg/kg) recorded a lower amount of available Sulphur (Table 7). Similar findings by Ghosh et al. (2020) reported for blackgram in sandy loam soil of the red and lateritic belt of West Bengal with the application of seaweed extract @ 15% Kappaphycus + RDF, resulting in higher availability and absorption of inorganic elements such as Ca, Na, K, Mg, N, Cu, Zn etc.

The treatment T2 (soil application of SWE @ 25 kg/ha) recorded higher amount of available zinc (1.17 ppm) followed by T1 (1.08 ppm) which was on par with T3 (1.04 ppm) and less amount of available zinc (0.32 ppm) was reported in T12. The amount of available Fe was showed a higher value under T2 (33.82 ppm), which was on par with T1 (31.84 ppm) and least was recorded under T12 (13.67 ppm), which was on par with T4 (14.74 ppm) (Table 7). A higher amount of available Cu was observed under T2 (1.61 ppm) followed by T1 (1.44 ppm) which was on par with T3 (1.37 ppm) and a lower value was reported under T12 (0.67 ppm). The available

| Treatments | EC (dsm⁻¹) | EC (cmol(+)kg⁻¹) | OC (%) | CEC (meq/100g) | S (mg/kg) | Ca (mg/kg) | Mg (mg/kg) | Fe (ppm) | Mn (ppm) | Zn (ppm) | Cu (ppm) | Cu (ppm) | Fe (ppm) | Fe (ppm) |
|------------|------------|------------------|--------|----------------|-----------|------------|------------|----------|----------|----------|----------|----------|----------|----------|
| T1         | 7.0        | 0.50             | 37.6   | 0.90           | 24.3      | 17.3       | 37.7       | 0.96     | 21.7     | 1.44     | 17.12    | 7.0      | 0.51     | 37.6      |
| T2         | 7.0        | 0.51             | 37.7   | 0.96           | 21.8      | 19.2       | 34.7       | 0.80     | 21.1     | 1.61     | 18.97    | 7.1      | 0.51     | 37.7      |
| T3         | 7.1        | 0.50             | 34.7   | 0.80           | 27.8      | 15.9       | 34.4       | 0.55     | 16.8     | 1.37     | 15.92    | 7.1      | 0.51     | 34.7      |
| T4         | 7.1        | 0.51             | 29.2   | 0.55           | 21.8      | 11.9       | 32.7       | 0.58     | 17.2     | 0.81     | 8.85     | 7.1      | 0.51     | 29.2      |
| T5         | 7.1        | 0.50             | 31.8   | 0.75           | 21.3      | 11.9       | 31.2       | 0.75     | 20.8     | 0.81     | 9.28     | 7.1      | 0.50     | 31.8      |
| T6         | 6.9        | 0.49             | 32.7   | 0.77           | 20.8      | 14.7       | 29.7       | 0.72     | 19.4     | 0.81     | 9.23     | 6.9      | 0.49     | 32.7      |
| T7         | 7.0        | 0.50             | 30.1   | 0.70           | 19.4      | 11.9       | 29.5       | 0.67     | 18.9     | 0.79     | 9.49     | 7.0      | 0.50     | 30.1      |
| T8         | 6.9        | 0.49             | 29.5   | 0.70           | 19.7      | 11.9       | 27.2       | 0.84     | 18.8     | 0.69     | 12.43    | 6.9      | 0.49     | 29.5      |
| T9         | 7.0        | 0.50             | 27.2   | 0.72           | 19.8      | 13.0       | 25.7       | 0.77     | 15.6     | 0.81     | 11.22    | 7.0      | 0.50     | 27.2      |
| T10        | 7.1        | 0.49             | 25.7   | 0.80           | 22.8      | 13.0       | 23.1       | 0.84     | 15.7     | 0.67     | 12.31    | 7.1      | 0.49     | 25.7      |
| T11        | 6.9        | 0.49             | 25.7   | 0.77           | 19.4      | 15.1       | 23.1       | 0.84     | 18.8     | 0.69     | 12.31    | 6.9      | 0.49     | 25.7      |
| T12        | 7.0        | 0.50             | 27.2   | 0.84           | 22.0      | 16.0       | 27.2       | 0.84     | 18.8     | 0.69     | 12.09    | 7.0      | 0.50     | 27.2      |
| T13        | 7.1        | 0.49             | 25.7   | 0.77           | 19.4      | 15.1       | 23.1       | 0.84     | 18.8     | 0.69     | 12.31    | 7.1      | 0.49     | 25.7      |
| T14        | 6.9        | 0.49             | 25.7   | 0.77           | 19.4      | 15.1       | 23.1       | 0.84     | 18.8     | 0.69     | 12.31    | 6.9      | 0.49     | 25.7      |
| T15        | 7.0        | 0.50             | 27.2   | 0.84           | 22.0      | 16.0       | 27.2       | 0.84     | 18.8     | 0.69     | 12.09    | 7.0      | 0.50     | 27.2      |
| T16        | 7.1        | 0.49             | 25.7   | 0.77           | 19.4      | 15.1       | 23.1       | 0.84     | 18.8     | 0.69     | 12.31    | 7.1      | 0.49     | 25.7      |

Table 7. Influence of seaweed extract on organic carbon, available Ca, Mg, S and Micronutrients of rice.
Mn (18.97 ppm) was higher under T2 (18.97 ppm) followed by T1 (17.12 ppm) and the least was recorded under T12 (8.64 ppm), which was on par with T4 (8.85 ppm) and T5 (9.28 ppm) (Table 7). Layek et al. (2017) reported that in clay loam soil of eastern Himalayas, the application of *K. alvarezii* (K sap) or *Gracilaria edulis* (G sap) at 10% along with 100% RDF increased micro-nutrient (Fe, Cu, Mn and Zn) and protein content in rice. Pal et al. (2015) reported for maize that the foliar application of seaweed extract @ 15% *Gracilaria* (G sap) along with RDF observed higher available nutrients viz., N, P, K, Ca, Mg and micronutrients. Nayak et al. (2020) showed that in rice the application of 100% RDF + Biozyme granule @ 15 kg/ha observed higher organic carbon, available nitrogen, phosphorus and potassium in sandy loam soil of BCKV, West Bengal. Raverkar et al. (2016) noted that in green gram, the foliar spraying of seaweed saps @ 10% *Kappaphycus* sap along with RDF increased the grain nitrogen content, protein content and inorganic elements viz., Ca, Na, K, Mg, Zn. Bhattacharya et al. (2020) described that the seaweed biorefinery made a great effort towards improved utilization of biomass with a low water footprint and minimal effluent discharge.

Though there is research available on the role of seaweed on different crops, the information regarding seaweed on improving the rice crop yield and soil quality is lagging. The present study mainly focused on the Cauvery delta zone because more than 90% of the area is under rice cultivation and the nature of the soil was heavy clayey textured. The soil fertility was getting declined due to continuous rice cultivation. So the seaweed application, one of the organic sources which boost the soil ecology and soil health in a most prominent way through the soil and foliar on rice productivity and soil fertility in this Cauvery delta zone, is highly essential.

**Conclusion**

The study on the influence of the seaweed extract *K. alvarezii* on the rice crop (*O. sativa*) var. ADT53 yield and soil fertility concluded that the soil application of seaweed extract @ 12.5 kg/ha along with the foliar spraying of seaweed extract liquid @0.5% twice at tillering and panicle initiation stage had higher crop growth parameters like plant height, LAI, DMP & SPAD and yield parameters viz., no of grains/panicle, panicle length, no of productive tillers/m², grain yield and straw yield. The rice yield was also increased by 18 -20% over the recommended dose of fertilizer. However, the soil application of seaweed extract @ 25 kg/ha was found to be superior in improving the available nutrients like N, P, K, Ca, Mg, S and micronutrients. The recommendation emanated from the study for the deltaic farmers is the soil application of seaweed extract along with foliar spray @ 0.5 % twice at tillering and panicle initiation stage for enhancing the rice productivity and soil fertility.

**Conflict of interest**

The authors declare that they have no conflict of interest.

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